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Abstracts

O001
Vestibular Function Revisited: Influence on Physiological Homeostasis
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Background: Previous work by our laboratory as well as others has demonstrated that gravity influences the regulation of body mass, body composition, intermediary metabolism and energy metabolism. More recent work by our laboratory has suggested that the vestibular system may largely mediate this gravitational influence on the physiological regulation of energetics and metabolism. Data supporting this vestibular-metabolism interrelationship includes the observations that mice lacking macular gravity reception demonstrate different food intake, body mass and composition responses to long-term increases in gravity (+G).
Objectives: The objective of these studies has been to elucidate the role of the vestibular system in the regulation of physiological homeostasis.
Methods: We have generated our observations by utilizing surgical and chemical bilaterally labyrinthectomized rats (Labx), as well as recombinant and mutant mouse vestibular animal models, to ascertain the influence of vestibular inputs on physiological homeostasis, including food intake, body mass and composition, temperature regulation, activity and plasma leptin at normal Earth gravity (1G).
Results: Thus far, we have consistently observed a significant decrease in body mass, adiposity, and plasma leptin in Labx animals as compared to Sham-operated (sham) controls. The lower body mass in the Labx animals appears to be a 'regulated' phenomenon. We conclude this based on our observation that fasted Labx animals, upon realimentation, recover lost body mass as quickly as their Sham counterparts, suggested nutrient uptake and assimilation is not compromised in Labx animals. In addition, body composition analysis suggests that this loss of body mass is almost entirely attributable to a selective loss of carcass fat. Consistent with the loss of carcass fat is a corresponding decrease in plasma leptin levels. Somewhat paradoxically, mass-independent food intake is elevated in the Labx animals as compared with Sham controls. In contrast to body mass, body composition and leptin, neither body temperature nor locomotor activity levels were significantly different between the Labx and Sham groups. Finally, using c-Fos immunoreactivity, we have confirmed vestibular modulation of hypothalamic centers involved in physiological homeostasis, including energy balance.
Conclusion: Collectively, the data suggests that the vestibular system can influence energy metabolism, though direct calorimetery will be needed to confirm this. Though currently unclear as to how the vestibular system can modulate energy metabolism, both altered autonomic and neuroendocrine outflow are implicated.

O002
The Role of the Vestibular System in Respiratory Regulation
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Background: Changes in posture can affect the resting length of respiratory pump muscles, requiring alterations in the activity of these muscles if ventilation is to be unaffected. For example, nose-up tilt of quadrupeds or standing in humans from a supine position can produce diaphragm shortening. The activity of some upper airway muscles also increases during certain postural alterations. This increase in activity is most evident when humans assume a supine position or quadrupeds are tilted nose-up, because under these conditions the tongue tends to shift to the back of the throat and may obstruct the airway. In particular, the tongue protruder muscle genioglossus must be more active during these postural changes in order to maintain airway patency.
Objectives: The results from four groups of experiments will be discussed, which indicate the following: 1) stimulation of vestibular receptors alters the activity of respiratory muscles; 2) bilateral labyrinthectomy alters the responses of respiratory muscles during postural alterations; 3) the medial medullary reticular formation (MRF) participates in relaying vestibular signals to respiratory motoneurons.
Methods: In the first experiment, electrodes were surgically placed on the round window of felines for stimulating vestibular afferents, and the effects of this stimulation on activity of the respiratory pump muscles and the airway muscle genioglossus were recorded while the animals were conscious. In the second experiment, the effects of a bilateral labyrinthectomy on the background activity and responses to nose-up and ear-down tilts of respiratory muscles were ascertained. In a third experiment, a neural tracer (pseudorabies virus) that was transported retrogradely across synapses was used to determine pathways that may relay vestibular signals to respiratory motoneurons. As noted below, these experiments revealed that the MRF likely participates in generating vestibulo-respiratory responses. In a fourth experiment, we recorded from MRF neurons whose axons could be stimulated from the vicinity of diaphragm motoneurons, and determined whether these cells received vestibular inputs.
Results: Electrical stimulation of the labyrinth produced short latency changes in activity of the diaphragm, abdominal muscles, and genioglossus. Changes in muscle activity were also elicited by nose-up tilts of the whole body, but

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these responses were significantly altered by a bilateral labyrinthectomy. Anatomical studies revealed that in addition to neurons located in the brainstem "respiratory center," cells in the MRF provide inputs to respiratory motoneurons. Recordings from MRF units whose axons were antidromically activated from the vicinity of diaphragm motoneurons confirmed that some of these cells received labyrinthine inputs.

Conclusion: The present results show that the vestibular system participates in regulating the activity of respiratory muscles during movement and changes in posture. These vestibulo-respiratory responses are mediated in part by neurons in the MRF.

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O003

Vestibular Effects on Cerebral Blood Flow Regulation

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Background: Previous research has demonstrated an important role for the vestibular system in autonomic regulation [4]. However, it remains unclear what role the vestibular system plays in regulation of cerebral blood flow. We have previously found that subjects that become motion sick during parabolic flight had greater cerebral hypoperfusion upright postflight [1]. Recently we found that subjects exposed to 30 minutes of hypergravity demonstrate impaired cerebral blood flow regulation that correlates with direct measures of otolith sensitivity [2]. Similarly, stimulating otoliths by changing head position relative to gravity changed cerebrovascular resistance [3]. While these data support an important role for otolith activation in cerebral blood flow regulation, further work is needed to examine the role of vestibular inputs on cerebral blood flow regulation during orthostatic stress.

Objectives: The objective of this symposium is to examine recent evidence from our lab systematically exploring the role of otolith activation on cerebral blood flow regulation. Furthermore, this data will be examined with regards to the affect of vestibular inputs on helping to maintain cerebral blood flow during orthostasis.

Methods: To examine this question, data from a series of studies will be examined. Cerebral blood flow velocity was measured using transcranial Doppler in healthy and labyrinthine deficient patients during upright tilt. To isolate otolith inputs, subjects were translated from center of rotation to off-center on a short-arm centrifuge.

Results: Data from these studies suggest that otolith stimulation activates adaptive mechanisms causing cerebral vasodilation to increase cerebral blood flow in the upright posture.

Conclusion: These findings have important implications for a variety of groups including returning astronauts, aviators, vestibular patients and the elderly. Reductions in vestibular function with aging or spaceflight could minimize the otolith inputs and thus reduce or eliminate these adaptive mechanisms. Further work is necessary to examine the role of otolith inputs in orthostatic intolerance. This work was supported by the NIA, NIDCD and NASA.

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O004

Labyrinthectomy Decreases Bone Mineral Density in the Femoral Metaphysis in Rats

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Background: Recently, it has been shown that sympathetic nervous system regulates bone remodeling [1, 2, 3]. As it is well known that vestibular system influences the sympathetic system [4] it might also affect bone remodeling.

Objectives: To determine whether the vestibular system could influence bone remodeling in rats.

Methods: This experiment was carried out on 14 pigmented male adult rats (DA/HAN). Seven of them were bilaterally labyrinthectomized, the others serving as controls. Bone mineral density was measured with dual energy X-rays absortiometry before and 30 days after vestibular lesions.

Results: Comparatively to intact control rats, labyrinthectomized animals showed a reduced bone mineral density in distal femoral metaphysis ($p=0.007$): the changes in bone mineral density between day 0 (D0) and day 30 (D30) were +3% for controls and -13.9% for labyrinthectomized rats. No significant difference between the 2 groups was observed in the whole body or in the spine mineral density. The body weight of control and bilaterally labyrinthectomized rats were not different at D0 nor at D30.

Conclusion: The major finding of the present study is that bilateral labyrinthectomy in rats decreases bone mineral density of the distal femoral metaphysis but not of the spine or of the whole body. These results suggest that the peripheral vestibular apparatus is a modulator of bone mass and

more specifically in weight bearing bone. We cannot rule out the possibility that the effect observed in the present study could be mediated via non-specific alterations in motor behavior induced by vestibular lesion. However, previous studies on bilabyrinthectomized animals found only moderate and temporary alterations in behavioral activities or in tonic muscle activity. Thus, it appears unlikely that a change in motor system is the main explanation for the alteration in bone mineral density. We suggest that the vestibular system is involved in the control of bone remodeling via the sympathetic system.

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O005

Clinical Implications of the Vestibulo-Autonomic Interaction

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A number of clinical questions make the study of vestibular-autonomic function an area of practical significance. Why patients with vestibular disorders hyperventilate? Does hyperventilation interfere with balance control? Is there an overlap between orthostatic intolerance and vestibular dysfunction? How important is the vestibular system in human cardio-respiratory control? In this symposium we will review some experiments prompted by these problems although many answers are still in an embryonic stage. Initial experiments did show that hyperventilation does increase postural sway, both in normal subjects and in patients with vestibular lesions. Such effects appeared to be mediated primarily by interference with the somatosensory system and central vestibular compensation [Sakellarri et al (1997); Brain 120:1659]. Reciprocally, several studies suggest that the vestibular system contributes to the respiratory drive. For instance, bilateral labyrinthine defective subjects (LDS) do not increase their respiration rate as normal subjects do when oscillated in yaw whilst standing [Thurrell et al (2003) Exp Brain Res150:325] or in roll whilst seated [Jauregui-Renaud et al (2001) Neurosci Lett. 298:17] or during ear caloric irrigation [Jauregui-Renaud et al (2000) Brain Res Bull53:17]. Since respiratory muscles are not actually part of the autonomic system (i.e. striate as opposed to cardiac or smooth muscle) it is possible that vestibulo-respiratory effects reflect a general drive by the vestibular spinal system to integrate respiratory and whole body movements. In addition we have observed that, in many instances, vestibular-respiratory effects lead to secondary modulation of heart rate and blood pressure changes. However, some vestibular effects on the cardiovascular system appear to be direct. For example, in normal subjects heart rate was accelerated by sudden 'head drops' occurring within 500-600 ms of a beat, but no rapid effect was noted in LDS patients [Radtke et al (2000) Lancet 356(9231):736 & J Vestib Res (2003) 13:25]. The speed at which the vestibular signal accelerated heart rate implies a direct reflex as opposed to a respiratory-mediated mechanism. Furthermore, acute vertigo as experienced during the acute phase of vestibular neuritis also interferes with autonomic cardiovascular tests, e.g. reduced blood pressure response induced by hand immersion in icy water and deficient decrease of the respiratory component of heart rate variability during orthostatic posture [Jauregui-Renaud et al (2003) Arch Med Res 34:200 & Erratum 34:444]. In summary, vestibular-cardio-respiratory effects are quantitatively small but, nevertheless, their disruption by disease may contribute to the general malaise experienced by vestibular patients.

O006

Effect of Aging on Vestibular Regulation of Sympathetic and Respiratory Responses

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Background: We have shown that vestibular activation elicits changes in muscle sympathetic nerve activity (MSNA; Am J Physiol 272:H1780-1784, 1997; J Physiol 538:303-308, 2002) and respiration (Am J Physiol 282:R689-694, 2002) in humans. Because of known morphological and functional changes to the vestibular system with aging, it was hypothesized that aging would alter vestibular regulation of MSNA and respiration.
Objectives: To test this hypothesis we compared MSNA and respiration responses in young (26±1 years) and older subjects (65±1 years) during activation of the vestibular system using head movements.
Methods: In our first study, we measured MSNA (microneurography), arterial blood pressure (Finapres), and heart rate during head-down rotation to engage the otolith organs in young and older subjects (Circulation 105:956-961, 2002). In our second study, we compared ventilatory response (e.g., breathing frequency, tidal volume, minute ventilation) in young and older subjects during head movements that engaged the semicircular canals and otolith organs (J Physiol 548:955-961, 2003).
Results: Aging elicited an attenuation of MSNA during activation of the otolith organs by head-down rotation. This attenuated MSNA response in older humans was associated with a decrease in mean arterial pressure unlike in the young. Likewise, increases in breathing frequency elicited by dynamic head movements were attenuated in older humans with greater vestibular stimulation needed to activate respiration in these individuals.
Conclusion: Vestibular reflex control of sympathetic nerve activity and respiration is attenuated with aging. These functional changes in older humans may contribute to increased orthostatic intolerance with aging.

O007

Vestibulo-Ocular Reflex of Chinchilla During Head Rotation and Functional Electrical Stimulation

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Background: Bilateral vestibular sensory deficiency can be disabling for patients who fail to compensate. Galvanic stimulation can elicit vestibular nerve activity [1, 2] and eye rotations [3] qualitatively similar to responses normally elicited by head rotation, supporting the feasibility of a vestibular prosthesis. A prototype prosthesis has been shown [4] to generate an angular vestibulo-ocular reflex (aVOR) in one rotational dimension with subnormal gain (-eye velocity/head velocity). Increased gain and extension of this approach to three dimensional (3D) rotations will be required to achieve a clinically useful prosthesis.
Objectives: Establish performance goals for a prosthesis by characterizing the 3D aVOR of chinchillas, and ascertain whether galvanic stimulation of ampullary nerve endings elicits eye movements quantitatively approximating normal aVOR responses to head rotation.
Methods: We used 3D scleral search coils and 3D binocular video-oculography to examine eye movements in response to 0.05-15 Hz, 20-100˚/s head rotations of normal awake chinchillas in the dark, and in bilaterally vestibular-deficient awake chinchillas during patterned galvanic stimuli applied via ampullary electrodes. Stimuli were biphasic current pulse trains modulated sinusoidally (to encode head angular velocity), delivered via mono- or bipolar electrodes in one or more semicircular canals.
Results: Slow-phase eye movements of normal chinchillas during head rotation were conjugate in direction and amplitude, and reached >80˚/s for 100˚/s head rotations in the horizontal, left-anterior/right-posterior (LARP) and right-anterior/left-posterior (RALP) directions. The mean horizontal aVOR gain of 6 normal chinchillas at 20 deg/s peak stimulus velocity was 0.07±0.05, 0.23±0.12, 0.27±0.13,0.28±0.11,0.35 ±0.17, 0.45±0.28, 0.45±0.15,0.55 ±0.03,0.58 ±0.07 (mean±SD) at 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 and 15 Hz, respectively. LARP and RALP gains were similar. Electrically evoked eye movements were conjugate in direction and amplitude, spanned the range of frequencies for which the aVOR is active, and reached maximal slow phase velocity of 60˚/s. A compensatory aVOR (gain=1) in one dimension was observed during horizontal head rotations encoded by horizontal semicircular canal electrode stimuli. However, 3-D analysis revealed LARP and RALP components suggesting current spread to other ampullary nerves.
Conclusion: Prosthetic stimulation can elicit compensatory eye movements through the aVOR, although improvement in directional selectivity is needed. 3D analysis of eye movements should facilitate refinement of electrode design and stimulus protocols to meet this goal.

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O008

Vestibular Adaptation Studied with a Prosthetic Semicircular Canal

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Background: Since peripheral vestibular damage is usually permanent and can be disabling, we have investigated an implantable semicircular canal "prosthesis" in non-human primates.
Objectives: The objective was to study long-term vestibular adaptation using the canal "prosthesis." Specifically, we examined static adaptation of the spontaneous nystagmus produced by tonic electrical stimulation of the ampullary nerve and adaptation of the gain, phase, and axis of vestibulo-ocular reflex (VOR) produced by modulations in electrical stimulation during yaw-axis head rotations. We also examined interactions between the prosthetic "canal" cue and otolithic signals that sensed gravity
Methods: Two squirrel monkeys were instrumented with a frontal eye coil and head-restraint implant. The canal prosthesis was fixed to the head with the velocity sensor aligned with the axis of the lateral canal, both lateral canals were surgically plugged, and a stimulating electrode was placed near the lateral canal ampullary nerve on one side. The electrode provided biphasic current pulses at a tonic rate of 250 Hz (with the head stationary), and the pulse rate modulated as the hyperbolic tangent of the (filtered) head velocity transduced by the prosthesis. The pulse rate increased for head rotations ipsilateral to the implanted ear and decreased for rotations contralateral to that ear.
Results: When the prosthesis was activated with the animals stationary and in the dark, a brisk nystagmus occurred, beating toward the stimulated ear. This nystagmus gradually abated over several hours. During yaw-axis rotation, a VOR response was present after the prosthesis was activated. After an initial decline, the gain of the VOR gradually increased over a period of months, as did the time constant of the VOR, although it remained substantially less than the time constant of the afferent cue provided by the current pulses. The axis of the VOR was aligned with the velocity sensor in both animals. When electrical stimulation was provided with the head statically rolled 45 deg towards one ear, the VOR response aligned with gravitational vector.
Conclusion: The results demonstrate that squirrel monkeys can adapt readily to the tone asymmetry produced by electrical stimulation of the vestibular nerve, and that a compensatory VOR can be produced by the prosthetic "canal" during yaw axis rotation. The VOR response gradually adapted over time, evidenced by changes in gain, phase,

and axis. Furthermore, the eye movement response driven by electrical stimulation interacted centrally with the gravitational cue sensed by the otolith organs. Together, these findings suggest a prosthetic "canal" may be a useful approach to study adaptation driven by changes in the vestibular afferent signal, and imply that a canal prosthesis may eventually become a beneficial treatment for patients suffering from vestibular hypofunction.

O009

Auditory Feedback Prosthesis for Improving Balance Control During Stance and Gait Tasks

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Background: The need for a balance prosthesis is very apparent to those working with patients and the elderly who have a tendency to fall. Fortunately, progress in the miniaturization of sensors and microprocessor suggests that a balance prosthesis is achievable in the near future.
Objectives: In this study we investigated with vestibular loss subjects whether the CNS can integrate the prosthetic auditory feedback of trunk sway and natural sensory inputs on balance to provide unitary balance commands with improved control of trunk sway.
Methods: We examined trunk sway of 6 compensated bilateral peripheral vestibular loss subjects when using either angular position or velocity based auditory feedback during stance and gait tasks. Roll and pitch angular trunk displacements were recorded with angular velocity transducers mounted just above the waist. The two types of feedback or no feedback were provided to the subject in random order. Feedback was delivered via 4 loudspeakers placed left, right, front and back of the 4 by 4 m test environment. In the feedback modes, sway greater than preset angular or velocity position thresholds (lower for stance than gait tasks) caused a tone to be emitted from the speaker towards which the subject moved. The tone volume increased with increasing angle or angular velocity amplitude.
Results: Several stance tasks showed a reduced sway with feedback. Specifically for the task of standing on 1 leg eyes open with position auditory feedback, amplitudes of pitch and roll angles and angular velocities were indistinguishable from those of normal controls, whereas without feedback, sway was significantly larger. For gait tasks there was a progressive decrease in trunk sway with the greatest reduction with velocity feedback.
Conclusion: These initial results indicate that subjects with vestibular loss can successfully incorporate the auditory prosthetic sensory information into their balance commands, and position information appears more useful in reducing trunk sway during stance tasks and angular velocity during gait tasks. Future work will need to determine the effect of a training time on the improvement in balance control using such a prosthetic device.

O010

Vibrotactile Sensory Substitution Approach to Restoration of Balance: Transition for Standing to Walking

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Background: Experiments using dynamic computerized posturography have shown that a vibrotactile display of body tilt can significantly reduce postural sway in vestibulopathic patients [1]. Our group has shown that sway induced by motor control test perturbations can be significantly decreased by the use of vibrotactile feedback of body tilt. We have developed a wearable prototype multiaxis balance prosthesis for use in walking experiments [2].
Objectives: To investigate the performance of subjects (1) during locomotion along an uneven surface, and (2) during perturbations of locomotion.
Methods: 1) Locomotion over uneven surfaces. We deliberately introduced right-left tilts into the five segments of a 26-foot walkway. These tilts caused the subjects to exceed M/L thresholds, which activated the tactile vibrators mounted on their right and left sides. 2) Perturbations during locomotion. Our standard Balance Disturber protocol [3] was used to test responses with and with out vibrotactile feedback of body tilt. We used pre-test trials with no feedback where perturbation and control (no perturbations) trials were presented in random order. This was followed by blocks of vibrotactile feedback training trials. Each block repeated the same condition five times. We then presented perturbation and control trials in random order but with vibrotactile feedback. Finally, we ran post-test trials per the pre-test protocol.
Results: 1) Locomotion over uneven surfaces. Two healthy normal subjects were tested eyes closed with an equal number of trials having vibrotactile feedback of tilt and control trials with the device turned off. The averaged root mean square tilt from these preliminary data with the device turned on was significantly less ($p < 0.05$) compared to control trials with no feedback. 2) Perturbations during locomotion. In one vestibulopathic subject, the means of the Random (with feedback) trials and Post-test trials (after training with feedback, but with feedback turned off) are significantly less than the pre-test ones ($p < 0.05$). This reduction in body sway after training with vibrotactile feedback is much larger than effects we have observed in repeated perturbation trials of vestibulopathic subjects who had no vibrotactile tilt feedback.
Conclusion: These preliminary results suggest that we will be able to use vibrotactile feedback of body tilt to help control mediolateral body sway during walking over uneven surfaces, and during perturbations while walking.
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O011

Characterizing Dizziness After Head Trauma

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Background: Traumatic brain injury (TBI) is the second most common of all neurological disorder with an incidence of greater than 180/100,000. Current world affairs, stronger athletes, and faster and larger motorized vehicles have resulted in an increase in the rate of head trauma over the last several years. Temporary and permanent disability due to CHI which is often related to vestibular disorders can be devastating to the individual, their family, and their workplaces. Unfortunately little evidence is available characterizing dizziness after TBI. The nature of our treatment facility has given us the ability to evaluate, study, and treat one of the largest populations of head trauma patients.
Objectives: This study had two objectives. We first characterized the dizziness associated with TBI and then examined the therapeutic results of vestibular rehabilitation both with respect to passive and active measures of function.
Methods: Individuals identified with TBI and presenting with vestibular symptoms were evaluated utilizing a standard test battery. The test battery included a detailed otolaryngologic history and physical exam, dynamic computerized posturography, rotational chair testing, and dynamic visual acuity testing. In addition, individuals were scored for a Dynamic Gait Index (DGI) and administered the Dizziness Handicapped Index (DHI) and the Activities Specific Balance Confidence Scale (ABC) surveys. The test battery was administered before, during, and after treatment.
Results: Over one hundred individuals suffering from dizziness after head injury and presenting to our clinic in a one year period of time were divided into three diagnostic groups. In mild head trauma patients 41% of the individuals suffered from post-traumatic vestibular migraines, 28% of the individuals had post-traumatic positional vertigo, and 19% of the individuals were classified as post-traumatic spatial disorientation. The remaining 12% of the patients could not be characterized. The positional group had objective physical exam findings, which cleared with treatment in all cases. 84% of the migraine group demonstrated an improvement of their vestibular test results as compared to 27% of the disorientation group. Mean time to return to work was less than 1 week for the positional group, 3.8 weeks for the migraine group, and greater than 3 months for the disorientation group. A higher percentage of individuals with moderate and severe head trauma were in the disorientation group and mean time to return to work was significantly longer for moderate and severe head trauma patients in each diagnostic group.
Conclusion: Using our patient population we were able to characterize the majority of dizziness secondary to head trauma into one of three more specific diagnostic groups. In this paper, which represents one of the largest series in the literature to date, we present diagnostic criteria, suggested treatment guidelines, and our prognostic data.

O012

Role of SSRIs in the Treatment of Dizziness

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Background: When treating dizzy patients, psychiatric aspect should be carefully addressed regardless of whether they have a well-defined organic disease.
Objectives: In this prospective study, we aimed to elucidate the role of selective serotonin reuptake inhibitors (SSRIs) in the treatment of dizziness.
Methods: Forty-seven patients who complained of dizziness were treated with 20mg of paroxetine per day. Depressive state of the patient was evaluated by the Zung Self-rating Depression Scale (SDS). Treatment outcomes were measured with self-assessment of subjective handicaps in daily life using a dizziness and unsteadiness questionnaire. The questionnaire consisted of five factors related to emotional or bodily dysfunction that could be affected by dizziness. Changes in SDS scores and subjective handicaps were assessed at 4 and 8 weeks after the start of the SSRI.
Results: In patients having well-defined organic diseases with high SDS scores, the SSRI improved all five subjective handicap factors as well as SDS scores. The decline in SDS scores showed a significant correlation with improvement of subjective handicaps, which was related to emotional problems but not of factors related to bodily dysfunction. The SSRI was also effective for an improvement of factors related to emotional problems and SDS scores in patients not having organic diseases but with high SDS scores. In patients either with or without organic diseases with low SDS scores, the SSRI had no effect on any subjective handicap factors and SDS.
Conclusion: In the treatment of dizzy patients, SSRIs are effective at relieving subjective handicaps due to dizziness specifically in patients with high SDS scores.

O013

Head Impulse Sign in Cerebellar, Medullary and Labyrinthine Stroke

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Background: Diagnosis of peripheral vestibular syndrome (PVS) and cerebellar stroke (CS) is difficult due to overlap of symptoms and signs. An evaluation protocol has been proposed [1], which did not include the head impulse sign (HIS).
Objectives: The goal was to prospectively utilize a vestibular protocol, which included the HIS in patients with sudden ataxia-vertigo, sharing stroke-risk factors. Imaging correlation verified the accuracy of the lesion localization.
Methods: To be included, patients experienced sudden vertigo and ataxia. Primary or gaze evoked horizontal nystagmus in light or darkness had to be present. Stroke-risk factors and no previous episodes of vertigo or preceding URI were required. Protocol included fixation, in light and darkness, using Frenzel's glasses, the HIS, eye movements, neurological examination, trunkal balance, cerebral imaging.
Results: Average age was 64.7 ± 13.9. Five patients had presumed labyrinthine stroke; 26 had CS: 19 patients in the vascular territory of the middle branch of the posterior-inferior cerebellar artery (m-PICA); 3 in the superior cerebellar artery (SCA); and 4 in the anterior inferior cerebellar artery (AICA). Four patients had lateral medullary (LMS) and 1 ponto-medullary stroke. Several strokes occurred in 10 patients. Among 19 PICA or m-PICA stroke patients, 7 had involvement of the inferior vermis (nodulus, uvula, pyramid and/or the paravermal biventral lobule), 2 had nystagmus mimicking a PVS with normal HIS, 3 had bi-directional nystagmus, 2 had head shaking and positioning nystagmus, 12 had unidirectional gaze-evoked nystagmus. Eighteen patients had a normal HIS and 1 was abnormal. SCA patients had no nystagmus and normal HIS. Among 4 AICA patients, 2 had nystagmus in darkness and abnormal HIS; 4 LMS patients with isolated vestibular abnormalities had horizontal nystagmus with normal HIS. Imaging was abnormal in 34 patients. Five patients with PVS had ischemic leukoencephalopathy and 2 LMS patients had an initial normal MRI.
Conclusion: Sudden onset of ataxia, vertigo, nausea and vomiting in this age group is a non-specific presentation for PVS, medullary and CS. The protocol used, yielded correct localization diagnosis in this cohort an increased our diagnostic sensitivity. M-PICA strokes involving the nodulus, uvula and paravermal structures are likely to be associated with nystagmus that resembles a PVS as in 2 patients with PVS-like nystagmus, a normal HIS, predicted cerebellar localization. In short, the HIS correctly identified all PVS cases; it was positive in 3 stroke patients. Two had AICA infarct with presumed labyrinthine infarction in one; the other with vestibular nuclei infarction. A third case had a m-PICA stroke, with caudal cerebellum edema and brainstem compression. Involvement of vestibular nuclei by infarction or compression may be considered as unusual causes of a positive HIS. Four LMS patients with initially isolated vestibular presentation but normal HIS had eventually an infarct detected by MRI.

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O014

Advances in 3-Dimensional Imaging and Data Exploration of the Structures of the Middle and Inner Ear

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Background: Dramatic advances in the speed and resolution of computed tomography (CT) and magnetic resonance imaging (MRI) have taken place in the last 3-5 years, with significant implications as to their application in clinical evaluation in a large number of important conditions. Scan times have been reduced by one or more orders of magnitude and yet the achievable resolution has at least remained the same if not noticeably improved.
Instead of acquiring a limited amount of data on each patient, which could then be viewed in a single plane, a volume of data can now be acquired and then explored in many different ways. This can increase patient compliance with the scan, provide a greater number of 'ideal' quality studies, reduce the radiation dose to the patient (in the case of CT scanning) and also reduce the operator dependence of the procedure.
In addition, with continued increases in computing power, real-time data visualization techniques have become a reality, allowing for data exploration in ways previously though impractical or impossible.
Objectives: To demonstrate the current state-of-the-art in imaging techniques and data exploration methodologies.
Methods: Representative data sets from clinical studies will be explored in real-time using a 3-dimensional image processing workstation (GE Medical Systems Advantage Workstation), which now fits on a relatively standard laptop computer.
Results: Detailed multiplanar and 3-dimensional reconstructions of the nerves of the internal auditory meatus, the cochlea, vestibule, semicircular canals and the course of the facial nerve can be performed in real-time from scans acquired on current model CT and MRI equipment. Comparative evaluation of the structures of the ossicular chain and the features of the mastoid can be easily performed.
Conclusion: Recent advances in CT and MRI now provide for the rapid acquisition of highly details 'volumes' of data, which can then be explored in 3-dimensions in real-time, giving a far greater appreciation of the finest of structures and allowing for better comparative assessments to be made for individual patients.

O015

Microvascular 8th Nerve Compression Can Cause Vertigo and Tinnitus

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Background: Microvascular compression is now well accepted as being the predominant cause of trigeminal neuralgia, glossopharyngeal neuralgia and hemifacial spasm. Amazingly there has been entrenched skepticism that it could be a cause of vestibulo-cochlear symptoms, largely due to (1) a neurosurgical minimalist attitude to vertigo and assumption it is otological, and (2) otological ownership with a presumption that it could not be proved otherwise. The most likely otological condition to cause recurrent vertigo is Meniere's disease for which there is now a reliable electrophysiological test—electrocochleography (EcochG).
Objectives: To establish the cause of their symptoms in 4 adult patients. Three had a long history of very frequent vertigo attacks and one had unilateral tinnitus only.
Methods: In the three patients with vertigo at least two EcochGs were "normal" (implied no hydrops). Axial and coronal scans showed an AICA on or close to the 8th nerve, making microvascular compression a possible cause. They were explored via a posterior craniotomy with elevation of the AICA off the 7th/8th nerve complex and interposition of sponge. Three operative video clips will be shown. In the patient with unilateral tinnitus only the MRI showed vertebral artery compression of the cochlear nerve at the brainstem, and ABR was abnormal compared with the other side.
Results: In the 3 vertigo patients with AICA compression the vertigo ceased (as did tinnitus and pressure in 2) with a followup period of 3--6 years. In the patient with unilateral tinnitus possible decompression was discounted because of her age.
Conclusion: Microvascular compression can cause cochleo-vestibular symptoms— vertigo and tinnitus. If multiple EcochGs exclude Meniere's disease an alternative diagnosis should be sought, and microvascular compression should be in the differential diagnosis. It now seems likely that in some patients who have had vestibular nerve section for " Meniere's disease" the true pathology was microvascular compression.

O016

Analysis of Trunk Sway in Patients with Spinocerebellar Ataxia

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Background: The autosomal dominant spinocerebellar ataxias (SCA) share features of adult-onset progressive gait and limb ataxia and balance impairment. Early screening for these features is highly relevant for future therapeutic trials.
Objectives: We sought to prove if quantified stance and gait tests could provide a screening technique for early-symptomatic patients. As we had seen larger pitch than roll instabilities in these patients with dynamic posturography [1], we wondered if a similar pattern would be seen in stance and gait.
Methods: Eleven SCA patients (8 men; mean age 49.5 yrs) and eleven age-matched healthy controls (8 men; mean age 48.0 yrs) were examined. All had oculomotor abnormalities. Postural and balance control were quantified using measurements (amplitudes) of trunk angle and angular velocity, in the roll and pitch directions (SwayStar) during a battery of stance and gait tasks. Stance tasks involved standing on two legs with eyes open or closed, on a normal and on a foam support surface. Gait tasks consisted of tandem gait walking, walking normally with eyes closed, walking with the head rotating or pitching, walking over barriers, and rising from a chair and walking 3 m.
Results: In all stance tasks, angle displacement and angular velocity in both the pitch and roll planes were significantly larger in the SCA group compared with the control group. Within the group of ataxia patients, instability was more pronounced in the pitch than in the roll direction with oscillations at 1.4 Hz. A similar dominance of pitch over roll instability was also observed in gait tasks. For example, in tandem gait and while walking with rotating head movements, trunk angle displacement and velocity in the pitch and roll directions were larger than controls, again with the greatest instability in the pitch plane. In the 'get-up-and-go' test, angular velocity of the trunk movement in the pitch plane in the get-up phase was decreased in the SCA group.
Conclusion: The method of trunk sway analysis presented here proved to be an effective tool to detect and quantify the gait and balance abnormalities in SCA patients, indicating that this method might be used to detect early-symptomatic patients. Further the method might help to identify those patients at risk of falling. The postural instability in SCA was found to be multi-directional, although there is generally more pitch than roll instability, which corresponds to the predominant involvement of the spinocerebellum.
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O017

Vestibular Vertigo in the General Population: Prevalence and Health-Care Utilization

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Background: Dizziness and vertigo rank among the most common complaints in medicine. So far, the prevalence of

vestibular vertigo has been studied only in selected patient groups but not in the general population.
Objectives: To determine the prevalence of vestibular vertigo in the general adult population in Germany and patterns of health care utilisation.
Methods: A survey on dizziness and vestibular vertigo was conducted with a subsample of the German Telephone Health Interview Survey 2003, which is representative for the adult population residing in Germany. Out of 4869 participants of the German Telephone Health Interview Survey, 1403 men and women had a history of moderate or severe dizziness or vertigo and 1157 were willing to participate in a subsequent interview. A detailed dizziness interview developed through piloting and validation was conducted via telephone by medical students thoroughly trained in a dizziness clinic. Each interview was discussed with a specialised neurotologist. Diagnostic criteria for vestibular vertigo were rotational vertigo, positional vertigo, or recurrent dizziness with nausea and at least one additional feature (head motion intolerance, oscillopsia or imbalance). In a concurrent validation study, 61 patients were interviewed by telephone and independently examined in a specialised dizziness clinic by a neurologist trained in neurotology. Vestibular vertigo was detected by telephone interview with a specificity of 94% and a sensitivity of 88%.
Results: From the original sample (n=1157) 1003 interviews were completed (response rate 87%). A history of vestibular vertigo was reported by 243 participants (178 women and 65 men), 89% of whom had recurrent vestibular vertigo. Vestibular vertigo in the last 12 months was reported by 158 participants (120 women, 38 men). The proportion of vestibular vertigo within the whole dizziness/vertigo group varied with age, increasing from 14% (men 8%, women 17%) in the age group 18-39 years, to 28% (24%, 31%) in the age group 40-59 years and 37% (32%, 41%) in the age group >=60 years. The estimated lifetime prevalence of vestibular vertigo in the general population in the three age groups was 7%, 10% and 16% in women and 2%, 5% and 8% in men. The estimated 12-months prevalence of vestibular vertigo in the general population in the three age groups was 6%, 6% and 10% in women and 1%, 3% and 5% in men. The consultation rate (any physician) was higher for vestibular vertigo (70%) than for non-vestibular vertigo (54%). However, only 120 of the 171 participants who had consulted a physician for their vestibular vertigo stated that a diagnosis was made (70%) and less than half of paraphrased diagnoses could be interpreted as possibly vestibular.
Conclusion: Vestibular vertigo is a common health problem that becomes more frequent with age and affects women twice as often as men. Vestibular vertigo leads to high health care utilisation but misdiagnosis seems to be frequent.

O018
Vertigo with Vertical Nystagmus

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Background: The localization of vertigo with downbeat nystagmus in those three patients is thought to be in the vestibulocerebellum and, in addition, functional disturbance of otolith-ocular reflex, vestibuloocular reflex and otolith may be present.
Objectives: To understand mechanism and localization of vertigo with vertical nystagmus in patients with episodic ataxia, neuro-otological evaluations were performed.
Methods: We examined three patients with paroxysmal vertigo and vertical nystagmus without cochlear signs. Neuro-otological examinations including nystagmus, caloric response, visual suppression (VS) of caloric nystagmus, pursuit and saccadic eye movements, optokinetic nystagmus and brain MRI were performed during an interictal state.
Results: Patient 1 is a 62-year-old man who was known to have nystagmus at the age of 18. He experienced vertiginous attack at the age of 48, 51, 53 and 62. Vertigo and gait disturbance lasted for one week, then subsided and disappeared in one month. He had marked downbeat nystagmus on all eye positions even upward gaze. Positional and positioning downbeat nystagmus were present. Nystagmus increased on lateral gaze and head positioning. The VS was normal. The saccadic hypermetria was present and optokinetic nystagmus was impaired. MRI demonstrated mild atrophy of the cerebellar vermis. Patient 2 is a 49-year-old man who started to have difficulty with visual fixation at the age of 40. Four years later he had vertiginous attack. Since then, he had experienced increased attacks in frequency. When he walked around and turned, he felt more vertigo and his daily life was severely impaired. He had downbeat nystagmus on all eye positions, head positions and head positioning. Nystagmus was fluctuated in severity and correlated with sensation of vertigo. The VS was impaired, but other neuro-otological findings as well as brain MRI were normal. Patient 3 is a 30-year-old woman who has had episode of unsteady gait since childhood. At the age of 28, we first saw her for vertiginous attack and headache. Marked downbeat vertical nystagmus was observed on all eye positions, head positions and head positioning. The VS was slightly impaired, but other neuroto-ological findings as well as brain MRI were normal. Those three sporadic patients had marked downbeat nystagmus, which was exaggerated during the vertiginous attack and movements of the body. Bed resting was most effective for vertigo and nystagmus. Drug treatments including acetazolamide and isosorbide were of no effect.
Conclusion: The localization of vertigo with downbeat nystagmus in those three patients is thought to be in the vestibulocerebellum and, in addition, functional disturbance of otolith-ocular reflex, vestibuloocular reflex and otolith may be present.

O019

Postural Strategy Under Vibratory Proprioceptive Stimulation in Phobic Postural Vertigo

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Background: For patients with dizziness and anxiety there is evidence for coexisting vestibular dysfunction and abnormal findings in postural investigations[1][2]. Patients with Phobic Postural Vertigo(PPV)show increased sway activity in the frequencies above 0.1 Hz during quiet stance as compared to normal subjects[3]. However, in difficult balance tasks, the performance of patients with PPV is the same as that of normal subjects[4]. PPV patients show less postural reactions to visual stimulation compared to healthy subjects[5]. It has been suggested that patients with PPV exhibit an anxious balance control strategy[3][4][6]. Patients with a related disorder, panic disorder with agoraphobia, show an impaired balance function if proprioceptive information is reduced[1].

Objectives: We investigated if patients with PPV use proprioceptive cues rather than visual cues to control upright stance[1][5].

Methods: We compared posturographic recordings of 14 consecutive patients diagnosed with PPV according to criteria formulated by Brandt, with 24 normal subjects [6]. Patients showed no pathology on neuro-otological investigation. The subjects were instructed to stand on a force platform with arms crossed. Spontaneous body sway was recorded during 30 seconds of quiet stance. A vibratory stimulation was applied to the calf muscles and were randomly turned on/off with eyes open and eyes closed during 205 s.

Results: During quiet stance PPV patients showed higher torque variance than normals, especially above 0.1 Hz. The vibratory stimulation increased differences between normals and PPV patients. Patients with PPV were less able to use vision to compensate for the vibration-induced movements.

Conclusion: Patients diagnosed according to the PPV criteria are sensitive to proprioceptive disturbances and less apt to use visual information to control upright stance. A change of postural strategy due to anxious balance control is a possible underlying mechanism of PPV, which is in accordance of what is suggested by Brandt [6].

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O020

Time Course Analysis of Angular Control of the Body and Head While Rising from a Chair

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Background: Vestibular dysfunction causes a change in the strategy used to stabilize the head while rising from a chair. We previously reported on the angular control of the body and head in the sagittal plane as one rises from a chair, with a focus on the amplitude of the angular movement. In healthy subjects, the head was aligned according to a gravitational reference. In patients with unilateral peripheral vestibular hypofunction, by contrast, the head tended to be fixed to the body instead of the gravitational reference. And in patients with bilateral peripheral vestibular hypofunction, the head was fixed in space only if the eyes were open, indicating that visual input provides a reference that substitutes for gravity and thus compensates for the vestibular loss. To verify them exactly, we can focus on the time course difference of the body and head movement. Feedback control based on proprioceptive input could put the head movement off from the body for certain period, rather than feed-forward control standing on vestibular input as a gravity reference.

Objectives: The aim of the present study was to use time course information to better understand the vestibular contribution to postural control as one rises from a chair.

Methods: A total of 24 healthy controls and 42 patients with varying degrees of vestibular dysfunction were studied. Time course of the angular motion of the body and head, when rising from a chair with eyes open and closed, was evaluated. The delay between the onset of the motion of the body and head was compared between subject groups. We also investigated concerning transitional points from the forward lean of the body to the backward reversion and from the backward tilt of the head to the forward reversion.

Results: In regard to the onset of chair rise, we found significant delay of head from body motion between healthy controls and subjects with bilaterally impaired vestibular deficiency, only when the eyes were closed. The time between the transition points of the head and body was stable between these groups.

Conclusion: The mechanisms controlling the onsets of head and body movement differ in normal subjects and those with bilateral vestibular deficit. In the latter, the loss of reference of gravity would cause decrease of feed-forward postural control, compensated with somato-sensory feedback mechanism. Visual input seemed to provide alternative reference of gravity.

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O021

Why the Feeling of Vertigo Happens in the Patients of the Neurotic Stress-Related and Somatoform Disorders and in the Depression? Pharmacological Approach

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Background: In "ICD-10, Classification of Mental and Behavioral Disorders", the vertigo or dizziness are noted in the neurotic stress-related and somatoform disorders and in the depression. Berthoz and his co-workers reported that the abnormal re-absorption of serotonin in the hippocampus induced the vertigo using animal model. The purpose of this clinical study is to clarify the reason why patients with the anxiety disorders, the somatoform disorders and the depression complain the vertigo.
Objectives: In this study, we took the neurologically normal patients who complained the vertigo diagnosed as the anxiety disorders, the somatoform disorders and the depression. Fifty patients of the anxiety disorders, 15 patients of the somatoform disorders and 20 patents of the depression were taken in this study.
Methods: These patients were given Fluboxiame or Paroxetine (i.e. the selective serotonin re-absorption inhibiter) tablet, and were asked the existence of vertigo 2 and 4 weeks after that.
Results: In the anxiety disorders, the vertigo was disappeared 57% of the patients after the 2 weeks, 92% of them after the 4 weeks. In the depression, the vertigo was disappeared 60% of the patients after the 2 weeks, 97% of them after the 4 weeks. Meanwhile in the somatoform disorders, the vertigo never disappeared.
Conclusion: The results of animal study and our results, the abnormal re-absorption of serotonin in the hippocampus provokes the feeling of vertigo in the cases of the anxiety disorders and the depression. In contrast of these, the feeling of vertigo in the somatoform disorders should be provoked by the other pharmacological mechanism.

O022

Serotonergic Effects on Vestibular Function: Evidence from Treatment Trials for Chronic Dizziness

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Background: Serotonin may affect the function of central vestibular pathways and their interactions with limbic centers, modulating the sensitivity of vestibular reflexes and the influence of affective state on balance function. In animal studies, serotonin altered the response of >85% of secondary vestibular neurons to physiologically relevant stimuli and changed the gain of postural reflexes. Selective serotonin reuptake inhibitors (SSRIs) improved poor balance performance in a strain of anxious mice. Humans suffer from a syndrome of chronic subjective dizziness (e.g., phobic postural vertigo), which occurs in the absence of overt vestibular defects, but may co-exist with anxiety and depression. The cause is unknown, but deficits in central vestibular function (mismatched efferent copy of balance signals) or vestibulo-limbic (psychosomatic) interactions have been postulated. Patients with an anxious, harm avoidant temperament may be particularly vulnerable to this syndrome. Variations in the promoter region of the serotonin transporter gene have been linked to this personality style.
Objectives: We previously reported that SSRIs are effective for chronic subjective dizziness. We now present data to test the hypothesis that serotonin modulates balance function via central vestibular pathways (physical symptoms) and vestibulo-limbic connections (affective comorbidity).
Methods: We pooled data from a retrospective, study (N=60) and a prospective trial (N=20) of SSRI treatment of chronic (>6 months) subjective dizziness, with or without anxiety and depression. Patients underwent thorough neurotologic evaluations, structured psychiatric interviews, and assessments of pre-morbid temperament. Treatment outcomes were measured with the Clinical Global Impressions Scale (CGI). We compared outcomes between patients with and without psychiatric illness to test the hypothesis that serotonin directly affects central vestibular pathways. We then compared outcomes between patients with and without anxious temperaments to assess serotonin effects on vestibulo-limbic interactions.
Results: Treatment response did not depend on affective state. In the pooled analysis, 35/42 (83%) treatment completers with and 14/18 (78%) without major psychiatric illness showed significant improvement. Twenty (25%) patients did not tolerate a SSRI. Chronic subjective dizziness developed after a transient neurotologic event (e.g., BPPV) in 2/3 of patients. Those with an anxious temperament developed more persistent symptoms after the triggering event. They had a poorer treatment response ($p<0.05$).
Conclusions: SSRIs reduced physical symptoms of chronic subjective dizziness, regardless of the patients' affective state. Subjects with an anxious temperament were predisposed to more severe symptoms and had a poorer treatment outcome. These findings support the hypothesis that serotonergic mechanisms modulate both central vestibular function and vestibulo-limbic interactions.

O023

Pressure in the Inner Ear Compartments and Its Regulation

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Inner ear fluids are classified according to their apical or basolateral location relative to the membranous labyrinth. The apical fluids are the K-rich cochleo-vestibular endolymph and the Na-rich endolymphatic sac luminal fluid. The basolateral fluids, which are Na-rich and K-poor, are perilymph, cortilymph, the intrastrial space and spiral ligament extracellular fluids, and the interstitial fluid of the connective tissues that surround the semicircular canals and the endolymphatic duct and sac. Homeostasis of the volume and composition of cochleo-vestibular fluids is essential to the mechano-electrical transduction, i.e. the transformation of physical auditory or vestibular stimuli into nervous inputs. The mechanisms responsible for inner ear fluids secretion and for the maintenance of their volume and composition are only partly elucidated. A better knowledge of these mechanisms has been gained through animal experimentation and through the study of several human pathologies linked with inner ear fluids alterations such as Menière's disease, genetic deafness due to transporters mutation, or perilymphatic. This knowledge opens new clinical perspectives concerning the non-invasive assessment of the inner ear fluids in patients. It also brings new medical or surgical therapeutic options in pathologies linked with perturbations of inner ear fluids homeostasis.

O024
Flows of the Inner Ear Fluids

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In the undisturbed state, the rates of longitudinal flow of endolymph and perilymph in the cochlea are extremely low and solute movements are dominated by diffusion. Disturbances of endolymph volume, by injection of artificial endolymph into the cochlea or withdrawal of endolymph, do induce longitudinal fluid flows directed to or from the base of the cochlea respectively. Associated with these manipulations are substantial physiological and morphological changes of the endolymphatic sac, consistent with endolymph being driven into the sac lumen by endolymphatic injections. The response of the endolymphatic sac to perilymphatic manipulations is more complex. Although withdrawals from perilymph that reduce perilymph pressure cause K^+, pressure and potential decreases in the sac, injections into perilymph that increase perilymph pressure cause no measurable changes in the sac of most animals. The endolymphatic duct appears to close during the application of positive perilymphatic pressures. Anatomically, the wall of the endolymphatic sinus appears structured to close the endolymphatic duct and limit endolymphatic movement with pressure in the vestibule. When low frequency pressure stimuli are applied to perilymph, K^+ increases are observed in the endolymphatic sac. It is concluded that each cycle of the stimulus may permit a small bolus of endolymph to be driven into the sac with the effects being cumulative. Regulation of endolymph volume may depend on the many factors that influence volume flow through the endolymphatic sinus, including the degree of endolymph distension, the static pressure of perilymph and on pressure fluctuations in perilymph. The mechanical properties of the endolymphatic sinus could play an important role in endolymph volume regulation. Understanding the properties of this structure in normal and hydropic ears may help treat hydrops and may explain the operation of the Meniett.

O025
Role of Endolymphatic Duct and Sac in Meniere's Disease and Inner Ear Homeostasis

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The pathophysiology of Meniere´s disease (MD) is currently not well understood, but it is generally believed that endolymphatic fluid pressure is pathologically increased leading to swelling of the membranous labyrinth. Endolymph congestion could arise through a dysfunction of the endolymphatic duct (ED) and sac (ES) due to inflammation, vascular disturbances and/or perisaccular/ductal fibrosis (Hallpike and Cairns 1938, Danckwardt-Lilliestrom et al. 1997, Friberg et al. 2001). Possible autoimmune mechanisms have also been discussed. Results from experimental endolymph injections and withdrawals seem to support earlier concept of the ES as an active volume/pressure regulator of the endolymph system. This involves both a local secretion of osmotically active substances and its degradation through enzymatic processes. Macrophages derived from surrounding bone marrow space may also play a role since migration of cells can be observed after manipulation of the cochlear endolymph volume. Thus, the ES could monitor volume/pressure partly through a secretion/degradation system of osmotically active agents. Our knowledge about endolymph resorption and ion transport mechanisms is beginning to increase but is still incomplete especially in the ED. In the ES the epithelial ion transport systems have been indirectly studied by the recording of ES transepithelial potential and the luminal concentrations of Na+ and K+. The role of the periductal and perisaccular tissue surrounding the endolymphatic duct and sac for fluid absorption and Meniere´s disease have been analyzed in more detail. Here we focused on the relationship between the fiber network and connective tissue cells for regulation of connective tissue pressure and dynamics.

O026
Local Overpressure Treatment of Meniere's Disease

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Background: Meniere's Disease is an intermittent type of disease. Fluctuations of labyrinth function do not permit any central compensation. The disease is best treated locally. Not any treatment so far has the aim to cure the disease but to improve patient well-being, *i.e.* to control the disease.
Methods: Local overpressure treatment has resulted in a new treatment concept – the first new one since almost 30 years. The pressure pulse (at the level of 0.4-1.2 kPa) of the Meniett™ device is fluctuating at a frequency of 6 Hz during 0.6 s with a total treatment sequence of approximately 5 min. Three sequences of approximately 45 s pressure exposure are intercepted by pauses of 45 s. The pressure pulses are transferred from the external ear canal into the middle ear through a ventilation tube.
Results: Experimentally the overpressure treatment reduces the development of hydrops. Clinically an improvement of transtympanically recorded electrocochleographic potentials occurs immediately in Meniere´s patients following exposure to pressure pulses. In a Scandinavian clinical randomized multicenter placebo controlled study (n=40 patients) we have shown that the functionality level improved statistically significant in the active group compared to the placebo group (p=0.0014) as well as the VAS evaluation of vertigo (p=0.005). Tinnitus, aural pressure and hearing were not statistically improved.
Conclusion: Local overpressure treatment is non-invasive, non-destructive and safe. It reduces hydrops and can be repeated as many times as needed.

O027
What Visual Information is Used to Regulate Adaptive Human Locomotion?

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Background: Vision is the only sensory modality that can provide accurate and precise environment information about the both animate and inanimate features of the environment at a distance: information essential for control of adaptive human locomotion.
Objective: In this presentation, I will examine several tasks each of increasing complexity to understand the nature of information used for regulating locomotion.
Methods: These tasks are: a) stepping on a target area in the travel path; b) approaching and stepping over an obstacle in the travel path; c) steering to a target with no obstructions in the travel path; d) navigating around obstacles to an end goal; e) stepping on isolated footholds without changing direction; and f) selecting & stepping on isolated footholds with changes in direction. Behavioral measures, gaze patterns and models that use different visual information to guide locomotion will be discussed.
Conclusion: It will be shown that visual information used for travel in a cluttered environment is task specific: targeted intermittent gaze fixation on features & end-goal is used to predict & control travel path. Supported by grants from NSERC Canada and Office of Naval Research, USA.

O028
Underlying Mechanisms of Gaze Stabilization During Continuous Circular Locomotion

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Background: Compensatory head and eye movements maintain gaze in the direction of heading when walking on a linear treadmill When making turns during overground walking, transient gaze tilts of the head and eyes are induced that orient gaze towards the direction of the net gravito-inertial acceleration (GIA).
Objectives: To determine whether gaze tilts are sustained during continuous circular walking and to characterize the compensatory and orienting head and eye movements that are used to stabilize gaze.
Methods: Head and body movements were measured with a video-based motion analysis system (OPTOTRAK, Northern Digital, Inc) and eye movements with video-oculography.
Results: The body followed the circular trajectory quite faithfully when walking at both large and small radii, even in darkness. In light, the head led the trajectory by 10-25° about the yaw axis. The head also oscillated about the steady state circular trajectory both in pitch and yaw. The head fixation point (HFP) was »0.5-0.6 m from the subject when projected into the pitch and yaw planes, as during linear walking. When the head and eye rotations from walking in light were combined in three dimensions, the yaw component of gaze velocity in space was maintained close to zero, stabilizing the visual surround. Gaze position incrementally shifted in the direction of walking with rapid saccades. In darkness, there was little or no compensatory gaze velocity relative to the body in the steady state. As a result, gaze velocity in space about a yaw axis was close to the angular walking velocity. There was also a significant gaze tilt relative to the trajectory in response to the centripetal acceleration on the head. This tilt tended to align the yaw axis of the eye in space (gaze) with the direction of the GIA. The gaze tilt was produced predominantly by the head and eyes, while the trunk was held upright. Pitch head and eye movements were closely related to pitch movements of the trunk with a phase lag.
Conclusion: The data demonstrate that compensatory and orienting responses of the head and eyes superimpose to stabilize gaze in three dimensions relative to the body trajectory in space. This implies that body heading in space is a critical parameter that is coded centrally and that the vestibular system adjusts the head and eyes to compensate for

perturbations about this trajectory to maintain a stable equilibrium while walking.
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O029

Gait Analysis in Patients with Vestibular System Disorders by the Use of Tactile Sensor

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Background: Human bipedal locomotion is a well-controlled whole body movement, and vestibular system plays an important role. Therefore patients with vestibular system disorders should have some form of gait abnormality. Degree and anatomical variability of a lesion could affect pattern of gait abnormality. From this point of view, we have conducted a study of gait abnormality in patients with vestibular system disorders by introducing tactile sensors that were placed under each foot.
Objectives: The aim of this study is to elucidate certain characteristics of gait abnormality obtained by foot movement analysis in variety of patients who have vestibular system disorders.
Methods: Subjects were cases with acoustic neuroma, vestibular neuronitis, and spino-cerebellar degeneration (SCD). Healthy adults served as a control. Employed variables were coefficient of variation of stance, swing, and double supports. Stability of foot pressure progression and trajectories of center of force, and foot pressure difference between both feet were also examined.
Results: In pathological cases, significant increment of CV values, which were, in general, parallel to degree of gait ataxia, was obtained. In cases with unilateral vestibular lesion, under gait with eyes closed, significant greater foot pressure was found on the lesion side foot and significantly greater horizontal sway movement of trajectories of center of force was resulted on the lesion side foot. Regarding cases with SCD, in addition to greater CV values of gait phase related variables, irregular foot pressure progression during body weight translation period was found. As for relative length of trajectories of center of force, somewhat shorter value was obtained in cases with peripheral vestibular lesion and longer in cases with SCD, respectively.
Conclusion: Gait analysis gives us objective important information on dynamic equilibrium function as a whole, and is useful for one of the equilibrium function tests.

O030

Generation of Locomotor Trajectories: Influence of the Geometry of the Path on the Anticipatory Head Direction

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Background: The importance of the head stabilization and the anticipatory head and gaze strategies have been demonstrated for the steering of human locomotion while subjects were required to walk (with or without vision) along rectilinear (Pozzo et al., 1990), circular (Takei et al., 1996;Grasso et al., 1996) or triangular (Glasauer et al., 2002) paths. This anticipatory head orientation relative to the future walking direction probably relies on a mental simulation of the locomotor trajectory (Vieilledent et al., 2003).
Objectives: Here we tested the robustness of this anticipatory behaviour by asking subjects to walk along complex trajectories in a large environment.
Methods: Data were recorded in a large room (10 x 8 meters) using a Vicon system equipped with 24 cameras.
Conclusion: Results show that humans likely use information about the geometrical variations of their ongoing trajectory in order to 1) modulate their walking speed (Vieilledent et al., 2001;Hicheur et al., 2004) 2) anticipate their future walking direction. This kind of interaction between geometry of the path and locomotor behaviour reveals that a spatial cognitive simulation of the trajectory is combined with motor strategies for the steering of locomotion.
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O031

Multiple Brain Regions Are Involved in the Elaboration of Bipedal Locomotion in M. Fuscata: A Pet Study

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Background: Japanese monkey, *M. fuscata*, is normally quadrupedal (Qp) but it can be operant-trained to walk bipedally on the moving treadmill belt. To better understand CNS mechanisms involved in the elaboration and refinement of bipedal (Bp) locomotion, we have assessed previously the reactive and anticipatory control capability of *M. fuscata*'s Bp locomotion on a level, an inclined, and an obstacle attached treadmill belt. In all these test conditions, the monkey recruited several kinematic strategies similar to those used by the human. The results suggested that this non-human primate model animal could advance understanding of CNS mechanisms that contribute to the elaboration of Bp locomotion.

Objectives: The main objective of this study is to explore brain-Bp locomotor behaviour relationships. For this, we employed a non-invasive neuroimaging PET protocol and detected the brain areas involved in the elaboration of not only Bp but also Qp locomotion in various walking conditions.
Methods: We measured regional cerebral metabolic rates of glucose usage by use of [^{18}F] fluoro-2-deoxy-D-glucose ([^{18}F]-FDG) and PET. This approach allowed us to detect the accumulation of FDG in brain tissue for a relatively longer period of time, such that imaging of brain activity is possible even after termination of a given locomotor task. After initial transmissions scan, we injected [^{18}F]-FDG intravenously into the awake, adult monkey (n=3). Immediately after the FDG injection, the animal was conditioned to walk bipedally on the moving treadmill belt for 30 min at its comfortable speed (0.4-0.6m/s). The tasks included 1) Bp walking on a level (Bp-level), 2) Qp walking on a level (Qp-level), and 3) Bp walking on an obstacle attached level treadmill belt (Bp-obstacle). The monkey was also asked to sit quietly on a specially designed chair for 30 min (control task). PET data was then collected and statistically analyzed.
Results: We found several brain areas that were activated selectively while *M. fuscata* was elaborating Bp and Qp walking. These included the primary motor area (M1), supplementary motor area (SMA), premotor area (PM), visual cortex and cerebellum. Of particular interest were the differences observed between the activation patterns during Bp- vs. Qp-level walking in the same monkey. During Bp-level walking, M1, SMA, and PM, bilaterally, were relatively much more activated than during Qp-level walking. Midline area of the cerebellum was also highly activated. During Qp-level walking, the cerebellum as a whole was activated. During Bp-obstacle walking, thalamic nuclei, bilaterally, were significantly activated in addition to the motor cortices and the cerebellum.
Conclusion: In parallel activation of several brain areas with a different weighting suggest that selective yet multiple brain sites are involved for the monkey to meet Bp and Qp walking tasks. The monkey seems to recruit a cerebello-thalamo-cerebral loop to meet an obstacle clearance locomotor task.

O032

Head Stabilization Mechanisms During Quadrupedal Locomotion

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Background: Vertical translation and associated pitch of the head during bipedal gait maintain a stable head fixation point in humans [1-6]. Similar compensation occurs during quadrupedal walking [7]. The kinematics of quadrupedal gait have been studied in the monkey (8), but little information is available about the exact interaction of fore and hind paw placement and head and body movement and whether the vestibular system contributes to this interaction.
Objectives: To determine vestibular contributions to head movement during quadrupedal locomotion.
Methods: Rhesus and cynomolgus monkeys walked on a linear treadmill at velocities between 0.4 and 0.9 m/s. The linear and angular positions of rigid bodies placed on the paws, chest and head were monitored in angular and linear dimensions by a video-based motion detection system (Optotrak, Northern Digital Inc).
Results: Monkeys walked with a reciprocal gait with hind paws leading the contralateral forepaw by 100-150 ms. Step length increased as monkeys walked faster. Stride frequency rose from 1.2 to 1.7 Hz with increases in treadmill velocity (step frequencies of 2.4 to 3.4 Hz). Peak vertical accelerations of the head and body ranged from »0.4 to 0.5g and were closely related to forepaw placement in the stance phases. A striking finding was that the head pitched at the step frequency with amplitudes between 5-18°. Peak head pitch velocity increased linearly with peak head Z-axis acceleration. Instantaneous head Z- and head pitch velocities were reciprocally related. At slower walking speeds upward head Z- and downward head pitch velocities were faster than the reverse, but the two equalized at faster walking velocities. Spectral analysis showed that coherence between head acceleration and walking velocity and between head pitch velocity and head acceleration was high at the step frequencies at all walking speeds. Similar frequencies of head Z-axis acceleration and head pitch velocity were present in the spectrum of these signals out to ≈8 Hz, but maximum power was at the forepaw step frequency, suggesting filtering of the higher frequencies.
Conclusion: The data show that vertical head translation and head pitch are related in a compensatory manner during quadrupedal walking in the money. These findings are consistent with the hypothesis that compensatory head pitch during quadrupedal locomotion is due to the activation of the linear vestibulo-collic reflex (lVCR).
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O033

Qualitatively Different Strategies Are Used to Elicit Reflexive and Cognitive Responses

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Background: The otolith organs measure linear acceleration and gravity. From personal knowledge of our perceptual experiences as well as scientific investigations, we know that humans perceive both tilt and translation. This demonstrates that the human nervous system separates the ambiguous measurement of gravito-inertial force into neural representations of tilt (i.e., gravity) and translation (e.g., linear acceleration) without demonstrating what strategies are used to accomplish this separation.
Objectives: Our objective was to determine the neural mechanisms that humans use to process ambiguous cues from the otolith organs.
Methods: We simultaneously measured vestibulo-ocular reflexes (VORs) and perceptions of tilt and translation using 3 motion paradigms in 8 human subjects. In two paradigms, identical sinusoidal inter-aural otolith cues were provided across a broad frequency range by either tilting the subject in roll about an earth-horizontal, head-centered, rotation axis ("Tilt") or translating the subject along their inter-aural axis ("Translation"). In the third paradigm ("Tilt & Translation"), subjects were sinusoidally roll tilted but with ears above or below the rotation axis. This latter paradigm provided sinusoidal roll canal cues that were the same across trials while providing sinusoidal otolith cues that varied linearly with ear position.
Results: The data showed that the perception of tilt and perception of translation were dependent on canal cues, with substantial roll tilt and inter-aural translation perceptions reported even when no inter-aural force cues were present. These findings match internal model predictions that rotational cues from the canals influence the neural processing of otolith cues. The data also demonstrated horizontal translational VORs at higher frequencies (>0.2Hz) during both "Translation" and "Tilt"; these responses were dependent on otolith cues but independent of canal cues. These findings match frequency segregation predictions that translational VORs include contributions via simple high-pass filtering of otolith cues.
Conclusion: These findings demonstrate that internal models govern human perception while showing that simple filtering contributes substantially to the human translational VOR above 0.2 Hz. Hence, qualitatively different neural mechanisms contribute to perceptual and reflexive responses. While human perception and eye movement responses may sometimes share common neural pathways, this difference between eye movements and perception clearly shows that one cannot simply measure eye movements and assume that this measure is representative of perception nor simply measure perception and assume that this measure is representative of reflexive responses. Taken together, these behavioral measures (both eye movements and perception) can be used to determine what strategies the nervous system uses to process the incoming sensory information and to guide neural recordings that elucidate how these strategies are implemented by the nervous system.

O034

Influence of Neck Muscle Vibration in Self Motion Perception

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Background: Neck muscle proprioception provides information about the position of the head in relation to the trunk, contributing to posture control and internal body representation. Recently, we have found that static head deviation may also affect the beating field of the optokinetic responses, space perception and vestibulo-ocular reflex (VOR). In addition, it has been shown that muscle vibration influences the body centered coordinate system and that repetitive neck muscle vibration is able to induce long term change in the internal space representation.
Objectives: The present research examines how neck proprioceptive signals can influence the vestibular system and movement perception. We studied short and long term effects of the neck muscle vibration on VOR and movement perception at different head-body angles (± 45°) before and after neck muscle vibration.
Methods: Subjects were asked to imagine a spot position, presented only before the vestibular stimulation, and to track it in darkness with a pointer during asymmetrical body rotation (40° amplitude, 20% asymmetry and 0.15 Hz frequency). In addition, the vestibuloocular reflex (VOR) was recorded by EOG. Neck muscle vibration was applied to the splenius and trapezius neck muscles (0.8 mm and 100 Hz (HFS) or 5 Hz (LFS) for 3 and 8 min).
Results: Four cycles of asymmetric oscillations caused a progressive shift of the imaginary target position in the same direction as the slower vestibular stimulation side. In the straight ahead position the shift was about 45°, but increased to about 85° when the head was deviated toward the faster vestibular stimulation side and decreased to about 5° with the head in the opposite direction. VOR gain showed a similar modulation. After HF vibratory stimulation applied on the posterior neck muscle ipsilateral to the faster vestibular stimulation, we observed an increase of VOR as well as of the imaginary target shift, similar to that induced by ipsilateral head deviation. A second HFS provoked a further enhancement of the effects and this remained unchanged 48 hours later. LFS caused the same effects in terms of direction, but with smaller amplitude. Interestingly, the HFS effect was fully abolished by a second LFS given after HFS or LFS
Conclusion: We concluded that tonic head rotation toward the side of faster head rotation enhances self motion perception and VOR in this direction. Similar effects are in-

duced by unilateral neck vibration. However, since the influence of the neck muscle vibration is similar to that induced by the shortened muscle during head deviation, we suggest that vibratory effect can not be interpreted as a result of the increase of neuromuscular spindle afferent discharge following muscle elongation. Finally, muscle vibration is able to provoke long term potentiation in the central circuit and cancel it depending upon the frequency of stimulation as occurs in the vestibular nuclei after HF and LF stimulation of the vestibular nerve.

O035

Hippocampal Theta Activity Results from Dynamic but not Static Vestibular Stimulation

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Background: The vestibular system fulfils an important role in navigation and spatial ability. Studies indicate that if vestibular input to the hippocampus is compromised or absent, idiothetic navigation is impaired. It appears that hippocampal theta activity is correlated with successful processing of spatial information, but the relationship between vestibular input and hippocampal theta remains unclear. Particularly, it is not known whether dynamic and static vestibular stimulation produce differing hippocampal responses.
Objectives: The current study examined whether theta activity was elicited by both dynamic and static vestibular input. It also evaluated whether angular and linear natural vestibular stimulation produced comparable hippocampal responses.
Methods: Electrodes chronically implanted in the hippocampus were used to measure hippocampal electrical activity in alert but restrained guinea pigs. Two paradigms of natural vestibular stimulation were used: angular and pure linear. Angular stimulation consisted of a series of passive accelerations in the roll, pitch, and yaw planes. Pure linear stimulation comprised of passive accelerations in the naso-occipital and inter-aural planes. Each acceleration was followed by a period of maintained position.
Results: Angular and linear vestibular stimulation produced comparable hippocampal activity. Theta activity was elicited by dynamic stimulation, but did not persist during the maintained position component of the stimulus.
Conclusion: These results suggest that both canal and otolithic input can initiate hippocampal theta activity. It appears that theta activity is elicited primarily by dynamic vestibular stimulation (that is, input regarding change in position) rather than static vestibular stimulation (concerned with maintained position in space).

O036

Role of Tactile Situation Awareness System on Visually Evoked Vection

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Background: Vection is a spatial disorientation phenomenon that often confronts pilots in flight. This problem can be induced by seeing the motion of the world outside the window. The recently developed "Tactile Situation Awareness System" (TSAS) by the Naval Aerospace Medical Research Laboratory in Pensacola, may have the potential to help mitigate this problem. TSAS provides non-visual orientation information through the sense of touch. This somatosensory stimulus may improve the ability for the assessment of self-motion and position in space coordinates. This is of importance for pilot control of an aircraft.
Objectives: The present study aims to investigate whether an illusory perception of self-motion (vection), induced by the slow rotation of a visual scene, can be reduced by tactile stimulation using TSAS.
Methods: Self-motion perception was provoked in 12 healthy volunteers sitting still within a rotating spherical device. The sphere rotation velocity was varied between 15 and 60°/sec. and the experienced vection was 100% in all subjects. After 45 sec. of rotation with constant velocity we tried to reduce the visually evoked vection with the tactile situation awareness system (TSAS). TSAS is a vest with vibrators situated in columns around the torso, which can generate a moving tactile stimulus around the torso in a pattern to create a sensation of rotation in the opposite direction to the experienced visual vection.
Results: In all subjects TSAS reduced the visually evoked vection. The magnitude of vection reduction varied and showed inter-individual difference. However within each subject the reduction of vection was relatively constant when the experiment was repeated.
Conclusion: This experiment indicates that in the process of visual-vestibular-somatosensory interaction for self-motion perception in space, the visual stimulus that generates vection could be attenuated by tactile stimuli. This is important in developing countermeasures that could reduce the visual illusions such as disorientation of pilots in flight.

O037

Prediction and Anticipation in the Interaural Translational VOR

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Background: Previous studies [1,2] have shown that the brain can modulate the gain of the tVOR response by enhancing it in space-fixed trials and suppressing it in head-fixed trials, but the timing and mechanism of such modulation are uncertain. The role of higher-level mechanisms involving cognitive factors may be relevant in the understanding of the ability of the brain to modulate the response of the tVOR.
Objectives: We sought to clarify the timing of such modulation and how it is affected by prior knowledge of the direction of head motion and the location of the target rela-

tive to the motion of the head. To better identify the effects we opted for high transient accelerations and close targets which lead to a relatively robust slow-phase response [3].
Methods: Variables were: prior knowledge of the head direction and the position of the fixation target relative to the head (head-fixed (HF) or space-fixed (SF)). A manually-driven device provided a step-like head translation (~35 mm, 0.6-1.3 g). Subjects looked at the SF or HF target, at 15 cm distance, in otherwise complete darkness. The five testing paradigms were: random interleaving of SF and HF targets with unknown direction of head movement (RND), known target location with random head direction (SFR or HFR), and known target location with known head direction (SFP or HFP). A 'gain' was calculated with respect to ideal performance (maintained fixation of the SF target).
Results: We found no significant differences between HF and SF trials in the RND condition; the average gain was ~30% of ideal. Responses in the SFR and HFR conditions differed as early as 20 ms after the head began moving. The average gain was higher (0.33 vs. 0.26, $P<0.05$) for each subject in the SFR than in the HFR condition. For SFP and HFP, the responses differed from the very onset of head motion. Average gain was higher (0.40 vs.0.23, $P<0.02$) for each subject in SFP than in HFP. We computed average responses for each subject in each condition and simulated a mathematical model of the tVOR using the corresponding average head acceleration as input. We hypothesized different parametric adjustments to explain the changes observed experimentally and found that our experimental findings could be simulated with parametric adjustments of the gain of otolith afferents.
Conclusion: Our results show a fundamental role for cognitive factors in the modulation of the tVOR response that can be modified within times that are shorter than the latency of visual information, but only when subjects have a priori information about the position of the target and/or direction of the movement of the head. The results of our simulations suggest that cognitive control of the VOR could occur as early as the synapse of primary afferents upon neurons in the vestibular nuclei or in the cerebellum.
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O038
Suppression of Visually- and Memory-Guided Saccades Induced by Electrical Stimulation of the Monkey Frontal Eye Field
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Background: Electrical stimulation of the frontal eye field (FEF) has been reported to elicit saccades, and recently also to suppress saccades.
Objectives: This study was performed to characterize properties of the suppression of visually-guided (Vsacs) and memory-guided saccades (Msacs) induced by stimulation of the FEF in trained monkeys.
Methods: For any given stimulation site, we determined the threshold for electrically-evoked saccades (Esacs) and then examined the suppressive effects of stimulation at the same site on Vsacs and Msacs.
Results: We found that there were two types of the suppression of saccades: suppression of ipsiversive saccades and suppression of ipsi- and contraversive saccades. In unilateral suppression sites, FEF stimulation suppressed the initiation of only ipsiversive Vsacs and Msacs during and ~50 ms after stimulation at thresholds lower than for eliciting Esacs at less than 50 μA, but did not affect the vector of these saccades. In bilateral suppression sites, stimulation suppressed the initiation of both Vsacs and Msacs in any direction during and ~50 ms after stimulation, but did not affect the vector of these saccades. This stimulation usually did not evoke any saccades at 80 μA, indicating that the bilateral suppression area was different from the unilateral suppression area where stimulation evoked saccades at less than 50 μA. Thresholds were almost similar for the suppression of Vsacs and Msacs, and that of ipsiversive and contraversive saccades.
Conclusion: Our results suggest that the FEF may play roles in not only generating saccades but also suppressing saccades and maintaining fixation.

O039
Vestibular-Projecting Area in the Periarcuate Cortex and Its Relation to the Smooth Pursuit-Related Area in the Monkey
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Background: Vestibular inputs to the cerebral cortex are important for spatial orientation, body equilibrium, and controlling head and eye movements. However, vestibular representation in the cerebral cortex is poorly defined compared with other sensory modalities and the pathways from the vestibular nerves to the cortex are still controversial. Most of the studies on vestibular-evoked potentials were restricted to recording potentials on the surface of the cerebrum for technical reasons and the buried cerebral gyri have not been systematically surveyed yet.
Objectives: We examined vestibular input to the periarcuate cortex.
Methods: Experiments were performed in the Japanese monkey by analyzing laminar field potentials evoked by electrical stimulation of the vestibular nerve on either side.
Results: Laminar field potential analysis in the depths of the cerebral cortex showed that vestibular-evoked potentials consisted of early-positive and late-negative potentials

and early-negative and late-positive potentials in the superficial and deep layers of the periarcuate cortex, respectively, with latencies of 4.8 - 6.3 ms, suggesting that these potentials were directly conveyed to the cortex through the thalamus. These potentials were distributed bilaterally continuously in the fundus, dorsal and ventral banks of the spur and the bottom of the junctional part of the arcuate sulcus and spur. This vestibular-projecting area overlapped the cortical distribution of corticovestibular neurons that were retrogradely labeled by tracer injection into the vestibular nuclei (previously reported area 6pa) after electrophysiological identification of the vestibular nuclei. The distribution of smooth pursuit-related neurons recorded in the periarcuate cortex including area 8 was determined in a trained monkey. Then, the vestibular-projecting area was systematically mapped in the same animal under anesthesia. The vestibular-projecting area overlapped the smooth pursuit-related area.
Conclusion: These findings support that the smooth pursuit-related area receive vestibular signals and control gaze.

O040
Synaptic Inputs and Their Pathways from the Fixation and Saccade Areas of the Superior Colliculus to Inhibitory Burst Neurons
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Background: Excitatory (EBNs) and inhibitory burst neurons (IBNs) in the brain stem are known to show burst activities during saccadic eye movements that are induced by inputs from the superior colliculus (SC). The rostral pole of the SC contains fixation neurons, whereas the more caudal SC contains movement neurons.
Objectives: We investigated properties of inputs to IBNs from the rostral and caudal parts of the SC using electrophysiological and morphological methods in anaesthetized cats.
Methods: We recorded intracellular potentials from neurons in the paramedian pontomedullary reticular formation where IBNs are known to exist.
Results: IBNs were identified by their antidromic responses to stimulation of the contralateral abducens nucleus and/or by morphological features revealed by intracellular staining with horseradish peroxidase. Stimulation of the caudal parts of the contralateral and ipsilateral SC evoked monosynaptic excitation and disynaptic inhibition in IBNs, respectively. Stimulation of the rostral parts of the ipsilateral or contralateral SC evoked disynaptic inhibition. Combined stimulation of the rostral parts of the bilateral SCs showed spatial facilitation of these disynaptic inhibitions, which indicates that these inhibitions were mediated by common inhibitory interneurons. Lesion experiments showed that the inhibition from the caudal part of the ipsilateral SC was mediated to IBNs by contralateral IBNs, and the inhibition from the rostral parts of the bilateral SCs was mediated by inhibitory interneurons other than IBNs, most probably pause neurons. The results indicate that the rostral fixation area in the SC on one side exerts inhibition on bilateral IBNs, and the caudal saccade area in the SC exerts monosynaptic excitation on contralateral IBNs and antagonistic disynaptic inhibition on ipsilateral IBNs via contralateral IBNs. Intracellular staining revealed that single pause neurons that received inputs from the bilateral SCs sent extensive axon collaterals to the EBN area as well as the IBN area.
Conclusion: The results indicate that the fixation area in the rostral SC may inhibit burst neurons via pause neurons during visual fixation and suppress reflexive saccades to inappropriate targets that appear in the visual field.

O041
Mental Transformations of Perspective During Whole-Body Roll Rotation
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Background: Egocentric perspective transformations require an imagined transformation of the body necessary to make spatial judgments from another person's view. Psychophysical, neuroimaging, and neuropsychological studies have provided evidence that egocentric perspective transformations rely on mechanisms that are - at least partially - separate from other types of mental transformations (e.g., as used in mental object rotation). In this study, we explored the possibility whether body transformations in imagery and perception share some of the underlying mechanisms. Previous research demonstrated that visual mental imagery and visual perception draw to some extent on the same mechanisms. To our knowledge, however, no study has been conducted to investigate the role of vestibular perception while people are engaged in a mental perspective transformation task.
Objectives: The aim of this study was to investigate whether imagined body rotations rely on mechanisms, which are also involved in the perception of body rotation (i.e., vestibular information). If partly the same mechanisms are involved in these two different types of tasks we would expect interference or facilitation when they are performed simultaneously.
Methods: The body rotations used in this experiment were performed with the 3D human turntable (Acutronik, Jona, Switzerland) at the University Hospital Zurich. Rotations were performed in the body roll plane (to the left/right). Starting from the initial upright position (0°) subjects (N=11) made a complete 360° rotation (constant velocity of 90°/s, constant 160°/s2 acceleration and deceleration of the roll-axis). We used line drawings of human bodies as visual stimuli. These line drawings could be presented in front/back view and they had one arm outstretched. The subjects' task was to decide whether the figure's right or left arm was outstretched. The figures were presented in different orientations (0, 45, 90, 135, 180° CW or CCW) in the picture plane.

Results: We calculated a 2 (direction of body rotation, CW or CCW) x 2 (stimulus orientation, CW or CCW) repeated measures ANOVA. The results showed a tendency for a main effect of the direction of stimulus orientation, $F(1,7) = 5.20$, $p = 0.056$. The subjects made slightly more errors when the stimuli were tilted CCW than when they were tilted CW. There was no main effect of the direction of body rotation, $F(1,7) = 0.97$, $p = 0.36$. However, the two variables interacted, $F(1,7) = 7.7$, $p = 0.028$. The subjects made more errors when the imagined body rotation and the direction of physical rotation were incongruent (i.e., both either CW or CCW).
Conclusion: The results indicate an advantage in task performance (accuracy) when the direction of mental and physical body rotation were congruent. We conclude that partly the same mechanisms are involved when spatial transformations are performed in imagery and perception.
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O042

The Perception of Linear Self-Motion During 0-G Parabolic Flight

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Background: The sensation of illusory linear self-motion ("vection") during spaceflight is measurably stronger than the sensation in 1-g. [1] This is primarily from the reduced visual-vestibular conflict due to graviceptor unweighting, but vection may also be modulated by the observer's sense of "presence" in the virtual environment (i.e., the degree to which subjects suspend the reality of their physical environment and accept the virtual environment as the new frame of reference within which they are immersed). In spaceflight, subjects reported the stimuli were similar to what they experienced during normal movement and more compelling than in 1-g.
Objectives: Our primary goal was to determine if the sensation of linear vection in parabolic flight was similar to that seen in short duration spaceflight and if habituation or adaptation occurred over three days of testing. We also investigated whether a subject's sense of presence in these virtual environments correlated with our measures of vection.
Methods: We tested five subjects on two CNES-sponsored parabolic flight campaigns. All subjects were tested on three consecutive flight days (10 parabolas/day) during the 0-g and 1-g portions of the flight. They sat on the floor of the plane facing the cockpit while wearing a head mounted display showing stereoscopic images of a long virtual corridor. We simulated 10s of linear motion at one of four different speeds (0.4-1.6 m/s) and measured the latency to the onset of vection and percentage of the visual scene motion attributed to self-motion ("%saturation"). Subjects performed two trials in 0-g followed by two identical trials in 1-g level flight. After each trial, they verbally reported their peak sense of presence on a 1-7 scale.
Results: We found a significant main effect of gravity condition on the %saturation of vection (0g: 66%, 1g: 51%), the latency to vection onset (0g: 3.5s, 1g: 4.7s), and verbal ratings of peak presence (0g: 4.1, 1g: 3.5). There was also a significant effect of simulated scene speed on the %saturation and latency. The only significant effect of Flight Day was for an increase in %saturation between Flight Days 2 and 3. Fits of linear regression models of presence and latency (0g: $r2 = 0.34$; 1g: $r2 = 0.36$) were relatively better than for presence and %saturation (0g: $r2 = 0.1$; 1g: $r2 = 0.28$).
Conclusion: Our results imply that the sensation of linear vection changes immediately upon entering 0-g and does not require physiological adaptation. Presence also increased in 0-g, but was generally not well correlated with our measures of vection, suggesting that changes in visual vestibular conflict affect vection at a processing level below cognition.
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O043

Spatial Disorientation – How the Brain Interprets Linear Acceleration During Flight

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Background: During takeoff and landing of aircraft sustained accelerations are experienced that sum with the linear acceleration of gravity to generate the gravito-inertial acceleration (GIA) vector. In this altered gravitational environment pilots interpret the GIA as the spatial vertical, leading to erroneous perceptions of tilt that can have serious implications for flight safety. In commercial aviation, this somatogravic illusion has proven to be a major contributing factor to several accidents, particularly during aborted landings, where an aircraft accelerating downwards is sensed by the pilot to have an upward trajectory. SD is also of concern in the space program, with 90% of shuttle crewmembers experiencing illusory perceptions of motion during reentry that adversely affect landing performance.
Objectives: We have recently begun to explore how the brain interprets vestibular input during flight, using an Airbus A340-600 motion simulator to model the final seven minutes of a shuttle landing.

Methods: The pilot performs a descending banking turn from 40000 ft to 14000 ft (the HAC maneuver), then an 11° glide slope with a flare maneuver at 2000 ft and touchdown at 210 knots. Head-eye movements were recorded in 3D using a new laptop-based integrated eye, head, and cabin tracker developed by the investigators.
Results: During the 45° bank around the HAC the head and eyes rolled out from the turn towards the scene-derived 'spatial vertical' by 5°. The angular and linear vestibulo-collic and vestibulo-ocular reflexes compensated for random perturbations (turbulence) of the cabin during the steep final approach to maintain gaze, which alternated between the instrument panel and the approaching landing strip. During rollout, there was optokinetic nystagmus (OKN) with downward slow phases as the pilot concentrated on the centerline.
Conclusion: During shuttle reentry head movements in pitch and roll are provocative, and generate erroneous perceptions of self- or surround movement. In particular, roll tilts of the GIA, such as during the HAC maneuver, are misjudged. Astronauts may tend to 'strap down' their heads by increasing neck stiffness to minimize provocative head movements, as observed in post-flight locomotion. Incorrect orientation of the head to the gravitational vertical during banking may exacerbate erroneous perception of the roll attitude of the spacecraft. During turbulent final approach a 'strap down' strategy would increase the range of 'eyes only' gaze movements, degrading visual acuity. Finally, our results from Neurolab (STS-90) suggest that during downward OKN following spaceflight the eye tends to drift upwards by 10°, which may degrade vision during rollout. Supported by NASA contract NCC 9-128.

O044

Evidence for Interacting Cortical Control of Vestibular Function and Spatial Representation in Man

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Background: Anatomical and electrophysiological evidence has been provided in monkey for multiple vestibularly-driven cortical areas distributed from the posterior parietal cortex to the frontal regions. In man, while imagery studies provide some insight into the functional organization of vestibular cortex, the role of the different vestibularly-activated cortical regions remains quite obscure. Recently, a possible role for these different regions has been suggested to include self-motion perception, spatial perception and memory, all based on the integration of vestibular related signals.
Objectives: We hypothesize that the neural transformation sub-tending the representation of space in the parieto-temporal cortex includes the integration of vestibular information. In this context, we investigated whether such a vestibular cortical mechanism is linked only to the perceptual or cognitive aspects of the vestibular function, or to its motor output as well and, in this latter perspective, whether the vestibulo-motor deficits will be correlated to the visuo-spatial disorders.
Methods: In this study, we addressed these questions by investigating vestibulo- ocular performance of 15 patients presenting with a unilateral cerebral cortex damage, including the parieto-temporo-occipital (PTO) junction either in the right hemisphere, accompanied or not by a left hemineglect, or in the left hemisphere, without neglect. First, in all the patients, we recorded the vestibulo-ocular reflex (VOR) in complete darkness by rotating the subject around the vertical axis by sinusoidal rotation at different frequencies and by steps of acceleration or deceleration. Second in one case presenting visuo-spatial disorders due to a right cortical lesion, we analyzed the vestibularly-driven saccade performance to the remembered spatiotopic position of a visual target, after whole-body rotation.
Results: The main findings of this study in unilateral PTO lesions are a significant VOR asymmetry as revealed by a directional preponderance of the gain to the contralesional side and in contrast, a VOR bias and a directional preponderance of the time constant to the ipsilesional side. Interestingly, these latter vestibular deficits are more pronounced in patients with parieto-temporal lesions localized in the right hemisphere accompanied by hemineglect syndrome. In case of right lesions vestibularly-driven saccades were inaccurate or misdirected only when the visuo-vestibular computation implied body rotations to the left i.e. to the neglected hemispace.
Conclusion: In conclusion, the co-occurrence of VOR time constant deficits and visuo-spatial disorders suggest a functional link between the representation of space and the integration of inertial vestibular information in cortex. In favor of this theory are our recent findings showing an inability to use vestibular input to update a memorized visual representation, expressed only when the head movements are directed in the neglected hemispace.

O045

Differential Expression of Immediate-Early Genes (Fos and Zif268) in the Vestibular Nuclei and Related-Structures After Unilateral Vestibular Loss in the Cat

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Background: Immediate-early genes (IEGs) are generally expressed in response to sensory stimulation or deprivation and can be used for studying the molecular events underlying CNS plasticity.
Objectives: The current study provides a comparison of the expression of two IEGs, c-fos and zif268, in the vestibular nuclei (VN) and related-structures, after unilateral vestibular neurectomy (UVN) in cats.
Methods: Immunohistochemistry was used for Fos protein and Zif268 labeling, and the induction of both IEGs was

investigated at various postlesion intervals (2h, 8h, 24h, 3 days, 1, 2 3 and 4 weeks).
Results: Results showed three main points of differences between the two IEGs expression. (1) Fos-like immunoreactivity (IR) was detected at early time points after UVN with a early induction peak at 2 hours, and a delayed one at 24 hours, and progressively declined, over the survival period up to 1 week. By contrast, Zif268 protein showed a later expression with a single peak occurring at 1-3 days, which slowly decreased later on, but was still consistent at the 2 weeks survival delay. (2) IEGs-like immunoreativity is structure-dependent. Fos was mainly expressed in the medial (MVN) and inferior (IVN) vestibular nuclei, and in related-structures such as the prepositus hypoglossi (PH) and the inferior olivary nuclei (IO), but was totally lacking in the lateral vestibular nuclei (LVN) and in the cerebellum. Zif268 expression was exclusively found in the LVN, MVN, IVN, PH and in the cerebellum. Both IEGs were asymmetrically expressed in the VN with a prominent staining on the lesioned side. (3) By using the double staining technique, we evidenced that IEGs expression was dependent on the neurochemical phenotype of the neurons. Zif268 protein was detected in the glutamatergic and cholinergic vestibular neurons while only cholinergic staining was colocalized with Fos labeling. Both IEGs showed no overlapping staining with GABAergic IR in the VN.
Conclusion: Taken together, a more complex picture is emerging for the role played by Fos and Zif268 in the activation of neural pathways in the vestibular compensation process. We conclude that the early spatio-temporal pattern of Fos expression likely reflects the activation of excitatory circuitries, involving mainly the MVN, IVN and IO, which might underlie a modification of the VN neural excitability, after UVN. By contrast, the delayed Zif268 expression would rather activate a different neural pathway including both the LVN and the cerebellum. Since this IEG is strongly implicated in the long term potentiation (LTP) in the CNS and that similar cellular events (LTP and/or LTD (long term depression)) take place in these Zif268-positive structures, we postulate that the Zif268 expression after UVN might be the structural base for motor re-learning process underlying vestibular compensation.

O046

Spatial Characteristics of Central Vestibular Neurons Before and After Lateral Canal Nerve Section

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Background: Spatial characteristics of 56 central vestibular neurons were studied in two normal cynomolgus monkeys and in 36 neurons of two monkeys, several years after both lateral canal nerves were sectioned to test whether the central neurons had spatially adapted to the loss of lateral canal input.
Objectives: Recordings were obtained from the vicinity of rostral medial vestibular (MVN) and superior vestibular nuclei (SVN).
Methods: Neuronal activity was recorded while animal oscillated around a spatial vertical axis in the upright, tilt forward and tilt backward positions.
Results: The average head orientation at which the lateral canal-related neurons were maximally activated (optimal response plane) was about 24° tilt forward for the two normal animals (25°±6° and 22°±3°). Vertical canal related neurons had average an optimal response plane of about 60° tilt backward (-63°±5° and -57°±7°). Animals were also sinusoidally rotated about a spatial horizontal axis with different head orientation relative to the axis of oscillation. Average response vectors of the vertical canal-related neurons in one animals were 43°±14° for ipsilateral anterior/contralateral posterior and -43°±12° for contralateral anterior/ipsilateral posterior canals related neurons and 46°±10° and -49°±13° in the second animal.
After both lateral canal nerves were section, canal-related units were found only in SVN, not in the rostral MVN. If there had been spatial adaptation of the central vestibular neurons, the plane of activation should be shifted toward the lateral canal planes, when animals were oscillated about a vertical axis. No units were maximally activated by rotation about lateral canal planes, and all were maximally activated when the head was tilted back -47°±17° and -50°±12° in the two animals. These planes of maximal activation were close to the predicted orientation of the vertical canals (-50°) and to the spatial responses of the vertical canal-related neurons of the normal animals.
Conclusion: We conclude that there was no spatial adaptation of central vestibular neurons after lateral canal nerve section.
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O047

Plastic Changes of the Cervico-Ocular Reflex After Short-Term Optokinetic Stimulation or Pursuit Eye Movements

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Background: Neck-proprioceptive stimulation in the horizontal plane induces weak eye movements (cervico-ocular reflex, COR), first described by Barany. While these movements are small and variable in normal adults, they become functionally relevant in patients with absent labyrinthine function, contributing to gaze stabilization during head movements. However, the mechanism of COR gain enhancement, compensatory to head movements, is not clear.
Objectives: The objective of this study was to find out how the COR enhances after bilateral vestibular loss.

Methods: We studied the horizontal COR during passive trunk oscillations of ± 16 under the stationary head at 0.1 Hz, before and immediately after combined neck-proprioceptive and optokinetic stimulation for 45 min (A). During the adaptation procedure, subjects (6 normal subjects, aged 24-30 years) stared at an optokinetic pattern moving in-phase with their trunk, while their head was stationary in space. This stimulus combination was thought to simulate the pattern of visual and proprioceptive input, when the head of patients without vestibular function is passively moved. In a second experiment (B), the same subjects had to fixate a stationary laser spot during the adaptation procedure. Again, the optokinetic pattern moved in-phase with their trunk, while the head was held stationary in space as in A. In further separate adaptation sessions (C), the optokinetic pattern was extinguished and the Ss had to pursuit the laser spot, otherwise in darkness, which moved in phase with the neck-proprioceptive stimulus, as in A and B.
Results: In all subjects the gain and phase of COR were not consistently modified after the 'retinal slip' adaptation procedure A and B (between 0.04 and 0.12, +90 and +165 respectively, i.e. in the 'anticompensatory' direction). A significant gain increase (0.23-0.48) and phase modulation (between –25 and –0,75) in the compensatory direction were observed in three out of six subjects, when in-phase pursuit eye movements were elicited continually during the neck-proprioceptive stimulation of the adaptation period in experiment C.
Conclusion: Our results indicate that pursuit may represent the 'error signal' modifying the COR in less than an hour. No such effect has been observed after contextual visual information ('retinal slip').

O048
Influence of Optokinetic Nystagmus on Postural Sway in Vestibular Deficits

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Background: The study of postural response has been determined as a good marker for evolution after vestibular rehabilitation. The influence of vestibular compensation after an unilateral deficit, in postural control has been studied, but no markers for unilateral vestibular deficit has been determined.
Objectives: The aim of this study was to determine postural responses in two groups of patients distributed depending on their compensation status after a vestibular insult.
Methods: Clinical signs of vestibular asymmetry (spontaneous, position and head-shaking nystagmus), were studied as a bedside test in 65 patients in order to determine the status of vestibular compensation. A group of 50 normal subjects was studied as control. Area and sway velocity of the center of pressure distribution were the parameters used for the assessment of postural control. Postural responses were recorded according to a protocol of a clockwise and counterclockwise optokinetic stimulation while standing on a foam.
Results: Patients with vestibular deficit showed a greater area and sway mean than the normal population. Patients with a decompensated vestibular deficit showed greater values than the compensated patients. Ipsilateral optokinetic stimulation showed greater values than the contralateral stimulation in the poorly compensated population.
Conclusion: Study of the postural response while performing optokinetic stimulation may represent a marker of vestibular compensation and should be considered as a functional test in order to evaluate the clinical evolution of the patient.

O049
Evaluating Vestibular Compensation

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Background: Acute loss of unilateral peripheral vestibular function induces instability, sensation of rotation, nausea/vomiting. Several measures may assess the degree of compensation: **1. Clinical.** Improvement of instability and disappearance of the other symptoms, including the nystagmus; **2. Reflex non-Linearity**. The normal VOR is linear for head velocities over ±300deg/s, with a gain typically >0.7 at high frequencies in darkness. With unilateral lesions, the VOR gain initially decreases (any rotation), with the linear range severely reduced during ipsi-lesional rotation. Following clinical, central compensation further improves the non-linear and dynamic properties by rearranging the bilateral signals; **3. Functional retinal slip** (gaze velocity in darkness). During head movements, the VOR minimizes retinal slip for clear vision. In darkness, the default visual goal is the stationary world, so gaze (eye+head) velocity represents retinal slip to "pseudo-visual" goals - another measure of VOR function[3].
Objectives: In clinically compensated patients, alternative VOR analysis is compared for its relevance in predicting slip performance inside slow phases.
Methods: Traditionally[1], X-Y plots of eye versus head velocity provide VOR dynamics and linear range, for an average fit (envelopes) through slow-phase segments, and average slip performance. Our alternate method[2] fits each slow phase segment individually, using a common vestibular process and a possibly deficient gaze holding system. This provides another estimate of VOR non-linearities and peak slip excursions, which can be correlated with the frequency of fast phases.
Results: With long-term compensation, traditional fits of VOR velocity show an improved near-symmetric linear range, but the average (envelope) gain can remain deficient. Our transient (segmental) analysis of nystagmus shows that many combinations of vestibular and gaze-holding time constants can result in indistinguishable average slow-phase envelopes. Also, a vestibular non-linearity can be unmasked from a response apparently linear in the "enve-

lope", explaining trends in the retinal slip seen in some experimental data. Associated higher fast-phase rates mean that less time is spent in slow-phase, with blurred vision as an additional deficit.

Conclusion: Retinal slip should remain below 2deg/s for adequate visual processing[3], for true VOR recovery in patients with potentially hazardous occupations (e.g. pilots, construction workers&). Transient analysis of the VOR distinguishes better between slow-phase dynamics and interactions with fast-phases, explaining slip results.

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O050

Vestibular Compensation and Psychological Adaptation

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It is not rare that patients suffering from Menière's disease still complain of discomfort following a vestibular neurectomy or labyrinthectomy, even though there is no sign of incomplete vestibular compensation. In our view, this paradox results from the psychological impact of the disease. Vertigo represents a frightening experience for most patients. Every spell of vertigo weaken the patient physically and mentally, allowing the reactivation of bad memories or psychological disorders successfully treated in the past. The mental impairment is such that some patients do not clearly differentiate a true spell of vertigo, the fear it generates and the resurgence of ancient psychological disorders. The confusion may persist long after the vertigo has been cured and necessitate specific therapeutic approaches. We will present the joint medico-psychological consultation set in Geneva in 1992 for patients suffering from Menière's disease, a technique designed to better evaluate and help patients suffering from different chronic disorders. Two therapists, a physician and a psychologist are present, altogether with the patient, from the beginning to the end of the consultation to discuss the dual aspect of the disease, somatic and psychological, according to some predefined and fundamental rules. Patient's management in the joint medico-psychological consultation is helpful in the preoperative and the postoperative periods.

O051

Contributions of the Vestibular System to the Head Direction Cell Signal

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Background: Previous studies have shown that a population of cells within the rat limbic system discharge as a function of the direction its head is pointing in allocentric coordinates. One brain area where these head direction (HD) cells are abundant is the anterior dorsal thalamic nucleus (ADN). An intact vestibular system is thought to be necessary in order to generate the direction-specific activity as earlier studies showed that either permanent neurotoxic lesions of the labyrinth or temporary inactivation of the vestibular hair cells abolished direction-specific activity in the ADN [1,2]. However, these experimental manipulations have drawbacks because the lesions may potentially affect areas beyond the vestibular labyrinth.

Objectives: To address this issue, we bilaterally plugged the semicircular canals in chinchillas and recorded from cells in the ADN.

Methods: Chinchillas were surgically implanted with an array of recording electrodes in the ADN and had their semicircular canals occluded bilaterally. Following surgical recovery, recordings were conducted for several weeks and animals were tested for vestibular function at the end of the experiment.

Results: Thus far, we have been unable to identify any cells that fire in relation to HD in two canal-plugged animals. There were, however, a number of cells that discharged with random bursts of activity. These bursts typically lasted about 1 sec, but could last longer, and were not correlated to any specific HD or place within the apparatus. This pattern of activity was similar to the activity seen in the ADN of rats with neurotoxic lesions of the labyrinth. We believe this activity represents HD cells that are disconnected from their inputs and thus the preferred firing direction drifts continuously. In a second experiment, we rotated rats on a turntable at constant speed at ~240°/sec for 2 min and then abruptly stopped the rotation and examined HD cell responses. When the platform rotation was terminated, HD cells sometimes responded with periodic bursts of activity for about 10 sec that were initially time-locked to the frequency of platform rotation. Each burst was ~1 sec long and the intervals between bursts increased progressively from the first burst to the last burst over the 10 sec period, as would be expected if the motion of the endolymph fluid within the semicircular canals gradually slowed down post-rotation. This result indicates how vestibular afterdischarge can influence subsequent HD cell discharge and is similar to post-rotatory nystagmus observed with eye movements following rotations.

Conclusion: These experiments provide further support for the view that the vestibular system plays a critical role in generating HD cell activity.

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O052

Vestibular Influences on Hippocampal Place Representations

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Background: Hippocampal neurons respond selectively as a rat or monkey occupies particular positions in the environment. Although these responses are strongly influenced by visual cues, there is now considerable evidence for vestibular influences.
Objectives: To review the principal findings concerning vestibular influences on hippocampal place responses, and how these interact with other sensory and motor inputs.
Methods: Studies involve recordings of multiple single neurons and electroencephalographic (EEG) activity in freely moving, or passively displaced, rats and monkeys in light and dark conditions. Other relevant neuroanatomical and neuropharmacological results are also evoked.
Results: Spatial representations in hippocampal neurons are updated on the basis of vestibular information. Theta rhythmic EEG activity typically found during active displacements are also triggered by passive translational and rotational displacements. Vestibular lesions dramatically impair the cellular responses.
Conclusions: The vestibular system is vital for hippocampal spatial representations that are strongly implicated for navigation behaviors and for spatial learning and memory functions.

O053

Vestibular Stimulation and Orienting of Attention: Studies in Normal Subjects and Neglect Patients

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Background: Observers can attend to positions in space "covertly", without performing overt motor responses. Several studies have now clarified that detection of a stimulus in one sensory modality is not only improved by spatial cues from the same modality but also by inputs coming from other modalities cueing attention toward the position of appearance of the stimulus [1]. Systematic investigations on the influence of vestibular signals on covert orienting of spatial attention are lacking, notwithstanding the existence of close functional links between vestibular inputs and the neural coding of space.
Methods: We shall describe a series of experiments aimed at investigating the influence of dynamic variations of vestibular inputs, due to rotatory accelerations around the vertical head-body axis, on covert attentional orienting in the visual and in the tactile modality. In these experiments we specifically wished to determine whether rotatory accelerations bias attention toward or away from the side rotation.
Results: Relevant suggestions on the links between the vestibular system and spatial attention are also provided by the study of patients affected by contralesional neglect due to the disruption, in one hemisphere, of the neural network underpinning the multimodal coding of contralesional space. In these patients caloric-vestibular stimulation of one ear, inducing a vestibular-ocular response (VOR) with the slow phase directed contralesionally, produces a transient and consistent remission of neglect [2] both in the visual and somatosensory modality. This evidence directly suggests that variations of vestibular input can modify the allocation of spatial attention in different sensory modalities. We shall review recent studies demonstrating specific pathological alterations of the VOR in neglect patients [3]. These evidences will be discussed in relationship to the ameliorative effects induced by caloric stimulation and the attentional effects of vestibular stimulation found in normal human subjects.

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O054

How Is Internal Spatial Representation Impaired in Patients with Unilateral Vestibular Loss

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Background: A subject moving in an unfamiliar environment acquires spatial knowledge of the surroundings. Many studies have documented the processes involved in spatial orientation in real world environments and have shown that different level of spatial knowledge, from "route" to "survey" are required according to the task to be performed. Under normal conditions of navigation, different sensorimotor cues (visual, proprioceptive, and vestibular) are involved in the coding of spatial information and provide congruent information. The optic flow provides information about the environment and about the pattern of motion of the observer. Muscle and joint receptors give kinesthetic information about relative head and limb positions, whereas the vestibular inertial system specifies self-motion trajectory through angular and linear accelerations of the head.

Methods: The purpose of these studies was to investigate the effects of unilateral vestibular loss on human ability to elaborate an internal spatial representation. Patients with Menière's disease were tested in situations involving whole-body movement and cognitive processing, such as navigation tasks. Patients' performances were recorded before unilateral vestibular neurotomy (UVN) and during the time-course of recovery (one week and one month), and were compared to those of matched control participants tested at similar time intervals. The consequences of vestibular lesion were analyzed in visual and nonvisual (or "locomotor") navigation tasks. To assess the contribution of vestibular cues to route-type versus survey-type mental representation, each navigation task required subjects both to reproduce previously traveled paths and to make spatial inferences. Their performance was assessed by measuring turn error and distance error.
Results: In the acute stage (1 week) after unilateral vestibular lesion, turn error was greater in patients than in controls for the highest level of mental representation (spatial inferences or reversing routes). Preliminary results also indicate distance errors. Impairment at making accurate rotations and linear displacements had disappeared by 1 month after vestibular lesion in both navigation tasks.
Conclusions: These results point to the role of vestibular cues, in interaction with other sensory modalities, in the elaboration of an accurate internal representation of the environment. In addition, they suggest that unilateral suppression of vestibular information would induce transitory spatial memory disorganization at a high level of information processing.

O055

Eye Torsion During Pitch Rotation

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Background: It has been generally assumed that no ocular torsion is generated by pitch maneuvers, but this so-called common knowledge was questioned by our observation in an earlier study where we noted that the torsional baseline in the upright position differed from the baseline in the supine condition. Equipment used in that study did not have the direct capability of performing pitch rotation; hence we conducted a study with the dual axis rotator at the Benjamin Franklin Medical Center in Berlin.
Objectives: Our objective was to rotate subjects in forward and backward pitch to determine whether systematic changes in eye torsion were produced by these maneuvers.
Methods: Twenty-one normal subjects (12 male, 9 female) aged 20 to 79 years, mean 29.5 (12.6 SD) were seated in a dual axis human rotator (Neurokinetics, Inc). The subject's head was positioned so that the interaural axis was aligned with the axis of pitch rotation. An individually fitted bite bar, inflatable helmet, six-point safety harness, hip and leg belting, and lateral supports to the torso and legs kept the subject secured. A fixation diode 60 cm distant suppressed vertical or horizontal eye movement during roll. Eye movements were recorded with a 3-dimensional eye tracker based on SMOS image sensors. Recording was performed in darkness except for the fixation point. Subjects were tilted in the pitch plane from upright to 90° occiput down, then forward to 45° face down.
Results: In pitch rotation, 16 of 21 subjects showed eye torsion changes in response to pitch. In ten subjects the eyes rotated clockwise when pitched backward, and counterclockwise when pitched forward. In six subjects the eyes rotated counterclockwise when pitched backward and clockwise when pitched forward. In five subjects responses were unclear. Amplitude of eye torsion ranged from approximately 2.5° to 5.0°.
Conclusion: The results showed that the majority of persons have an eye torsion response to pitch. Possibly the most interesting finding is that while most showed torsion in phase with the chair's pitch, others had torsion in the opposite direction. Possibly the explanation may lie in anatomical receptor or physiological vector orientations. Although the majority of utricular vectors point in a medial or lateral direction, there are some receptors and their response vectors that lie in an approximately forward and others in an aft direction. Anatomical variation in such receptors may account for the opposite directions of torsional response to pitch seen in our subjects. Those persons with unclear responses may have symmetric forward and aft receptors. It is also possible that one or both utricles may be angulated with respect to the midline in such a manner that the major receptor groups are also stimulated in pitch. A functional purpose of ocular torsion in pitch eludes us.

O056

Vibration-Induced Eye Movements After Unilateral Vestibular Deafferentation

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Background: Vibration excites vestibular [1] and proprioceptive afferents [2]. Vibration to the skull or to the neck muscles induces perceptual illusions and small eye movements in healthy subjects [3,4], and nystagmus and a shift of the subjective visual horizontal in subjects with unilateral vestibular loss [5,6]. Most previous studies have ascribed these effects to vibratory stimulation of neck muscle proprioceptors.
Objectives: To study 3-dimensional eye movements during unilateral vibration applied to the mastoid bone or to the sternocleidomastoid muscle in subjects with chronic unilateral well-defined vestibular deficits.
Methods: We studied 18 subjects with chronic unilateral vestibular deafferentation after vestibular neurectomy or

vestibular neuro-labyrinthitis. The head impulse test showed that 9 subjects had unilateral loss of function of all 3 semicircular canals, while 9 subjects had lost function of only the anterior and lateral semicircular canals. We used magnetic scleral search coils to record 3-dimensional eye movements both during visual fixation and in darkness during unilateral 92 Hz vibration applied to the mastoid bone or to the sternocleidomastoid muscle 25 mm below the mastoid process.

Results: During visual fixation vibration to the mastoid bone or to the sternocleidomastoid muscle on either side induced an ipsilesional tonic ocular torsion of up to 6.5 degrees (mean 3.5 deg). The amount of ocular torsion did not differ between sternocleidomastoid muscle or mastoid bone vibration on either side. Subjects who had lost function of 3 semicircular canals showed larger shift in ocular torsion (mean 3.8 deg) than did subjects who had lost function of only 2 canals (mean 2.4 deg) in response to sternocleidomastoid muscle vibration. In darkness vibration to the mastoid bone or to the sternocleidomastoid muscle on either side induced nystagmus with horizontal, vertical and torsional components. The vibration-induced nystagmus rotation axes differed significantly between subjects with loss of 3 semicircular canals and subjects with loss of 2 semicircular canals and tended to align with the nystagmus rotation axis expected from stimulation of the intact semicircular canal receptors.

Conclusion: Vibration to the mastoid or to the sternocleidomastoid muscle of subjects with chronic unilateral vestibular lesions induces eye movements similar to those seen spontaneously during the acute period after unilateral vestibular lesions. Stimulation of intact vestibular receptors should be considered as a possible explanation of oculomotor or perceptual findings when vibration is applied close to the head [7].

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O057

Direct Electrical Stimulation of the Inferior Vestibular Nerve in Humans

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Background: VEMPs are short-latency EMGs evoked by high-level acoustic stimuli, recorded from the tonically contracted sternocleidomastoid muscle (SCM). They can also occur in patients with severe sensorineural hearing loss, even in deafness.

Objectives: It was the aim of the present study to study the linear relationship between VEMPs upon direct electrical stimulation of the inferior vestibular nerve (IVN)and to compare them to pre- and postoperative VEMPs upon bone-conduction stimulation.

Methods: Seven subjects (4 male, 3 female, 20 - 70 years) were stimulated during otoneurosurgery of the CPA. Subdermal needle electrodes were placed in the middle of the SCM of both sides. The EMG signals of the SCM were recorded on a VIKING-IV system upon electrical stimulation of the IVN (0.4 - 1.0 mA; 0.2 ms duration, 4.7 Hz). These recordings were compared to bone-conduction evoked VEMPs.

Results: All subjects showed normal VEMPs preoperatively with latencies of 12.8 ms for the positive and 22.7 ms for the negative peak. The intraoperative, electrical stimulation of the IVN showed a linear stimulus/VEMP amplitude correlation. The mean latency of the positive peak was 9.1 ms and 13.2 ms for the negative one. No contralateral SCM response could be obtained by electrical stimulation.

Conclusion: There is a direct correlation between saccular activity as mediated by the IVN and SCM contractions as evidenced by direct electrical stimulation in this study. The VEMPs evoked by bone conduction cannot be compared to those upon electrical stimulation with respect to latencies and amplitudes. The threshold stimulus for eliciting a response seems to be at 0.3 mA in our study.

O058

Human Heave Linear Vestibulo-Ocular Reflex (LVOR) Initiation and Cancellation After Unilateral Vestibular Deafferentation (UVD)

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Background: The interaural (heave) LVOR is acutely asymmetric after UVD[1], eventually recovering symmetry at reduced gain[1,2]. In normal subjects, LVOR cancellation reduces gain by 50%[3]. The effect of cancellation has not yet been studied after UVD.

Objectives: To evaluate the LVOR and its cancellation after UVD.

Methods: 11 subjects of average age 55±13 (mean ± SD) yrs had UVD (5 left, 6 right) due to surgery for acoustic neuroma (N=8), Meniere's disease (N=2), and cholesteatoma (N=1). UVD duration averaged 52 (range 1-111) mos. Mean age of 7 control subjects was 64±6 yrs. Subjects underwent transient interaural whole body translation (peak acceleration 0.5 G) in darkness delivered by a pneumatic actuator. For each test condition 10 translations were delivered in directionally random sequence. Search coils measured binocular eye positions. A bite bar accelerometer measured head translation. Subjects regarded earth fixed targets 200, 25, or 15 cm distant that were extinguished at motion onset. Cancellation was tested during fixation of a

continuously visible laser target projected from the subject's head.

Results: LVOR slow phase magnitude varied inversely with target distance. Although slow phase magnitudes were smaller for distant targets, they were closer to ideal. Gain was measured relative to ideal earth-fixed target response100 ms after translation onset (Table). UVD gains were reduced to ~47% of controls, significantly so ($p<0.01$) for all conditions except cancellation at 200 cm ($p=0.07$). Ipsi- vs. contralesional responses in UVD did not significantly differ ($p>0.05$). Cancellation reduced LVOR gain ~65% in both subject groups. For the 15 cm target, LVOR latency was 51±5 ms in UVD significantly longer than 37±19 ms in controls ($p=0.01$).

Table:

Percent of Ideal Response for Earth Fixed Target 100 ms from Onset (mean±SD)				
Target Distance	Earth-fixed target, Controls	Earth-fixed target, UVD	Head-fixed target, Controls	Head-fixed target, UVD
15 cm	13±7 %	6±5%	8±4%	3±2%
25 cm	14±6 %	7±4%	8±4%	4±3%
200 cm	33±15	18±13%	23±18%	12±12%

Conclusion: Subjects with chronic UVD had LVOR gains varying inversely with target distance, but reduced to only 47% of normal, indicating incomplete but symmetrical recovery. Both UVD and control subjects cancelled about 2/3 of the LVOR, suggesting that cancellation is mediated by parametric gain decrease.

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O059

Comparison Between Stabilometry With and Without Head Tilts in a Roll Plane

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Background: The otolith organ is a receptor for G-force. The nervous system coordinate the necessary information, then directs the output to the vestibular-ocular and vestibulo-spinal system. The stabilometer is considered useful in evaluating the output of the vestibulo-spinal system objectively.

Objectives: We performed the head-tilting stabilometry to examine the effect of head-tilt on body-sway.

Methods: Subjects were 35 healthy adults. First, we measured under the condition with no-tilt. Second, tilting head to the left (left-tilt) was added. Third, tilting to the right (right-tilt) was done. We analyzed the obtained eye-closed data using static stabilogram analyzing software (version 1.10, Anima co. Ltd.), and evaluated the output value. The envelope area, length/time, length/envelope area, displacements on the X- and Y- axes, Romberg ratio, power spectrum, and standard deviation, kurtosis and skewness of amplitude histogram were measured. We made a statistical analysis using Wilcoxon's signed ranks test between no-tilt and left-tilt, and between no-tilt and right-tilt. Bonferroni's correction was used, and significant level at less than 5% was considered $p<0.025$

Results: We present the items significantly different from both left-tilt and right-tilt to no-tilt. The length/envelope area in both tilts significantly decreased compared to that in no-tilt (left-tilt; $p=0.0029$, right-tilt; $p=0.0002$). In power spectrum, the area ratio of low frequency bands in the X-axis in both tilts significantly increased compared to that in no-tilt (left-tilt; $p=0.0017$, right-tilt; $p=0.0006$), and the area ratio of middle frequency bands in the X-axis in both tilts significantly decreased compared to that in no-tilt (left-tilt; $p=0.0072$, right-tilt; $p=0.0192$). In velocity vectors, no item was significantly different. The standard deviation in the X-axis in both tilts significantly increased compared to that in no-tilt (left-tilt; $p=0.0018$, right-tilt; $p=0.0001$).

Conclusion: We obtained findings similar to ipsilateral labyrinthine disorder by head tilting. When a man is in the upright position, the force of gravity doesn't give on utricle. But when the head tilts 30 degrees for example, 0.5 G force of gravity gives on utricle. In this study, cervical and visual inputs enter in. But it has been reported that somatosensory, neck afferent had no constant effect on the vestibulo-ocular reflex [1]. Visual inputs can be ignored as we inquired into eye-closed cases. A stabilometer is a device that evaluates the output of the vestibulo-spinal reflex objectively. Head tilting stabilometry has a possibility of becoming an otolith function examination method. We hope the clinical applications of this evaluation will be further studied.

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O060

Vestibular-Evoked Peri-Ocular Potentials (VEPP) Produced by Bone-Conducted Stimulation

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Background: Recently, we reported a vestibular-evoked negative potential (N15) distributed in the frontal scalp electrodes, and speculated an ocular or peri-ocular source[2].
Objectives: We wished to investigate the likely origin of the N15 potential.
Methods: We studied 14 normal subjects with low VEMP thresholds (V_T) and 10 patients with vestibular or ocular disorders. Subjects were stimulated at the mastoid with bone-conducted tone bursts (500 Hz, 8ms) using a B71 bone vibrator. After V_T was determined, subjects were stimulated at fixed intensity levels relative to their individual thresholds. Surface potentials were recorded from Fpz and around the eyes (superior, inferior, medial and lateral to the eyes) and referred to linked earlobes. Subjects looked straight ahead. Some subjects were also stimulated with high frequency (5 kHz) tone bursts and during different directions of gaze.
Results: An N15 response was recorded at Fpz. Similar negative potentials with comparable shape and latency were recorded from the peri-ocular electrodes (amplitude 2.6 ± 1.4 μV, peak latency 13.4 ± 1.0 ms at +18 dB re V_T), but were larger than those at Fpz ($P = 0.044$). A mapping study showed that the potentials were largest around the eyes and these were nearly always in phase. Changing the direction of gaze modulated response amplitude and shape ($P = 0.003$). The response threshold was usually at or near V_T. The potentials were absent following high frequency stimulation, unchanged by facial muscle contraction and absent in patients with absent vestibular function. In a patient with Miller-Fisher syndrome, the potentials were delayed. In 4 patients with superior canal dehiscence the potentials were larger than in normals (6.0 μV, $P = 0.001$).
Conclusion: Our data provide evidence for a peri-ocular source for the N15 potential, vestibular-evoked peri-ocular potentials (VEPP), with volume conduction to other sites over the face. The potentials are largest around the eyes and are modulated by gaze direction. The potentials also show vestibular dependence, as they are only present above VT and in response to low frequency stimulation and are absent in patients with absent vestibular function. Their properties are not consistent with an eye movement as phase reversals between electrodes around the eyes, indicating displacement of the eye, were rarely seen. They are therefore likely to be produced by the peri-ocular muscles [1].

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O061

Vestibular Evoked Ocular Responses to Air- (AC) and Bone-Conducted (BC) Sound I: Eye Movements and Timing in Relation to Vestibular Evoked Peri-Ocular Potentials (VEPP)

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Background: Recent work has demonstrated the existence of an acoustically activated vestibular evoked ocular response [1] and related potentials in scalp [3] and peri-ocular electrodes [2].
Objectives: We wished to determine the eye movements activated by AC and BC sound and their timing in relation to the VEPPs.
Methods: The study was conducted using 2 ms, 500 Hz AC and BC pips. Thresholds (V_T) for AC and BC stimulation were first obtained using the VEMP test. VEPPs at 18 dB re V_T were then obtained in peri-ocular electrodes superior and inferior to both eyes referenced to C7 and vertical and horizontal eye movements were measured using an infra-red detection system. More exact measures of eye movements were also obtained using a search-coil in the left eye in response to the same stimuli.
Results: The VEPPs have an onset between 6 - 8 ms, 3 - 5 ms prior to the onset of movement between 11 - 12 ms, with peak latency between 17 - 21 ms and amplitude between .005 and .015 deg. Effects of AC and BC are different such that AC produces a conjugate upwards movement whilst BC produces a conjugate downwards movement. The coil measurements confirmed that AC produces conjugate elevation, with ipsilateral intorsion/adduction and contralateral extorsion/abduction, whilst BC produces conjugate depression, with ipsilateral intorsion/abduction and contralateral extorsion/adduction.
Conclusion: (1) The timing of the VEPPs alone rules out the possibility that EOG is a significant source, at least prior to 12 ms. Amplitude considerations, however, support this conclusion since a .01 deg movement would give about 0.1 μV of EOG (calibrated at 10 μV per deg), at least an order of magnitude less than the VEPPs. These factors indicate that the most likely source is myogenic and we therefore refer to the VEPPs hereafter as *ocular, vestibular evoked myogenic potentials* (OVEMPs). (2) The movement responses may indicate that AC generates excitation in contralateral inferior oblique and ipsilateral superior rectus whilst BC produces excitation in contralateral inferior rectus and ipsilateral superior oblique muscles. The fact that BC is complicated by conduction across the skull to the contralateral ear, however, would suggest that there are likely to be more inter-individual variability in the responses to BC of a larger sample. Clearly therefore further studies are required to substantiate these observations.
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O062

The Contribution of Semicircular Canal Pathways to Static Cyclotorsion in Vestibular Patients

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Background: Patients with an unilateral vestibular impairment like vestibular neuritis show among other symptoms a static cyclotorsion that can be observed clinically by fundus photography. While the acute spontaneous nystagmus is compensated for after 1-3 weeks, the cyclotorsion can persist even longer. In the past, this cyclotorsion was primarily interpreted as the result of impairment of utricular and not of semicircular canal (SCC) pathways, mainly because of the absence of nystagmus after compensation and because a similarly static ocular counter-roll can be seen in healthy subjects only during static head tilts [1]. The question of whether or not the impairment of SCC pathways also contributes to the pathological cyclotorsion has become part of an ongoing controversial discussion [2-4].
Objectives: To contribute to this discussion by adding evidence for the view that SCC pathways account for a dominant part of the static cyclotorsion. A nystagmus model for a putative pathomechanism of static cyclotorsion is proposed.
Methods: Torsional eye movements were measured with video-oculography in two series of experiments. In the first, patients with a unilateral vestibular disorder were instructed to repeatedly blink in order to unmask and trigger torsional nystagmus quick phases [3]. The patients were either in an acute to sub-acute (n=12) or in a persisting and compensated state (n=12). In the second experiment, purely SCC driven torsional VOR responses to different passive, whole-body angular accelerations (.5, 1, 2, 4, 8 $/s^2$) in roll around an earth-vertical axis were measured in healthy volunteers (n=7).
Results: Blinks always unmasked and triggered torsional quick phases in both series of experiments. Surprisingly, static torsional deviations could be observed in conjunction with decreased nystagmus frequency at the smallest acceleration levels of the pure SCC stimulation. For comparison, blinks had no effect in another control examination of healthy volunteers (n=4) who were statically tilted in order to induce an otolith-only ocular counterroll.
Conclusion: Both series of experiment suggest that, contrary to the common belief that cyclotorsion relies on otolith input, SCC pathways can also lead to torsional offset positions. This can be due to a lack of torsional quick phase generation, and indeed, insufficient nystagmus frequencies were observed both in healthy subjects at small stimulation levels and in patients in the course of vestibular compensation. A mathematical model that consisted of a neural integrator and a burst generator, both driven by the same SCC input, predicted a static cyclotorsion as the result of a decreased burst frequency. Blinks could unmask any SCC activity at the model input by triggering bursts that discharged the torsional integrator.
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O063

Clinical Assessment and Validation of the Cranial Vibratory Test. Implication in the Vestibular High Frequency Analysis

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Background: Vibratory test is a new challenging test introduced in Europe by KF.Hamann and in France by G.Dumas and J. Michel.
Objectives: To analyze the influence of high frequency vibrations applied to the skull on vestibulo ocular reflex (VOR) by the vibratory test (VT). To complement caloric test (CT) Rotatory test (RT) and head shaking test (HST) in total and partial peripheral lesions and in central cases. To determine sensitivity, specificity, the physiological implications and optimal conditions of the VT.
Methods: Hundred normal subjects were used for control group;52 severe unilateral vestibular lesions(SUVL), 81 moderate unilateral vestibular lesions (MUVL), 2 bilateral total vestibular lesions; 36 central brain stem lesions. The following parameters were studied: optimal stimulus frequency (20 to 150 Hz), topography (vertex, mastoïds, and posterior cervical muscles), the interference between the VT and CT on the normal side, the interference with the optokinetic test(OKT), and the influence of the head position. A 2D or 3D video-nystagmograph was used for recordings.
Results: In normal subjects VT has a specificity of 94%. In SUVL the VT revealed a defective nystagmus in 96% of cases at all frequencies, HST 94% and CT 100%.VT best responses were obtained between 80 to 120 Hz stimula-

tions. Responses did not depend on the head position (P =0.9). Nystagmus axis can change with the location of the stimulus on the head but not with the direction. Stimulus topography efficiency: mastoïd location is significantly better than cervical and particularly vertex stimulation P=0.03. Mastoïd stimulation efficiency is not correlated with the side of stimulation P = 0.9. VN slow phase velocity is correlated with the total caloric reflectivity on the safe ear P=0.02. VT can reverse the CT nystagmus at cold water stimulation and can modulate the slow phase velocity of the OKN. VN 3D analysis elicited horizontal component in 96%,vertical in 47% and torsional in 30% of cases. In MUVL: CT demonstrated significant unilateral weakness in 72%, HST in 53%, and VT in 76% of cases. VT is significantly altered in non acute periods of Meniere's disease in 76% of cases. HSN and VN are frequently of opposite direction in labyrinthine hydrops(66% of cases) meanwhile CT remains often normal. In small vestibular schwannomas, CT is altered in 45%, HST in 27% and VT in 45% of cases. The 3 tests are not altered at the same time. In central pathology, VT was altered in 36% of cases, HST in 31% and CT in 28%.

Conclusion: VT is efficient in mastoïd topography and explores frequencies ranging from 30 to 150 Hz. The optimal response is around 100 Hz. VT interacts with the CT and OKT. Stimulation is very strong and can reverse the caloric nystagmus at 20°C. In SUVL, VN is always defective at all frequencies, topography, and head position. In MUVL the direction of VN depends on stimulus frequency. The difference in responses between HST and VT in MUVL is depending on vestibular compensation. VT reveals asymmetric responses at high frequencies while other tests can remain normal.

O064

Effect of Cervical Injury on Vestibular Evoked Myogenic Potentials

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Background: Cervical injury caused by motor vehicle accidents (whiplash injury) or cervical manipulation (chiropractic) can provoke vertigo, and even nystagmus. To investigate the causes of vertigo after cervical injury, in addition to conventional electronystgmography (ENG), MRI scan and MR angiography (MRA), recent established vestibular evoked myogenic potential (VEMP) test is also conducted.

Objectives: The aim of this study was to investigate whether VEMPs are impaired after whiplash injury or cervical manipulation.

Methods: Twenty-three patients with vertigo after cervical injury were enrolled in this study. Ten patients were victims of whiplash injury (group A), while 13 patients were complicated by cervical manipulation (group B). All patients underwent ENG, MRI/MRA scan, and VEMP test.

Results: In ENG examinations, multiple central signs were disclosed in 90% and 85% of groups A and B, respectively, exhibiting non-significant difference ($p>0.05$, Chi square test). There are 40% patients of group A and 38% of group B showing organic brain/brainstem lesions on MRI/MRA scan. Absent VEMPs were demonstrated in 80% patients of group A. In contrast, group B revealed abnormal VEMPs in 8 patients (62%), including bilateral absent VEMPs 5, bilateral delayed VEMPs 1, unilateral absent VEMPs 1, and absent as well as delayed VEMPs on each side 1. Both groups did not differ significantly in these regards ($p>0.05$, Chi-square test).

Conclusion: Both whiplash injury and cervical manipulation manifest similar clinical VEMP features e.g. absent or delayed VEMPs, and share common mechanisms such as vasculopathy from the vertebral artery, neuropathy from vestibulo-spinal tract, or in combination.

O065

Sensory Organization of Balance: Correlation Between Equitest and Balance Quest

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Background: As defined by the American Academy of Otolaryngology-Head and Neck Surgery (2) (AAO-HNS) and the American Academy of Neurology (ANN), CDP includes:1.Isolation and Quantification of orientation inputs from the visual, vestibular and somatosensory systems 2.Isolation and Quantification of central integrating mechanisms for selecting functionally appropriate orientation sense(s)
3.Isolation and Quantification of functionally appropriate movement strategy(s) in a variety of controlled task conditions 4.Isolation and Quantification of motor output mechanisms for generating timely and effective postural movements. Since Balance Quest doesn't meet last criteria to be considered as CDP device we shall name it Dynamic Platform System (DPS).

Objectives: Since in our department we have the great privilege to benefit of the presence of two equilibrium platforms – Equitest and Balance Quest – the aim of this study was to correlates equilibrium scores and SOT obtained in the same subjects on the two devices.

Methods: To obtain both pathological and normal parameters, two groups were involved in this study: a group of 163 patients and a group of 106 healthy volunteers. All patients suffered by a peripheral vestibular disease. A standardized history was obtained for the two enrolled groups and a standardized ear, nose, throat, neurological, and visual examination was performed. Dynamic posturography was performed using the Balance Quest and Equitest the same day at few minutes interval. The recording on the two platforms was randomly performed to avoid a rank effect. Sen-

sory Organization Test (SOT) performed on the subject using the Balance Quest consisting of the six different conditions. The data were compared using ANOVA test.

Results: Whatever the condition is, eyes open (A), eyes closed (B), and visual disorientation (C), results obtained on the two platforms are significantly correlated ($p<0.0001$, $p<0.0001$, and $p=0.002$, respectively). On the unstable platform, equilibrium scores provided by the two platforms are correlated in condition D (eyes open, $p<0.0001$), in condition E (eyes closed, $p<0.0001$), and in condition F (visual disorientation, $p<0.0001$). Somatosensory and vestibular scores are significantly correlated ($p<0.0001$, and $p<0.0001$), whereas visual scores are not.

Conclusion: Very good correlations between somatosensory and vestibular equilibrium scores were noted after double vestibular assessment on Equitest and Balance Quest.

Since visual stimulation methods are different for the two platforms, the visual scores were not correlated.

In peripheral vestibular disorders both Balance Quest and Equitest provides crucial information for diagnosis and subsequent physical therapy.

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O066

Spectral Analysis of Head-Based Stabilogram in Normal and Bilateral Vestibular Dysfunction Subjects

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Background: Acquisition and analysis of head stability, as a part of dynamic posturography methods is largely undeveloped.

Objectives: To assess and compare the spectral parameters of head-based stabilogram (HBS) in healthy subjects and patients with bilateral vestibular loss.

Methods: Position of the head was recorded as a signal from a 2-axis MEMS accelerometer (mounted on a low-mass plastic hard hat) sampled for 100s at a rate of 30 Hz. Anterior-posterior and medial-lateral angular displacement data (HBS signal, derived by double integration of the acceleration data) were digitally acquired and analyzed. Eleven patients with bilateral vestibular dysfunction (BVD) and eight unimpaired subjects were studied using repeated measures in 2 basic conditions. Subjects were seated in a modified Romberg position (elbows lightly cupped in opposite hands): eyes open and eyes closed for trials of 100 seconds duration. Extended spectral and wavelet analysis was applied to recorded signals.

Results: Power spectra of both normal and BVD subjects exhibited several distinctive features within the 1-15 Hz range. Spectra of HBS for each subject had unique power 'signatures' comprised of several of peaks, each at distinct frequencies and magnitudes. The patterns for each subject were consistent and repeatable. Some spectral peaks were common to all subjects (e.g. respiration & heart rate), while others were specific to each individuals' physical and neurological make-up. In BVD patients the normal spectral pattern was severely depressed in the 2-15 Hz frequency range, and the main power in the spectra shifted to the 0.15-2.0 Hz range. Strength of HF depression and concomitant shift to lower frequency correlated with the severity of the vestibular damage. Spectral pattern of HBS in BVD subjects was also sensitive to stability improvement in BVD patients during our training and rehabilitation procedure.

Conclusion: In addition to standard force platform signal, HBS is a robust and informative tool for posture evaluation. There are significant and predictable differences in the HBS spectra of normal versus BVD subjects, suggesting changes in mechanism of fine postural control due to vestibular loss. Dynamic and spectrographic analysis of HBS may be useful for assessment and diagnosis of vestibular hypo-function or loss as a result of trauma, ototoxicity or aging.

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O067

The Relationship Between Three Dimensional Labyrinth Anatomy and Three Dimensional Eye Rotations

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Background: This presentation will focus on the close connections (the direct pathways) between the semicircular canals and eye movements. For different species the orientation of the individual canals and of the eye muscles requires specific neural transformations.

Objectives: To review the relationship between 3d canal anatomy and 3d eye movements with special reference to clinical implications of this relationship.

Methods: The anatomical methods involve reconstructions from many single points along the bony semicircular canals in stereotaxic space or more recently from digital reconstructions from CT scans and MRI scans with special emphasis on establishing the relation of the labyrinth anatomy to the external head landmarks (such as Reid's line). For 3d measures of eye movements, search coil procedures or more recently video eye movement recording procedures have been used.

Results: The anatomical measures not only show the average orientation of the semicircular canals in the head but also show the differences between individuals, which can be clinically important. The orientation of eye movements in relation to single semicircular canal stimulation goes back, in animals, to Flourens and Ewald. More recently it

seems that there are ways in which a single human semicircular canal can be stimulated - for example by otoconia rolling along a single canal (in BPPV) causing endolymph flow in just that canal. The "predicted" canal orientations given by such procedures are close to the established human canal planes. The loss of one labyrinth or even one single canal (e.g in canal blocking) has major effects on the 3d canal-ocular responses as shown by the head impulse response to passive head rotations (applied by the clinician) in the planes of the semicircular canals. Such a loss not only results in an inadequate eye velocity response, but also an eye rotation around an axis which is not compensatory for the head rotation - a 3d error. During active head rotations (initiated by the patient), that 3d error is minimized by a very early saccade-like eye movement.
Conclusion: In the complex paired three dimensional sensory system there are very close connections between anatomy and eye movement response. The exact pattern of eye movements in relation to the stimulus provides valuable information about the vestibular sensory regions affected. New developments in video image processing methods of measuring eye movements will allow some of the benefits of this understanding to flow to the clinic.

O068
Basic Properties of Angular and Linear VOR in 3D
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Background: The vestibulo-ocular reflex (VOR) assists binocular vision during locomotion. During head rotation the velocity of compensatory eye rotation should be equal and opposite to the head rotation. However, to assist vision effectively the VOR must exhibit a number of additional properties such as a) head rotation should activate a compensatory eye rotation in the same plane, b) canal and macular reflexes should be organized within a common reference frame, c) the neural organization should be malleable to allow corrections during development or disease.
Objectives: The reasons for the above requirements will be explained and the solutions chosen by the central nervous system will be described. Results from different experimental vertebrates will be compared to suggest that common problems are solved by common basic principles of VOR organization and reorganization.
Methods: This presentation summarizes results from eye movement or motor nerve recordings in response to angular or linear acceleration, from recordings of synaptic potentials following electric stimulation of individual vestibular nerve branches in-vitro and a combination of these approaches for the analysis of the synaptic reorganization two months after a vestibular nerve section and its consequences for the LVOR during natural stimulation.
Results: The orientation of the optic axis differs between frontal-eyed and lateral-eyed animals. But the plane of action of paired extraocular muscles changed the optic axis such that a given muscle action plane remains nearly parallel to the axis of its principal canal. Minor geometric misalignments between the planes of functional canal pairs and of extraocular muscle pairs are corrected by auxiliary canal signals that supplement principal canal inputs. LVOR signals for a particular extraocular muscle originate in a utricular sector that is oriented about perpendicularly with respect to the canal that provides this muscle with principal canal inputs. Hence, both reflexes can support each other dynamically without a change in the spatial response properties when co-activated. The spatial organization of these VORs alters adaptively during development in relation with a change in the orientation of the optic axis. Sudden loss of vestibular nerve inputs initiates an activity-related process of synaptic reorganization. Spontaneous, unassisted recovery of function ("vestibular compensation") can be associated with undesired functional consequences.
Conclusion: The basic design of the VOR is best appreciated by the notion that it takes the visual consequences of a head displacement into account by activating eye movements that reduce retinal image motion and binocular disparity. An activity-related process of synaptic reorganization shapes the spatial and dynamic properties of these reflexes throughout life. Acute vestibular deficits provoke an activity-related reorganization that can be modified in its functional consequences by rehabilitative training.

O069
3-D Control of Posture: From Animal Models to Patients
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Background: We have previously demonstrated, by using selective lesions of the vestibular apparatus in guinea pig, that the functional segmentation of the skeletal system corresponded to a differential distribution of vestibular afferents (De Waele et al 1989, Exp Brain Res 7, 166-182). Interestingly, the deviation of the head-neck ensemble caused by the utricular lesion only partially recovered. In contrast, the horizontal canal deficit fully recovered in a few hours following the lesion. These results would predict that vestibular patients could present an enduring deficit of the control of their posture in the frontal plane following unilateral vestibular lesion.
Objective: In order to test that hypothesis, the postural instability of 11 patients with bilateral and 88 with unilateral vestibular loss was investigated using static and dynamic posturography. **Results:** Except in bilateral vestibular loss patients, static posturography was unable to distinguish unilateral vestibular loss patients from control subjects in either eyes open or eyes closed conditions. In contrast, in the eyes closed condition, dynamic posturography using a non-motorized, low cost, seesaw platform allowed to differentiate bilateral and unilateral patients from control subjects. Bilateral patients were unable to stand up

without falling at any time following the lesion; unilateral patients were unable to stand up during the first week post-lesion. By the second week, patients could with difficulty maintain balance in the sagittal plane, but not the frontal plane. After two months, most of the patients could maintain their equilibrium in both planes but all the measures were higher for the frontal than the sagittal plane. After one year, values were closer to normal but they remained higher than normal in the frontal plane. **Conclusion:** Therefore, dynamic posturography on a seesaw platform could be a valuable tool for clinical diagnosis in vestibular loss patients up to one year after the lesion (longest delay investigated).

Objective: In order to investigate further the contribution of vestibular information in motor control, posture and locomotion were recently compared in wild type and congenitally vestibular deficient mice (IsK -/- mutant) using X-ray and cineradiography at 250 frame/sec.

Results: 1) the S-shaped resting posture adopted by wild type and mutant strains positioned several articulations at their extreme range thereby reducing the available degrees of freedom; 2) locomotion in wild type mice was characterized by i) the linear progression of limb movements which followed the lateral sequence and ii) the stability of the head and entire extended column relative to space; 3) in contrast, locomotion in IsK -/- mice was characterized by i) a permanent head bobbing in the sagittal plane and ii) continuous episodes of circling.

Conclusions: It suggests that vestibular inputs provide feedback required to signal the completion of a planned trajectory. When IsK -/- mice intend to change their heading direction this information is lacking, and therefore they continue to rotate. Hence, vestibular information would be mandatory for providing a reference for head position in the sagittal plane at rest and a reference for the heading direction during locomotion. In contrast, they are not required for the postural control at rest. These results may explain the deficits observed during navigation tasks in vestibular patients and the fact that head stability is selectively impaired in the pitch plane following bilateral vestibular deficits.

O070

Vestibular Disorders: Perceptual, Ocular Motor and Postural Link in Roll Plane

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Background: Vestibular disorders are characterized by a combination of perceptual, ocular motor, and vestibulospinal phenomena: vertigo, nystagmus, and postural imbalance. Vertigo and spatial disorientation involve the multiple temporo-parietal vestibular cortex areas; nystagmus is due to a direction specific tone imbalance of the vestibulo-ocular brainstem circuitry; postural imbalance reflects abnormal vestibulo-spinal activity. Vestibulo-ocular and vestibulo-spinal motor responses use common vestibular input and partially overlapping neuronal networks. The clinical signs of a vestibular tone imbalance in the roll plane include ocular tilt reaction, ocular torsion, skew deviation, and tilts of the perceived visual vertical.

Objectives: Examples of vestibular disorders from peripheral labyrinth via central vestibular pathways (vestibular nuclei, medial longitudinal fascicle and midbrain integration centers, thalamus, and vestibular cortex) to extraocular eye muscles will be analyzed with respect to the association or dissociation of perceptual, ocular motor and postural signs and symptoms in roll plane.

Methods: clinical analysis, imaging, modeling

Results: Stimulation or unilateral failure of the peripheral vestibular organ (e.g. vestibular neuritis) is known to cause perceptual, ocular motor, and postural effects that closely correlate in severity. On the other hand, central vestibular pathway lesions and isolated semicircular canal dysfunction may cause syndromes in which perceptual, ocular motor, and postural manifestations dissociate. Examples are (a) isolated anterior semicircular canal failure with ocular torsion but without perceptual tilt; (b) unilateral pontomesencephalic lesions of the medial longitudinal fascicle with contraversive skew torsion of the eyes and tilt of the perceived visual vertical without accompanying head or body tilt; (c) unilateral brainstem lesions with skew deviation and paroxysmal room tilt without body tilt; and (d) acute ischemic lesions of the dorsolateral thalamus or the parieto-insular vestibular cortex with ipsi- or contraversive tilts of the perceived vertical without associated ocular-motor disturbances.

Conclusion: Thus, perceptual, ocular motor, and spinal aspects of vestibular functions can operate in either a linked or separate mode, depending on the site of the lesion or stimulation. In vestibular disorders, clinical analysis of signs and symptoms and mathematical modeling of eye movements make it possible to define the lesioned vestibular structures and the involved reflex or integration mechanism.

O071

Superior Semicircular Canal Dehiscence Syndrome

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Background: Patients with superior semicircular canal dehiscence (SCD) syndrome can experience vertigo induced by loud noises or by maneuvers that change middle ear or intracranial pressure [1]. Other manifestations of the syndrome can include hyperacusis for bone-conducted sounds, autophony, a sensation of hearing eye movements, and chronic disequilibrium. Three-dimensional recordings of eye movements have played an important role in defining the syndrome and in identifying its manifestations.

Objectives: To review the clinical findings in patients with superior canal dehiscence.

Methods: The clinical records and 3-D eye movement recordings (scleral search coil technique) of patients with SCD syndrome were reviewed. These patients had evidence of superior canal dehiscence on temporal bone CT scans, recently performed with 0.5-mm-collimated helical CT and reconstructed in the superior canal plane [2].
Results: The eye movements evoked by sound or pressure stimuli in patients with SCD syndrome typically align with the plane of the dehiscent canal. Patients with larger dehiscences are an exception to this rule, and they typically have hypofunction in the dehiscent canal as evaluated by measurement of the 3-D VOR evoked by head thrusts that are excitatory for the superior canal [3]. Patients with SCD syndrome can also have sound-evoked head movements in the plane of the dehiscent canal presumably through activation of the vestibulocollic reflex. In addition to these vestibular manifestations, auditory abnormalities such as an air-bone gap on audiometry and lateralization of the Weber tuning fork test (512 Hz) to the affected ear may also be present. Auditory and vestibular symptoms and signs may occur concurrently or in isolation [4]. The threshold for vestibular-evoked myogenic potentials is abnormally low in the presence of dehiscence. Surgical repair of the dehiscence can be beneficial for patients who are debilitated by the vestibular symptoms [1].
Conclusion: The clinical manifestations of superior canal dehiscence include vestibular and auditory abnormalities. Studies of the 3-D eye movements in this syndrome have contributed to our understanding of the pathophysiology.
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O072

The Labyrinths of Vertebrates: Trends in Evolution

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Background: Gnathostome vertebrates possess a vestibulum bearing three semicircular canal ducts. The design of the semicircular duct organ is conserved, though researchers have noted interspecific variation in the mutual dimensions of duct parts.
Objectives: It is the aim of this paper to review and synthesize current insights into the functional relationship between canal morphology and behavior, and to examine how this relationship can be used to diagnose trends in evolution.
Methods: Using computed tomography, the morphology, circumferential arc length (streamline length), and planar orientation of the bony semicircular canals of tetrapod vertebrates are assessed. Particular attention is given to extant and extinct mammals (namely primates and cetaceans) and archosaurs (crocodiles, dinosaurs, and birds), for which a growing body of comparative evidence is now available.
Results: Consistent associations are found between locomotor competence, canal performance, and canal dimensions in the groups examined. Among primate species, a link between relatively large canal size and fast, active head movements is substantiated. Extant cetaceans are found to possess canal arc sizes three times smaller than other mammals, consistent with adaptations for dedicated agile swimming in a lineage with marked fusion of neck vertebrae and reduced neck motility. Analysis of fossil whales demonstrates that the acquisition of small semicircular canals and full independence from life on land was achieved early in cetacean evolution.
Conclusion: New data presented for birds demonstrates that bivariate and multivariate analyses of semicircular canal morphology are sensitive enough to discriminate between modes of soaring flight, flapping flight, and terrestrial locomotion in extant birds. Because flight performance in living birds can be correlated with canal size and orientation, it is possible to assess the mode of flight employed by early birds. Analysis of theropod dinosaurs, the closest extinct relatives of birds, sheds light on the neurophysiological adaptations associated with flight, and on the sensory and coordination functions that correspond with canal morphology in this lineage.

O073

Vertebrate Inner Ear Development

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The vertebrate inner ear develops from an initially ‘uncomplicated’ ectodermal placode adjacent to the hindbrain through vesicle stages into a complex three-dimensional structure essential for the senses of hearing and equilibrium. Classically, most studies have suggested that the “otic” placode is induced by signals from the chordamesoderm and hindbrain, notably fibroblast growth factors (Fgfs) and Wnt proteins. However many other genes have been identified whose functions are required for normal morphogenesis, and in most cases, it is not obvious how these roles are orchestrated to regulate the fine balance of “growth, ‚sculpting and death” that normally occurs during

the continuous remodeling of the epithelium. By contrast, the most fundamental structural events underlying vertebrate inner ear morphogenesis are well recognized; thus, this presentation will focus on recent work laying emphasis on mechanistic data capable of distinguishing bona-fide hindbrain-derived signals that act during placode induction, maintenance and otic vesicle patterning. Examples of abnormal location and differentiation of inner ear structures including mechanosensory hair cells will also be focused on to illustrate the discrete steps that utilize sequential signaling proteins to accomplish inner ear structural and functional complexity. The final goal of the review will be to discuss newer techniques (e.g., molecular screens and microarrays) that may lead to fundamental new insights shaping our understanding of the signaling interactions controlling early otic development.

O074

Central Vestibular Compensation in Infants and Children with Congenital Vestibular Loss

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Objectives: In deaf infants and children with loss of semicircular canal function, central vestibular compensation during their development and growth was studied.

Methods: In order to evaluate vestibular ocular response, the earth vertical damped rotation test was performed. All cases with absence or poor per-rotatory nystagmus were chosen to study.

Results: Development of gross motor, balance and locomotive function was seriously delayed in each case during the first 2 or 3 years of life. Thereafter, all children could achieve most landmarks of gross motor development, such as head control, independent standing, walking and running until school age. However, balance functions even at the age of entrance of the elementary school (6 yeas old) were variously impaired in each case and the better case could swim under water but the poor case could not maintain static balance with eyes closed. Although fine motor skills were normally achieved in all cases, these gross motor development due to central vestibular compensation could depend on the integration of inputs from the other sensory inputs such as visual, somatosensory and proprioceptive senses, and the maturation of motor control systems in the cerebellum, basal ganglia and motor cortex. In the next, we investigated development of two infants with congenital deafness and blindness in order to illuminate influence of vision on the vestibular and balance function. They are a girl and a boy who were congenitally deaf and also blind. The girl was two years old, and the boy was 3 years old currently. Opisthotonus-like retroflexion of the head has persisted until now and independent walking is not yet possible. In the boy due to his anophthalmia vestibular ocular reflex could not be examined using the traditional methods. However, the vestibular evoked myogenic potentials (VEMP) were normal. It has been reported that opisthotonus appeared by covering the eyes and destroying the bilateral labyrinths in primates. In our case, VEMP suggested that saccular function has been maintained well. However, semicircular canal functions were lost because of no perotatory nystagmus revealed by the damped rotation test. Finally, we investigated central vestibular function of a congenitally deaf ski jumper who was a candidate of the Nagano winter Olympic game in 1998. The longest distance of his ski jump record at the large hill was 130 meters. Because his cold water caloric irrigation to each ears were normal, he appeared to use visual and vestibular inputs to maintain his body balance in the sky during ski jumping without auditory input.

Conclusion: Central vestibular compensation could play important roles to develop motor functions of infants and children in spite of congenital loss of various sensory organs.

O075

Changes in the Responses to Vestibular Stimulation in Children: Vestibular Evaluation as a Function of Age

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Background: Children's responses to vestibular stimulation vary as a function of age. Several published studies show that while the anatomical and histological characteristics of the vestibular apparatus appear mature at birth, the vestibulo-ocular responses show dramatic changes during the first decade of life.

Objectives: This study will document the characteristics of vestibulo-ocular and vestibulospinal responses in children from 1 month to 15 years of age in recent tests currently used for complete vestibular evaluation; this will test some functional hypotheses about the role of vestibular system and its development during childhood.

Methods: A complete vestibular battery of tests commonly used in our department for vestibular evaluation since 1992 has been applied to normal children of several ages (from 1 month to 15 of age), as well as in children with balance problems. This included canal testing (caloric test, pendular stimulation, earth vertical axis rotation (EVAR) with 40°/s² acceleration and deceleration) and otolith testing (off vertical axis rotation [OVAR] at 60°/s² with 13° tilt, vestibular evoked myogenic potentials [VEMP], subjective vertical and horizontal measurements, SVH).

Results: Most of these tests can detect vestibular responses very early in life. In the caloric test, canal vestibulo-ocular responses (VORcanal) in young children show lower frequency quick phases (1 or 2 in 30 seconds in the first week of life) as compared adults (70 in 30 seconds). Furthermore, children show higher amplitude slow phases and a shorter time constant (tc) of the VORcanal at the EVAR test (tc averaging 6 seconds in the few months old child vs. 20 seconds in adults). The values progressively reach adult values during the course of childhood. The otolith VOR [VORotolith] shows characteristic changes during steps of acquisition of posturomotor control (for example independ-

ent walking is associated with an increase of the horizontal modulation component and a decrease of the vertical component) and modulation of the VOR otolith response to OVAR is smaller in adults than in children. VEMP have the same thresholds in children as in adults (90 to 100 dB for tone bursts of 750 Hz at a rate of 4/s) but P13-N23 amplitude for the same EMG level is much greater (by a factor of 3 to 4), easier to obtain and not requiring as many repeated stimulations than for adults (20 repetition period for a child while 50 to 100 for adults). SVH measurements are not possible before the age of 4 years, because the notion of verticality is not understood until that age (even though it is already detected accurately by the otolith system and employed for axial postural adaptation); SVH is not reliably measured from 4 to 8 y.o., but after 8 y.o. the values of SVH are as reliable as in adult.

In children with balance problems, we observed severe delays of axial postural control in those patients without otolith signals and delays in independent walking in case of severe impairment of the canal and otolith function, whether acquired early or at birth.

Conclusion: These data show that while the vestibular receptors are mature at birth, the vestibular responses (VOR and vestibulospinal responses) are not mature and probably need to be integrated in the CNS with other sensorimotor information. It is interesting to observe that vestibulo-ocular responses closely follow the posturomotor control development — this suggests a particularly important role for vestibular information during milestones of posturomotor control acquisition in young children.

O076

Locomotor Development and the Acquisition of Head Stabilization in Toddlers

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Background: Before their first attempt to walk without support, children almost never experience balance control in a situation of dynamical equilibrium during which they have to produce successive phases of disequilibrium and balance recovery, necessary for walking.

Objectives: The aim of the different studies on walking development presented here is to describe the motor solutions adopted by children to overcome the conflicting problem of create and master disequilibrium and the propelling forces to move the body forward. To maintain balance during walking, body motion in space and relative position of body segments have to be detected, through visual, vestibular, and proprioceptive information. This implies that sensory systems must be functional and that to be efficient, sensory information has to be integrated with a stable reference on which movement control is based. It has been suggested that the head is the frame reference for movement control because it contains the visual and vestibular systems. This implies on the one hand, that the head movement must be stabilized in space, and on the other, that head movement must be co-coordinated with the body movement induced by motor activity. The longitudinal analysis we present here allows us to examine whether postural control of the upper body follows a consistent progression in infants during the first year after onset of unsupported walking.

Methods: Walking ability was analyzed at the functional level of movement: the ground reaction forces that are proportional to the forces causing the displacement of the body or center of mass (global dynamical approach). As the same pattern can be the result of different mobilization of the body segments, the global dynamics were completed with the kinematics of head and trunk, the observation of arm posture and movements and the type of foot contact with the ground.

Results: The developmental trends of the different global and segmental (head and trunk rotations) parameters showed the same striking characteristic despite the fact that children started to walk independently at different ages. During the initial period after the onset of independent walking, global gait parameters (i.e. step length, step cadence and mean progression velocity) increased markedly whereas step width decreased. Those changes co-occurred together with a decrease of the amplitude of head and trunk rotations. After the period of rapid decrease of the mean amplitudes of trunk and head rotations, both remained stable and were similar to adult values. This time of rapid changes could correspond to the learning of mastering balance in a situation of disequilibrium. The developmental course of these parameters then stabilizes during the following months up to 7-8 years and might correspond to a more precise tuning of the different gait parameters.

Conclusion: These results suggest, for example, that the control of equilibrium, which is acquired during the first months of independent walking, is a prerequisite for the stabilization of head angular displacements. Head stabilization in turn appears as a condition for a more fine-tuning of the co-ordination of head movement with the walking movement. It is during the second phase that fine motor control such as anticipatory phenomena during gait initiation appear and develop. It is hypothesized that this progression is constrained by the dual requirements of walking i.e., stabilizing the body in an upright posture and moving the body forward.

O077

Surgery of the Inner Ear with Hearing Preservation: Experimental Studies and Therapeutic Implications

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Background: Surgery of the inner ear can result in hearing preservation under certain conditions, but the mechanisms responsible for hearing preservation/loss are not well understood.

Objectives: To understand how the cochlea is protected, auditory brainstem response (ABR) thresholds and histologic sections were obtained at different time intervals after surgery of the inner ear.
Methods: Guinea pigs underwent lateral semicircular canal (LSCC) transection and plugging, ampullectomy, or vestibulotomy. Tone-burst ABR thresholds at 2, 8, and 24 kHz were measured at intervals before and after surgery. Temporal bones were examined histologically after 1, 3, 7, or >21 days.
Results: Hearing was usually preserved after LSCC transection, sometimes after ampullectomy, and occasionally after vestibulotomy. Fibrosis and inflammation occurred near the site of surgical entry. Cochlear hair cells were nearly always preserved, even when hearing loss occurred. Greater hearing loss was observed when the inflammatory response extended to the cochlea.
Conclusion: The inner ear is capable of withstanding surgical trauma without loss of hearing. These experiments reveal strategies for cochlear preservation that might permit hearing preservation surgery of the inner ear in humans. Potential applications for the surgical treatment of vestibular disorders will be discussed.

O078

Multiple Isoforms of the Ryanodine and IP3 Receptors Are Expressed in Rat Inner Ear Ganglia and Endorgans

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Background: Ryanodine receptor calcium release channels have been shown to be widely expressed in a variety of mammalian tissues. Ryanodine receptor type 1 has been shown to be the predominant isoform in skeletal muscle, while isoforms 2 and 3 are more abundant in cardiac muscle and hippocampus, respectively [4]. There have been no studies, however, on their localization in the vestibular periphery and cochlea. One functional model, put forth by [6] for cochlea, where outer hair cells are contacted by efferent boutons opposite subsurface cisterns, is that the cistern creates a microdomain for α-9 nicotonic receptors to interact with calcium-gated potassium channels. They gave evidence for RyR involvement in this process.
Objectives: We hypothesized that RyR and IP3 receptors would be localized to cochlear outer hair cells and type II hair cells in the vestibular system at subsurface cisterns. In the present study, RT-PCR and immunochemistry were used to ascertain which ryanodine and IP3 receptor mRNA isoforms were expressed within the maculae, cristae, vestibular and spiral ganglia, and cochlea.
Methods: Inner ear organs were dissected from 6 rats and total RNA was obtained. Rat skeletal and cardiac muscle and hippocampus were also obtained to use as positive controls. Intron-spanning primers specific for ryanodine receptor isoforms 1, 2 and 3 [5] were generated and RT-PCR was performed on 20ng total RNA from each endorgan (with the exceptions of 10ng total RNA from cristae endorgans and 5.2 ng total RNA from cochlea endorgans).
Results: Results indicate that ryanodine receptor isoforms 1, 2 and 3 are present in maculae, cristae, and in vestibular and spiral ganglia. Ryanodine receptor isoform type 1 was shown to be present in cochlea, while isoforms 2 and 3 are yet to be tested. Results for IP3 receptor isoforms 1, 2 and 3 [1-3] show their presence in cristae, maculae, vestibular and spiral ganglia and in our positive controls (small intestine, liver and cerebellum). Confocal microscopy also confirms the presence of RyR in auditory and vestibular periphery. Pan ryanodine receptor antibody (Chemicon) staining indicates the presence of RyR in cochlear outer hair cells, striolar and extrastriolar hair cells in otolith organs, and hair cells in both central and peripheral crista. Immunogold electron microscopy shows that the RyR is localized on smooth endoplasmic reticulum in the hair cells. A pan-IP3 receptor antibody (Chemicon) shows IP3 labeling in calyces. We are using isoform-specific antibodies to determine more specific staining patterns.
Conclusion: RyR and IP3 are both present in hair cells and ganglia in the rat inner ear, and may play a role in efferent neurotransmission. Supported by NIH R01 DC2521, DC2058 and DC2290.
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O079

Usefulness of the Inner Ear Model Created Using Rapid Prototyping

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Background: Anatomy of the inner ear is complicated and its stereoscopic orientation is hard to understand for medical students and residents. The authors reported that the temporal bone model created by rapid prototyping is extremely useful for surgical training. In this paper, we attempted to create the inner ear model using the same technique.
Objectives: This study is designed to examine usefulness of the inner ear model in the educational and clinical setting.
Methods: A simulated 3-D model of a human temporal bone was prototyped using selective laser sintering method.

The helical CT data of the temporal bone were converted into STL file. The intensity level of STL file was determined to extract lumen and cavity structure eliminating the bony element. The powder layers were laser-fused based on this CT data and accumulated to create a 3-D inner ear structure.

Results: The prototyped model well reproduced inner ear structure. Semicircular canals, vestibule, cochlear coil, endolymphatic sac, internal auditory meatus, superior vestibular nerve and facial nerve were replicated. A magnified model was easily created. These models were particularly useful for instructing the anatomical orientation and surgical procedures.

Conclusion: The 3-D prototyped inner ear model using selective laser sintering method is useful for both medical education and surgical explanation.

O080

Investigation of Vestibular Adaptation to Changing Gravity Levels on Earth

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Background: During the first days in space 50-80 % of the astronauts suffer from the Space Adaptation Syndrome (SAS). The symptoms of SAS, like nausea and dizziness, are especially provoked by head movements. Although it is generally agreed that the vestibular system is involved in causing SAS, no distinct clue has been found to its aetiology, the individual's susceptibility, and its predictability. Susceptibility to SAS does not correlate with susceptibility to motion sickness on earth. However, astronauts have mentioned close similarities between the symptoms of SAS and the symptoms they experienced after a 3G centrifuge run on earth (Sickness Induced by Centrifugation, SIC). This suggests that a gravity transition from 3 to 1G provokes the same effects as a transition from 1 to 0G, implicating a general vestibular adaptation mechanism to changing G-levels.

Objectives: This study aims to further the insight in the process of vestibular adaptation to G-transitions. Two important parameters are the perception of body motion and attitude during the adaptation process. A second objective is to investigate the correlation between susceptibility to SAS and SIC.

Methods: During several space missions the correlation between susceptibility to SIC and SAS has been investigated [1]. Since head movements are shown to be provocative, this provocativeness was taken as an indicator for SIC and SAS susceptibility. Susceptibility to SIC was assessed after a 1 h centrifuge run at 3Gx, susceptibility to SAS during the mission. Within the framework of the 2004 Delta Mission, vestibular adaptation was addressed for 2 astronauts in four vestibular function tests carried out about a 1h 3Gx centrifuge run (-1h, +0h, +2h, +4h). The tests included motion perception and sickness ratings, stabilometry in a tilting room, subjective vertical measurements in a tilting chair, and eye movement registrations (Listing's plane).

Results: At present, a total of 9 astronauts were tested both in the centrifuge and in space. We found a positive correlation between susceptibility to SIC and SAS: 3 astronauts were both susceptible to SIC and to SAS, 6 were not (i.e. no cross-findings have been observed yet). The vestibular function tests showed that postural stability was decreased after the centrifuge run in one SIC-susceptible subject and unaffected in the other non-susceptible subject. So far we have not observed a clear effect of the centrifuge run on tilt perception.

Conclusion: The positive correlation between susceptibility to SIC and to SAS is in agreement with the hypothesis that SIC and SAS share the same underlying mechanism. This makes long duration centrifugation a valuable tool for investigating vestibular adaptation to G-transitions on earth. The gained knowledge can be implemented in a general model of vestibular adaptation. The vestibular tests showed that several vestibular driven processes are affected by the gravity transition. However, further testing is needed to identify key adaptation parameters.

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O081

Novel Means for Artificial Neural Network Classification of Otoneurological Data

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Background: Artificial neural networks are often used as a black-box algorithm to classify medical data. In numerous studies, they have been applied to medical problems usually without any precise analysis between input data and output classes. However, it would sometimes be very useful to unambiguously express and understand relations between input data and classification decisions generated in conjunction with multilayer perceptron networks. Previously, we found how difficult it was to apply neural networks to our otoneurological data that suffered from the small number of cases and the biased distribution between the disease classes [1]. Such problems are common to medical datasets.

Objectives: We developed novel evaluation means for the analysis of input variables and six output disease classes and tested them with the data of 38 variables (symptoms, patient history and clinical findings) from 815 patients. Their diagnoses made by the otoneurological specialists included 130 (16 % of all) vestibular schwannoma, 146 (18 %) benign positional vertigo, 313 (38 %) Menière's dis-

ease, 41 (5 %) sudden deafness, 65 (8 %) traumatic vertigo, and 120 (15 %) vestibular neuritis cases.

Methods: First, we formed a system of six separate neural networks (one per each disease) to predict, in the crossvalidation way, a test set of 10 % from the 815 cases. The rest 90 % formed its learning set. Thus ten separate test sets and their corresponding learning sets were formed and each of them was run ten times, 100 times in all. Their means produced accuracy results.

Results: We developed three methods to analyze input variables of the neural networks and their output for the six diseases. We called them scattering, spectrum and response analysis. Scattering was used to map the overlapping of the disease classes in the variable space. Spectrum reveals, disease by disease, which values of their variables affect each disease. Response analysis is useful to reveal relations between the input variables and the output disease classes of the neural network system.

Conclusion: Mean accuracy results of our neural network method were computed and they were from 73 % to 100 % depending on a disease. We computed scattering ratios for all the 38 variables. The five certain variables were crucial in the scattering analysis. They were also defined important by the otoneurological specialists [1,2]. Using the spectrum analysis we could present important variable values for the diseases. With the response analysis we were able to find interesting relations between the data and the six diseases.

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O082

Bayesian Modeling of Vestibular Illusions

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Background: Complex self-motion stimuli in the dark can be powerfully disorienting and create illusory motion percepts. The basis of these illusions is the ambiguous nature of vestibular information. Indeed, otoliths do not distinguish translation from tilt. Furthermore, inversing the transfer function of canals in order to estimate velocity requires a temporal integration and results in errors increasing over time.

During sustained rotation, the percept of velocity fades away. Similarly, sustained linear acceleration is misinterpreted as head tilt. This low-pass filtering behavior is commonly thought of as resulting from the rareness of sustained rotations and accelerations in natural situations. Therefore it appears that, in simple situations, the brain disambiguates vestibular signals by the use of information about likely motions.

Objectives: We aimed at determining whether illusions induced by complex stimuli, such as centrifugation [1] and off-vertical axis rotation [2], could be explained by a bias in favor of likely motions, in the context of probabilistic inference.

Methods: We designed a Bayesian model of vestibular information processing. This model transcribes in a probabilistic framework the following assumptions: 1) A geometric internal model of motion in space is used, allowing canal-otolith signal fusion. 2) The canals' responses to acceleration are noisy. 3) Low rotational velocities and translational acceleration are more likely to occur. We looked for the simplest model and reduced the number of parameters to four.

Results: By maximizing the posterior probability of self-motion given the sensory inputs, we successfully reproduced human subjects' motion estimates in all the experimental conditions quoted above. Our results also reproduce subtle known effects such as the delayed somatogravic illusion at the onset of centrifugation [1] and the sustained percept of slow rotation during off-vertical axis rotation [2].

Conclusion: By embedding intuitive assumptions into the Bayesian framework, we created a simple model that extends previous works [1, 3, 4]. The main original feature of this model is the use of an explicit prior toward likely motions; its other main advantage is its simplicity. These results illustrate the specialization of the brain's inference mechanisms to "natural" forms of self-motion.

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O083

Head Rotation Axes in Three Dimensions and Their Relationship to Orientation of the Dens in Different Head Positions

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Background: In order to characterize vestibular contributions to locomotion, it is essential to define the rotation axes of the head with the head in different positions. This relationship determines semicircular canal and otolith organ input, and must be considered when modeling head-trunk and head-eye interactions.
Objectives: To determine the axis of head yaw rotation with the head in different initial positions and to compare this to similar measurements of the axis of the dens (C2) relative to the plane of the lateral semicircular canals as determined in MRI. Our hypothesis is that the axis of the dens is approximately coincident with the head rotation axis.
Methods: We developed an algorithm for approximating the origin and coordinate axes for roll, pitch and yaw head rotations based on 4x4 displacement matrices, which represent translation and rotation of a rigid body in three dimensions. Head and trunk orientation was sampled using a video-based tracking system (OPTOTRAK, Northern Digital, Inc.). Head and trunk coordinates were established based on stable landmarks, which could then be related to the approximate orientation of the semicircular canals. Subjects were asked to oscillate their heads about the yaw, pitch, and roll axes with the head in twenty different orientations (up, center, down/ right, center, left). Head position and orientation relative to the trunk were sampled and converted to a sequence of displacement matrices, D0, D1.DN. A window of matrices around the i^{th} sample, D_{i-n}, D_i, D_{i+n} was used to derive a filter for obtaining the angular velocity vector, whose direction was along the instantaneous axis of rotation. The average of these instantaneous velocities determined the head rotation axes, when oscillating at a given head orientation. The yaw rotation axis relative to the Z-axis of the head during flexion and extension was determined in four subjects and was compared to axis of the dens relative to the axis of the lateral semicircular canals, determined from CT scans in one subject.
Results: Video-based results indicated that the yaw rotation axis of the head was approximately invariant for flexion, but increased linearly as a function of head pitch during extension. The slope was about 0.25 relative to the angle of extension, following a quarter-angle rule. These results were mirrored in the MRI findings, which showed the same trends in the angle of the line along the posterior margins of the dens relative to plane of the semicircular canals. When the head was centered or flexed, the angle remained approximately invariant, indicating that the axis of the dens was maintained along the head Z-axis. During extension, the angle declined, indicating that the axis of the dens increased relative to the head Z-axis.
Conclusion: We conclude that the dens plays an important role in determining the axis of rotation of the head about yaw when head moves into tertiary positions. Semicircular canal input should be invariant if the head moves in yaw when it is centered or in flexion, but the input changes in extension.
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O084
Caloric Stimulation Model
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Background: Barany's classical hydrodynamic theory is still debated: it has been thrown back into question by the zero-gravity Spacelab experiments. The original Barany's theory suggested that a convective endolymph current was involved.
Objectives: The aim of this study is to understand the mechanisms of the caloric stimulation.
Methods: We have developed a numeric and an experimental physical model of the semi circular canal (SCC). The duct (corresponding to the SCC) is deformable; a pressure transducer corresponds to the ampulla. There dynamical similarity has been respected, so the mechanical phenomena occurring in the SCC and in the model are identical. The time scale is close to one
Results: On the one hand, the physical model showed that a hydrostatic mechanism induces in the endolymph a gravity dependent transcupular stationary pressure difference. The modification of the local endolymph density, through the local temperature difference in the lateral part of SCC, is responsible for a buoyancy that produces a stationary pressure difference through the cupula, which will become bulged. On the other hand, the physical model showed also that the relative volume variations (fluid/duct) due to caloric stimulation leads to a pressure variation measured by the pressure transducer. The time history and the value of this pressure depend on the mechanical and thermal properties of the duct and the fluid. The qualitative responses of the physical model and of the vestibulo-ocular reflex after caloric stimulation were coherent. The numerical simulating model yielded a quantitative estimation of the transcupular pressure arising in a horizontal SCC (i.e. gravity independent) during caloric stimulation
Conclusion: The model predicts a percentage of gravity dependent effects of about 75%. For humans in the earth gravity field, enduring the caloric stimulation in supine position of the head, we observe a response that is twice the response (75%+25%=100%) of the prone position one (75%-25%=50%). It explains also caloric responses in all Brüning's positions I to IV.
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O085

Does Vestibular Adaptation to Coriolis Cross-Coupled Stimuli Transfer Across Planes?

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Background: Intermittent short-radius 23 rpm (138°/s) centrifugation is being studied as a possible countermeasure to the deleterious effects of long-duration spaceflight. During supine head-at-center rotation, certain head movements produce cross-coupled stimulation that generates VOR, illusory sensations of tumbling, and motion sickness. Repeated movements of the head in the yaw (transverse) plane have been shown to reduce the slow phase eye velocity (SPV) amplitude and time constant, thus demonstrating that adaptation to this stimulus is possible. This adaptation also reduces motion sickness and illusory sensations.
Objectives: The current study seeks to determine if and to what extent adaptation is specific to a given plane of head rotation. In particular, we investigated how adaptation to the effects of head movements in the yaw plane might transfer to the pitch (sagittal) plane.
Methods: Subjects performed head movements on 2 consecutive days while rotating at 23 rpm. 10 subjects in the Experimental Group performed 6 pitch head movements in the dark, before and after 24 yaw head movements. The 24 yaw movements consisted of a block of 6 head turns performed in the dark before and after 12 head turns in the light. The Control Group of 10 subjects performed only pitch head movements. VOR time constants and SPV amplitudes were measured for all head movements made in the dark. The measurements obtained from yaw and pitch head movements in the dark, before and after the yaw movements in the light, are compared to assess the amount of habituation and adaptation.
Results: Within the daily rotation sessions, subjects in the Experimental Group showed a significant decrease in the VOR time constant of both pitch ($p < 0.001$) and yaw ($p < 0.001$) head movements. The VOR time constant was also reduced across days for yaw ($p = 0.017$) and pitch ($p < 0.001$) in the Experimental Group. SPV amplitudes decreased significantly for yaw movements ($p = 0.017$) within each day, but were not reduced significantly for any of the pitch movements ($p > 0.05$). The Control Group also showed significant reductions in pitch movement VOR time constants within each day ($p = 0.009$), and across days ($p = 0.016$). The Control Group time constant reductions were not statistically different from those of the Experimental Group ($p > 0.05$).
Conclusion: The similar time-constant reductions for pitch movements in the Experimental Group and the Control Group fail to demonstrate any transfer of adaptation from the yaw plane to the pitch plane. The lack of any reductions of pitch movement SPV amplitudes in the either the Control or Experimental group, and the significant reduction in SPV amplitude for yaw movements, shows that habituation to yaw movements did not transfer to VOR gain in pitch. Therefore, adaptation appears to be specific to planes of head rotation.
This work was supported by the National Space Biomedical Research Institute through a cooperative agreement with the National Aeronautics and Space Administration (NCC 9-58).

O086

Multi-Segmental Coordination and the Presence of the Vestibulo-Ocular Reflex During Voluntary Turning in Humans

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Background: While previous studies have dealt with various aspects of eye-head coordination in humans when sitting, the present measurements have included movements of the trunk and feet during more or less natural voluntary pivot turns.
Objectives: To conclude about the presence or absence of the vestibulo-ocular reflex during gaze saccades that exceed the normal oculomotor range in naturally behaving human subjects. Also, to conclude how the eye and head motor systems influence the stepping motor control system.
Methods: Ten healthy adults (Ss), mean age 52±2.6 volunteered for the study. Participants were required to stand in the center of a circular array of lights (LEDs) in darkness. They were required to fixate their gaze on and align their bodies with a centrally located LED. During each trial, after a delay of 10s the central LED extinguished cueing the participant to rotate his whole body in order to align it with a second LED that lit up in one of seven eccentric locations (45 , 90 and 135 either right or left of center as well as at 180). After a time interval of 15 sec the eccentric LED was turned off cueing the subject to return back to the initial position. Head, upper body, and feet horizontal (yaw plane) movements were recorded using a Polhemus Fastrak motion analysis, while horizontal eye in head rotations were recorded using electro-oculography (EOG).
Results: Saccadic eye and head movements may be initiated at quite different times relative to one another, whereby the relative onset times are influenced principally by the predictability of the target location. When the target location is not predictable, the eye is the body segment that initiates the synergy (at 477±159 ms) searching to locate the target. The maximum eye velocity is reduced by the concurrent head movement, but the vestibulo-ocular reflex was clearly switched off later during the gaze saccade, if the head velocity was high (approximately more than 150 /s) and the resulting gaze shift large. In most trials a variable displacement was covered by the combined eye-head saccade (approximately 70). Thereafter, Ss continued the gaze displacement by using the quick phases of vestibular nystagmus ((i.e. scanning instead of calculating in advance the exact trajectory). Displacement of the trunk from the initial position when the foot was first elevated was

independent of the target location and amounted on average to 15 ± 8 .

Conclusion: These findings provide evidence how the voluntary innervation signals that generate the combined movements of the various body segments may interact with lower level brainstem and spinal cord input during the motor synergy of turning.

O087

Model and Experimental Data for the Utricular Medial and Lateral Partitions Based on the Unilateral Centrifugation Test

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Background: The utricle consists of a medial and a lateral part, with opposite polarization vectors. Tribukait and Rosenhall [3] estimated the relative contributions of the medial and lateral partitions based on anatomical investigations of 39 subjects. Their work suggests that the medial part has a lower sensitivity than the lateral part, when the number and orientation of hair cells is studied. Kondrachuk [2] proposed a model to describe the utricular function, based on the relative contribution of medial and lateral partitions. By using the recently refined technique of unilateral centrifugation [1,4] we have new data to further investigate the model proposed by Kondrachuk, as well as to extend this model.

Objectives: To investigate the sensitivity and relative functionality of the medial and lateral partitions of the human utricle, based on a theoretical model, as well as on unilateral centrifugation data.

Methods: We investigated in 10 healthy subjects the ocular counter rolling (OCR), monitored with 3D video oculography. The subjects were rotated around a vertical axis on a rotary chair (Neurokinetics) at a speed of 400 degrees per second. During ongoing rotation the subjects were laterally translated slowly over a distance of 8 cm. During this procedure, the axis of rotation moves sideways and when the excursion is less than 4 cm, both utricles are stimulated in opposite directions. Once beyond 4 cm, both utricles are stimulated in the same direction, but with largely different centrifugal forces. The utricular sensitivity (US) is represented by the slope of the OCR as a function of the apparent tilt of the head center. Based on the slopes of the 10 subjects, we determined the prevalence of medial and lateral partitions of the utricle.

Results: The test paradigm can be divided in two parts: a) when the axis of rotation is positioned between both utricles (i.e. < 4 cm): <US> = -0.253 ± 0.017 (degree OCR/tilt head center); b) when the axis is positioned beyond the utricles (4cm<axis<8 cm) the <US> = -0.196 ± 0.020. Using a modified and extended model of Kondrachuk, these data indicate that the medial partition of the utricle provides a greater response than the lateral part.

Conclusion: Our findings corroborate the model by Kondrachuk, suggesting that a great asymmetry exists between left and right utricles. We moreover found that the medial part is more responsive than the lateral part.

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O088

Translational (TVOR) and Angular (AVOR) Vestibulo-Ocular Reflexes Share Vestibular Pathways

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Background: The neural pathways used by the monkey's angular vestibulo-ocular reflex (AVOR) are relatively well known. These include the classical 3-neuron reflex arc from each canal as well as additional short latency pathways. In contrast, neither the neural pathways nor the physiology of the TVOR are well understood. The kinematic requirements of the TVOR are quite different from the AVOR. For example, the TVOR is dependent on gaze, i.e., the location of a viewed target relative to the subject. Thus, vestibular afferent signals related to head translation must be centrally combined with signals related to gaze in order to produce kinematically correct compensatory eye movements. Not only the amplitude but also the direction of the compensatory eye movements are gaze dependent, and the compensatory eye movements may be disjunctive.

Objectives: The different kinematic requirements of the AVOR and TVOR suggest that these reflexes might use distinctive central neurons or pathways. However, several recent single unit studies suggest that many central neurons associated with the AVOR also convey signals that appear to be related to head translation. To determine which central neurons might transmit shared signals and to characterize those signals, we have recorded from monkey vestibular neurons that discharge in relation to angular and/or linear head movement and to eye movements.

Methods: Single unit recordings were obtained from vestibular neurons in alert monkeys trained to perform a visual tracking task in exchange for juice rewards. Eye movements were recorded binocularly using search coils. Vestibular stimulation was provided by a servo-controlled earth vertical rotary axis located on a linear sled. In order to isolate vestibular and eye movement signals, we collected data

using several behavior paradigms. In particular, we compared neuronal data obtained during both steady state and transient (abrupt head acceleration) vestibular stimulation and when the monkey viewed near and far targets. The latter paradigm was especially useful for distinguishing translational vestibular signals from those related to compensatory eye movements.
Results: Our analysis suggests that there is substantial convergence of angular and linear signals on specific classes of central neurons (particularly the so called eye-head type II and position-vestibular-pause (PVP) type II neurons) despite the different kinematic demands of the two reflexes. However, other neurons (e.g., PVP Type I) appear to encode only signals related to the AVOR.
Conclusion: These data can be used to validate different models of the VOR that incorporate translational signals.

O089
Opening Remarks and Overview of the VEMP
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Background: In 1994 Colebatch et al. [2] reported a method of recording a short latency vestibulocollic reflexes from over the sternocleidomastoid (SCM) muscles in response to loud clicks. This work built on earlier observations of Bickford and coworkers [1]. The earliest response – termed p13n23 on the basis of its latency and polarity, occurred ipsilateral to the stimulus and was shown to be specifically vestibular dependent. Similar responses can be evoked using a variety of stimuli and these modalities are now being used in clinical evaluation of vestibular function.
Objectives: To present the properties of these responses that affect their interpretation.
Methods: Recording reliable click-evoked or air tone burst-evoked responses requires i) a method of ensuring reasonably similar levels of tonic activation in both SCMs ii) a calibrated sound source and iii) a method to exclude conductive hearing loss as a possible confounding source of a small or absent response. Bone conducted tone bursts [3,5] may be used to bypass the middle ear and short duration galvanic stimulation [4] acts proximal to the end organ.
Results: Considerable evidence indicates that the receptor activated by sound is the saccule. The response itself is generated by a short period of inhibition of tonic EMG activity, corresponding to the IPSP that has been shown following saccular stimulation in the cat. The amplitude of the potential scales with the level of tonic contraction of the SCM and the response is very sensitive to conductive hearing loss. Responses tend to become smaller with increasing age. These methods of stimulation have also been used to show vestibular projections to other cranial muscles and to the cortex.
Conclusion: It is now possible to probe the peripheral vestibular system at multiple levels. Unlike clicks, the specific vestibular afferents activated by bone vibration and galvanic stimulation are not yet clearly established. The amplitude, threshold and latency of the p13n23 response and the response to different types of stimulation may all potentially show changes in response to vestibular disorders.
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O090
The Physiological Basis of VEMPs - The Response of Guinea Pig Primary Vestibular Neurons to Air-Conducted and Bone-Conducted Sounds
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Background: In order to use VEMPs clinically, there needs to be direct physiological evidence demonstrating that sounds activate vestibular neurons. Are all vestibular sensory regions activated equally by the sound or is there a differential preference by some sensory regions for particular stimuli? Murofushi et al (1995) showed that guinea pig primary saccular afferents selectively respond to air-conducted clicks. The evidence about the response selectivity of primary vestibular afferents to bone-conducted stimuli is scant.
Objectives: To review the response of vestibular neurons to air-conducted and bone-conducted sounds.
Methods: Single vestibular neurons in anesthetized guinea pigs were classed as regular or irregular and the neuron was identified by its location in Scarpa's ganglion and its response to angular acceleration in yaw, pitch and roll and maintained position in pitch and roll in order to identify which semicircular canal or otolithic sensory region the neuron originated from. This information allows us to infer whether a neuron is from a particular semicircular canal or otolith organ. The response of each neuron to either clicks or continuous pure tones was then tested by either air-conducted stimuli - (delivered via a TDH49 headphone) or bone-conducted stimuli (delivered by a Radioear B-71 clinical bone conduction transducer cemented to the guinea pig's skull). These transducers limit the maximum stimulus

intensity that can be delivered. All sound intensities were referred to the threshold for ABR response to clicks.

Results: Both regular and irregular semicircular canal neurons are insensitive to air-conducted and bone-conducted sounds and few very respond up to the maximum levels the transducers could deliver. Regular otolithic afferents likewise rarely respond. For air-conducted clicks, irregular saccular afferents show a clear response preference. Irregular otolithic afferents from both saccular and utricular maculae showed a strong response to bone conducted sound and some neurons were activated at only 30dB above ABR threshold.

Conclusion: There is a clear preference for otolith afferents to be activated by sounds. Irregular saccular afferents respond to air-conducted clicks and irregular afferents from both the saccule and utricule respond to bone-conducted sounds at low stimulus levels. This result appears to be in conflict with Young et al 1977 but they were able to deliver more intense stimuli than here and their criterion for activation was phase locking rather than the detectable increase in firing criterion we used. The reason otolith organs show such a response preference for sounds may be related to evolutionary factors.

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O091

Neural Connectivity of the Otolith-Collic Reflex

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Background: The inputs from saccular (SC) and utricular (UT) maculae reach neck motoneurons (mns). In a clinical test, loud clicks evoke vestibular evoked myogenic potentials, VEMPs, in the sternocleidomastoid (SCM) muscles (Halmagyi et al. 1994). Since this stimulation seems to affect the saccular nerve, these potentials may reflect the function of SC-SCM pathway.

Objectives: In our experiments, inputs from the otolith organs to SCM mns were studied in decerebrate cats (Kushiro et al. 1999). I summarize what is known about the connectivity of SC or UT afferents inputs onto SCM motoneurons for better understanding of the VEMPs.

Methods: The cats were anesthetized with halothane-nitrous oxide and decerebrated. Left SC or UT nerves were selectively stimulated with bipolar fine silver electrodes (Sasaki et al. 1991; Uchino et al.1997). Intracellular recording was done in the SCM mns with glass micropipettes.

Results: SC nerve stimulation evoked disynaptic inhibitory postsynaptic potentials (IPSPs) in almost all (43/44) ipsilateral (i-) SCM mns (Kushiro et al. 1999). Some (10/43) IPSPs were preceded by small-amplitude excitatory postsynaptic potentials (EPSPs). In the contralateral (c-) SCM mns, the majority (28/31) did not show responses after SC nerve stimulation. UT nerve stimulation evoked disynaptic IPSPs (33/37) and disynaptic EPSPs (21/30) in most i-SCM and c-SCM mns, respectively. Kushiro et al. (1999) tried to determine the pathways of the PSPs by transecting the medial longitudinal fasciculus (MLF). After the transection of the MLF, IPSPs were not recorded in any of i-SCM mns following SC nerve stimulation, while some neurons showed small-amplitude EPSPs. The result suggested that the excitatory pathway might be separated from the inhibitory pathway. After transecting the MLF, UT nerve stimulation induced no visible PSPs in most i-SCM and all c-SCM mns, suggesting that the pathways from the UT to i-SCM and c-SCM mns are in the MLF.

Conclusion: The VEMPs are only seen ipsilaterally, and are believed to be produced by the sacculus (Halmagyi et al. 1994). Our experiments demonstrated that the SC-SCM pathway was mainly composed of ipsilateral disynaptic inhibition, which supports the idea by Halmagyi and his colleagues that VEMPs are mainly produced via the sacculus.

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O092

Vestibular Evoked Myogenic Potentials in Meniere's Disease

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Background: The conventional staging system for Meniere's disease was based solely on the audiological perspectives, e.g. 4-tone average or type of hearing loss, possibly owing to a paucity of reliable vestibular indicators. Since the saccule, next to cochlea, is the second most frequent site for hydrops formation, whether vestibular evoked myogenic potential (VEMP) responses can reflect the stage of Meniere's disease remains unexplored.

Objectives: Our goal was to try to evaluate whether the VEMP results can be useful in assessing the stage of Meniere's disease.

Methods: Forty patients (23 men and 17 women, mean age: 43 ± 12 years) with unilateral definite Meniere's disease were enrolled in this study. The latencies of p13 and n23, amplitude p13-n23, and the interaural amplitude difference (IAD) divided by the sum of amplitudes of both ears were measured, and the stages of the disease were compared with the types of hearing loss, the % unilateral weakness of caloric response, and the IAD ratio, respectively.
Results: Six ears were classified as stage I, including normal VEMPs in 5 and augmented VEMPs in 1, with a mean IAD ratio -0.02 ± 0.20. Twelve ears of stage II consisted of normal VEMPs in 7, augmented VEMPs in 2, depressed VEMPs in 1, and absent VEMPs in 2, with a mean IAD ratio -0.12 ± 0.39. Stage III was noted in 17 ears, including normal VEMPs in 10, depressed VEMPs in 4, and absent VEMPs in 3, with a mean IAD ratio -0.30 ± 0.30. Stage IV was in 5 ears, including normal VEMPs in 2, depressed VEMPs in 1, and absent VEMPs in 2, with a mean IAD ratio -0.54 ± 0.43. Comparing the IAD ratio and the stage of Meniere's disease demonstrates a significant relationship ($p<0.05$, ANOVA test), whereas no significant relationship exists between the % unilateral weakness of caloric response and the stage of disease.
Conclusion: The IAD ratio of VEMPs correlates with the stage of Meniere's disease, and can be served as another aid to assess the stage of Meniere's disease.

O093

VEMPs Induced by High Levels Sounds and Galvanic Currents: Its Interest in Clinical Otoneurology

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Background: Vestibular evoked myogenic potential (VEMP) evoked by high level sounds appreciate the function of the sacculo-spinal pathways whereas VEMP induced by galvanic currents gives information about the excitability of the spike trigger zone of the primary vestibular afferents.
Objectives: 1. to show in patients with acoustic neurinoma than clicks and short tone bursts brought complementary information about the potential dysfunction of the sacculocollic pathways. 2. To illustrate in Menière's disease patients treated by intratympanic gentamycin injections the interest of VEMPS induced by galvanic currents.
Methods: In 170 patients suffering from an acoustic neurinoma, we studied the average responses to 100dB clicks and 500Hz STB in the ipsilateral sternomastoid (SCM) muscle. In twenty-two Meniere's disease patients treated by intratympanic gentamicin injections, caloric and head impulse tests, VEMPs induced by high level sounds and short duration galvanic currents were performed over the following two years to assess the vestibular function.
Results: 36/170 acoustic neurinoma patients patients (21.2%) exhibited normal responses to clicks and to STB whereas 134/170 (78.8%) gave abnormally low or no responses. 78/170 (45.9%) showed no responses to both clicks and STB. In 56/170 patients (32.9%), VEMP-'s induced by high level clicks and STB were discordant: STB VEMP-'s were either normal (n=32) or low (n=24) in patients with an abnormal response to clicks (no response n=40 or low response n=16). In contrast, STB-induced VEMP-'s were always normal in cases of normal responses to clicks. No correlation could be found between saccular nerve dysfunction and either the degree of 4-8 kHz hearing loss or the extent of horizontal canal impairment. For the Meniere's disease patients, thirty-eight % of the patients who lost the caloric responses and displayed refixation saccades to head impulse tests at one or six months, reverted to normality within two years of the lesion. One month post-injection, early P13g and N23g on the SCM ipsilateral to lesion were abolished in 31.8% patients. This percentage rose to 40.9% by six months and one year post-injection, and to 45.6% by two years post-injection. Once the VEMPg had been abolished, the patients showed a strong horizontal canal and saccular paresis on the lesioned side as shown by the caloric and the VEMPc tests. Vertigo, VEMPc, VEMPg and caloric response did not reappear at any time after abolition of the VEMPg.
Conclusions: These data indicate that high level clicks and STB provide complementary information about the functionality of the saccular nerve. Clicks are useful to detect a minor saccular nerve dysfunction. In cases in which there is no responses to clicks, STB give valuable information about a potential residual function of the saccular nerve. The horizontal canal ampullary cells may regenerate one year after gentamicin injections, leading to recovery of compensatory eye movements. The galvanic test was satisfactorily monitored the effect of gentamicin on the vestibular afferents and could predict the risk of long term recurrence of vertigo attacks.

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O094

Vestibular Evoked Myogenic Potentials (VEMP) in Patients with Superior Canal Dehiscence Syndrome

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Background: Recently, Minor and co-workers presented a 'new' vestibular entity, the superior canal dehiscence syndrome (SCD syndrome) (1). It is caused by failure of nor-

mal postnatal bone development in the floor of the middle cranial fossa leading to absence of bone at the most superior part of the superior semicircular canal. This creates a 'third mobile window' and alters vestibular and auditory function. The typical features for this syndrome are sound and pressure-induced vertigo with torsional eye movements, pulse synchronous tinnitus and apparent conductive hearing loss in spite of normal middle ear function. CT demonstrates a thinning of the skull base in this area and a dehiscence of the superior semicircular canal. However, not even high-resolution CT can always distinguish between complete absence of bone and very thin bone coverage. Consequently, a diagnosis of SCD syndrome must be a clinically based diagnosis (which gets support from the specific CT findings). Further, it has been suggested that vestibular evoked myogenic potentials (VEMP) can be helpful in substantiating the clinical diagnosis of SCD syndrome (2,3).

Objectives: The aim was to explore whether patients with SCD syndrome have VEMP features that are of clinical diagnostic value.

Methods: VEMP in response to both skull taps and sounds were studied in 20 patients with SCD syndrome. One patient had symptoms bilaterally, but all the others had sound and pressure-related symptoms in only one ear.

Results: In symptomatic ears, low-frequency sounds caused abnormally large VEMP with a low threshold, clearly separating the response from those of normals. This was so independent of whether the sound stimulation was presented by air or bone-conduction. There were no VEMP in response to high-frequency sounds and in this respect they did not differ from normals. Further, midline forehead skull taps caused symmetric VEMP similar to those seen in normals. Thus, patients with SCD syndrome differ from normals in VEMP showing a vestibular hypersensitivity specifically for low-frequency sounds in the symptomatic ears. Nevertheless, in several of these patients the high-resolution CT suggested a dehiscence also in ears with normal audio-vestibular function.

Conclusion: VEMP are helpful in substantiating the diagnosis of SCD syndrome. This is especially true in those without clearly lateralizing symptoms, because CT can wrongly indicate a unilateral or bilateral dehiscence of the superior semicircular canal.

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O095

VEMP in Vestibular Neuritis and Acoustic Neuroma

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Background: Vestibular evoked myogenic potential (VEMP) testing has been applied for various diseases including vestibular neuritis and acoustic neuroma. VEMP testing reveals disorders of the sacculo-collic reflex in patients with these diseases.

Objectives: Vestibular neuritis and acoustic neuroma are considered to have lesions mainly in the vestibular nerve. However, the frequency of the involvement of the sacculo-collic pathway is not clear. Furthermore, the site of lesions is not clear in patients with vestibular neuritis. We will answer to these questions using VEMP techniques.

Methods: Patients clinically diagnosed as having vestibular neuritis or acoustic neuroma were enrolled in this study. For the comparison we used data from patients with Meniere disease and healthy volunteers.

VEMPs were recorded from the sternocleidomastoid muscle that was activated bilaterally by maintaining an elevated head in the supine position. To record click VEMP, 95-dBnHL clicks (0.1 msec) were used. The stimulation rate was 5 Hz and the analysis time was 50 msec. To record galvanic VEMP, 3mA (1 msec) electrical stimuli were presented (cathode: mastoid, anode: forehead). To remove electrical artifacts in galvanic VEMP, we subtracted the averaged responses obtained without SCM contraction from the averaged responses obtained with SCM contraction.

Results: Among patients with acoustic neuroma, approximately 80% of the patients showed abnormal VEMPs; absent VEMP or decreased VEMP. Some patients showed prolonged peak latency (prolonged p13). Almost all patients that showed absent VEMPs on the affected side showed absence of galvanic VEMP when the cathodal electrode was on the mastoid of the affected side. Among patients with vestibular neuritis, approximately 40% of the patients showed abnormal VEMPs. Some of them showed recovery of VEMP responses in 6 months to 2 years after the vertigo attack. Eleven patients with absent VEMPs on the affected side underwent galvanic VEMP testing. Among them, 8 patients showed absent galvanic VEMP while 3 patients showed normal galvanic VEMP.

Conclusion: Using VEMP tests, click VEMP and galvanic VEMP, we can know the damages of the sacculo-collic pathway and the site of lesions (end-organ or nerve) in patients with vestibular disorders.

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O096

The Visual Stabilization of Gaze in a 3-D World

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Background: Primates have two types of vestibulo-ocular reflex that generate eye movements to compensate for head movements and so work to stabilize gaze: one uses canal inputs to compensate for rotations (RVOR) and the other uses otolith inputs to compensate for translations (TVOR). Neither is perfect so residual disturbances of gaze during motion of the observer must be commonplace. Visuo-ocular reflexes help to curtail these disturbances of gaze by tracking the associated disturbances of the retinal images and it is these visual reflexes that will be the major concern here.

Objectives: It has been customary to concentrate on those visuo-ocular reflexes that address the shortcomings of the RVOR by recording the ocular tracking responses elicited by a rotating striped drum that surrounds the subject: the well-known optokinetic reflex. However, one might also ask if there are visuo-ocular reflexes that are selectively sensitive to the visual disturbances associated with translation of the observer and so address the shortcomings of the TVOR. Whole-body translation in the dark along the fore-aft and inter-aural axes is known to activate TVOR mechanisms that generate vergence and version eye movements, respectively, that are a function of the vergence angle (as required by the geometry - though less than perfect). The present experiments sought to determine if such eye movements are also elicited when stationary subjects experience global patterns of optic flow that merely simulate the visual experience of the observer during fore-aft or inter-aural motion in the light.

Methods: Movements of both eyes were recorded while subjects viewed a screen onto which large patterns were back-projected. These patterns underwent a sudden change, simulating the visual events that the observer would have experienced if he/she had stepped towards or away from the screen ("fore-aft motion") or shifted to one side ("inter-aural motion"). The visual stimuli lasted only 200 ms after the step and ocular response measures were restricted to the initial open-loop period (<2 reaction times).

Results: Simulated fore-aft and inter-aural motion elicited vergence and version eye movements, respectively, at short latency (<90ms). These initial responses were compensatory and a linear function of the preexisting vergence angle. In the inter-aural case, partitioning the scene into subregions that differed in depth revealed that the tracking system was most sensitive to the motion of objects in the plane of fixation and much less sensitive to the motion of objects at other depths; also, inputs from the foveal region carried greater weight.

Conclusion: The TVOR has visual backup mechanisms that are analogous to the well-known optokinetic visual backup to the RVOR. In their dependence on viewing distance and preference for the foveal region and the plane of fixation, these backups to the TVOR are like the TVOR itself, perhaps reflecting some shared central pathways. There is a close synergy between the visual and vestibular mechanisms.

O097

Suppression of Visual Gaze-Stabilizing Mechanisms During Voluntary Tracking

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Background: When we experience movement of the visual scene, it is usually due to our own head movement relative to the environment. In such cases, visuo-ocular reflexes, in cooperation with vestibulo-ocular reflexes, help to stabilize the gaze. However, even when our head is stationary we experience motion of the visual scene whenever we track a moving object with our eyes. In this situation the motion of the background images on the retina is secondary to the tracking eye movements (reafference) and, insofar as it activates the visuo-ocular reflexes that operate to stabilize gaze, potentially impedes the tracking of the target. Yet we and monkeys are able to track small targets moving against textured backgrounds quite well, raising questions about the gaze-stabilizing visuo-ocular reflexes in these conditions.

Objectives: We sought to examine the possibility is that these visuo-ocular reflexes (termed ocular following) that normally help to stabilize gaze are suppressed when moving objects are tracked (termed smooth pursuit).

Methods: We recorded the ocular following responses elicited by sudden brief motions (perturbations) of a large random-dot pattern while the subjects (monkeys and humans) were pursuing a small moving target or fixating a stationary target. We measured the eye movements elicited by 50-ms perturbations of the background, 1) when the subject was pursuing a moving target while the background was stationary, 2) when the subject was pursuing a moving target while the background was moving with the target, 3) when the subject was fixating a stationary target while the background was either moving or stationary.

Results: We found that the ocular responses to background perturbations during smooth pursuit were selectively weaker when the perturbation was in the same direction as the reafferent background motion. However, some reduction in the sensitivity to background motion was also apparent even when the animal was fixating a stationary target against a moving background. In this situation, the ocu-

lar responses to subsequent brief perturbations of the moving background were appreciably weaker when the perturbations were in the same direction as the prior background motion than when in the opposite direction. It suggests that the modulation of the ocular response to the background perturbation during pursuit is not only due to the ongoing pursuit per se but also due to the reafferent retinal stimulation associated with pursuit.
Conclusion: The visuo-ocular reflexes that normally help to stabilize gaze with respect to the surroundings are selectively disabled during pursuit, rendering them largely insensitive to the reafferent visual input associated with normal pursuit across a stationary background. At least in part, this effect is independent of pursuit per se and attributable to a progressive reduction in the sensitivity to sustained background motion. The net result is that pursuit proceeds largely free of interference from the gaze stabilizing visuo-ocular reflexes.

O098
Evidence for Low- and High-Level Motion Processing in the Visual Stabilization of Gaze
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Background: In contrast to vestibular inputs, visual information used by gaze stabilization mechanisms must be extracted from the retinal image of a cluttered environment. Visual motion processing is often described as a two stages mechanism where a detection stage is followed by an integration stage that combines together local motion cues from the same part of the image to reconstruct the global motion of the visual object of interest. This later motion information can then be used to control the movements of the eyes.
Objectives: These experiments were designed to probe the dynamics of lower and higher levels motion processing that contributes to the visual stabilization of gaze. A first step was to decipher how different local motion cues are extracted and integrated together to reconstruct the 2D velocity vector (i.e. speed and direction) of the surface of interest by using simple, calibrated motion stimuli such as gratings or plaids. A particular attention was paid to the temporal dynamics of this motion integration process which can be measured from the time course of reflexive ocular responses in humans. The next step is now to understand how 2D surface motion integration depends upon the 3D structure of the visual scene.
Methods: Movements of the right eye were recorded while subjects viewed a screen onto which large, computer-generated patterns were back-projected using a video-projector. These patterns underwent a sudden translation lasting only 200 ms and ocular following response measures were restricted to the initial open-loop period. Motion stimuli were sinusoidal luminance drifting gratings presented alone or combined with static oblique gratings to generate a unikinetic plaid where 1D component (i.e. grating) and 2D pattern (i.e. plaid) motion directions differed by 45°.
Results: In humans, the earliest phase (latency: ~85ms) of short-latency ocular following responses rely upon a linear spatio-temporal filtering of the retinal image that extracts the local 1D motion cues (i.e. local borders in the image) and immediately computes their vector average. This linear processing is highly sensitive to contrast and pools motion over a large (~30° diameter) area of the visual field. We identified a second, later response component. Starting at ~110ms after stimulus onset, it deviates tracking direction towards pattern motion directions. This later component depends upon a more sluggish motion processing that extract 2D motion cues such as generated by local features in the image. 1D and 2D motion information are slowly integrated together so that ~200ms after stimulus onset, tracking and surface motion directions coincide exactly.
Conclusion: Our results demonstrate that visual stabilization of gaze depends upon a complex processing of the visual array which extracts lower (1D) and higher (2D) motion cues within parallel pathways of different dynamics.

O099
Differential Impairment of Low- and High-Level Visual Motion Processing in Neurological Patients
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Background: Studies of visual motion in neurological patients demonstrated that, in humans, motion is a "special visual perception" (Riddoch, 1917). Psychophysical studies of patients' performance on tasks embodying different motion mechanisms revealed interesting double dissociations of deficits which provide important insights into the nature of the functional architecture of the human visual motion system (Vaina, 1998, Vaina and Rushton, 2000).
Objectives: Here, using psychophysical data from several motion impaired neurological patients, we investigate the role in motion perception of differential impairments of low- and high-level motion tasks in 5 stroke patients.
Methods: Stroke patients and normal controls were repeatedly studied with computer generated psychophysical visual tasks to probe their ability to discriminate speed and direction of simple and complex motion, 2D and 3-D or from motion, and heading from optic flow alone or heading in the presence of landmarks. A 2AFC procedure was used in all tasks. Stimuli were presented using an adaptive staircase and threshold resulted from last six reversals.
Results: We show that deficits on low level motion (speed or direction) did not necessarily disrupt patients' discrimination of higher level motion (3DSFM, heading). Contrary to some computational theories the data revealed that accurate perception of 2-D and 3-D form from motion is not necessary for perception of heading from optic flow (Royden&Vaina, 2004). Our data also suggests that perception of heading in the presence of landmarks is possible when patients cannot use optic flow as a cue.

Conclusion: Taken together, the dissociation of deficits reported here suggest that the human visual motion system is not organized in a strict hierarchy (Vaina, 1990; Vaina et al, 2003) and that for higher level motion tasks the brain may not necessarily rely on very precise low level motion computations (Vaina et al, 1990; Vaina et al, 2003) We demonstrated that optic flow is not necessary for computing heading (Vaina et al, 2002; Vaina and Soloviev, 2004)

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O100

Vestibular Otolith Development in Spaceflight and Hypergravity

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Background: It is known that even moderate exposure to spaceflight conditions in adult animals can produce modifications in the anatomy, physiology, and neuromotor responses related to the vestibular system. In addition, more limited evidence shows that altered gravity environments can directly affect the development of vestibular receptors.

Objectives: The goal of the present study was to determine how gravity affects the development of the vestibular otolith organs.

Methods: The receptors, otoconia, and afferent innervation of the utricular and saccular maculae were examined in embryonic quails raised from fertilization in one of three gravity environments, including normal 1g, microgravity (0g), or hypergravity (2g). Fertilized eggs were first arrested from development by cooling, then placed into one of three gravity conditions and allowed to develop for 12 days at 37deg C. 1G and 0G embryos were developed in low Earth-orbital spaceflight (STS-108) in a specially designed incubator (ADF - SHOT, Inc) that contained a microgravity carousel and a 1g centrifuge carousel. 2g embryos were developed during constant centrifugation in a laboratory incubator. The utricle and saccule otolith organs from four 0g and six 1g space flight embryos, as well as eight 2g and ten ground based 1g E12 stage matched embryos were examined.

Results: The ratios of otoconial stone weight/body weight increased by 40% in 0g and by 80% in 2g embryos as compared to both flight and ground 1g controls, which were all equivalent. The mean saccular epithelium area was smaller in 0g embryos and larger in 2g embryos as compared to 1g controls. Examination of the hair cell stereocilia polarizations showed that normal organizational arrangements were present for all gravity conditions. Number of hair cells and type are currently being assessed. Neural tracing (HRP) reconstructions of macular afferents were performed on all E12 embryos. 0g fibers had smaller axons, were less branched, and had fewer terminals as compared to 1g controls. 2g afferents were significantly larger, contained more arborizations, larger terminals and more growth cones as compared to 1g controls. Electron microscopic observations reveal that the ribbon synapses were more numerous for type I but not type II hair cells in both 1g and 2g maculae, as compared to 1g controls.

Conclusion: The results show that vestibular otolith development is regulated by gravity for otoconia formation, synaptogenesis, and afferent innervation.

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O101

Head Motion of Freely Swimming Dolphins

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Background: The order Cetacea consists of toothed and baleen whales, dolphins, and porpoises. The cetacean vestibular labyrinth is significantly reduced compared to land mammals of comparable size. The radius of the semicircular canal in the massive blue whale, for example, is no longer than that of man. This reduction appears to have occurred as cetaceans returned from land to the water during the Eocene period. These animals therefore violate the long-observed allometric relationship between canal dimensions and body mass.

Objectives: Two mutually opposing theories have been proposed to explain this finding. One holds that these animals would suffer from disequilibrium if their canals were larger and presumably overly responsive to motion. The other suggests that their particular anatomy (including fused cervical vertebrae and a horizontal tail) limits their head movements sufficiently to reduce the input from their semicircular canals. We measured their head motions in an

effort to compare the signal available to the cetacean vestibular system with that of better studied mammals.
Methods: Four captive bottlenose dolphins (*Tursiops truncatus*) were trained to carry a waterproofed array of orthogonally oriented rotational rate meters in their mouths during a series of activities. After each activity, data were downloaded from the meters to a computer for analysis. The activities included natural swimming with a series of turns, rolling (or "spinning") underwater, coming to the surface for a breath, and shaking the head "no" and "yes" with the head out of the water.
Results: Data were obtained from all four animals. Rotational accelerations in the yaw plane commonly exceeded 1250 deg/sec^2. Rotational velocities in this plane regularly exceeded 400 deg/sec. Rotational accelerations and velocities in the other planes were lower, with velocities rarely exceeding 50 deg/sec during regular swimming. The dominant frequency of head motion for each animal was approximately the same in all planes and unique to the animal, with values between 1.5-2 Hz regardless of the activity.
Conclusion: Small cetaceans undergo head movements of the same general range as other mammals. They appear to have a dominant frequency of movement common to all planes of motion, a phenomenon possibly dependent on their body size and liquid habitat. It is unlikely that these animals do not experience sufficient head movement to stimulate the semicircular canals adequately as had been previously suggested. Other reasons must be sought for their particular vestibular anatomy.

O102
The "Wait and Learn Strategy" of Postural Control in Children—A Fall Isn't That Bad
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Background: Acquiring bipedal stance is considered to be a milestone in children's motor development, which takes months to master. As the body grows, both functionally and physically, the dynamics of the postural control system is constantly challenged. Little focus has directed to how postural control is mastered and the changing adaptation patterns through the life span. We have previously described how adults learn and adapt to novel postural challenge, separating between initial re-arrangement of responses and the 2 phase adaptation behavior to a novel stimulus, which seems to follow the general paradigm of how motor memories are formed, i.e. from a short-term fragile state through a time-dependent process known as consolidation to a long-term memory. However, as children are not little adults and the neonatal brain has more and different connections and more neurons, children's learning of postural control may show other properties than adults.
Objectives: To compare postural adaptation between adults and children
Methods: Repeated vibratory posturography for 5 consecutive days and after 3 months on 13 healthy children aged 7-9 and on 12 healthy adults.
Results: New motion strategies were generated over time both in adults and children. The first motion strategy constitutes an adaptation during the trial, only visible in adults ($p< 0.05$). The second is visible between the consecutive trials, where the body sway behavior in adults is further refined in order to withstand the perturbations ($p<0.001$). The children exhibit a similar second adaptation pattern and seem to adapt their balance control more and faster than adults ($p<0.001$). Starting with a substantially larger body sway, the children quickly reduced their response to the stimulation. No rebound increase in sway after 3 months was observed for both children and adults, suggesting a formation of long-term memory.
Conclusion: The results indicate that the learning procedure differs between adults and children when the postural control system is presented to a novel challenge. The adults rapidly use a strategy in order to decrease the effect of the perturbations whereas the children unconcerned test the fresh experience to gain experience and at the next trial perform significantly better. Thus a 'wait and learn strategy' of children. This is important to bear in mind when analyzing how children react to perturbations and other test set-ups to determine the development of motor programs.

O103
Development of Firing Pattern in Chick Vestibular Nucleus Neurons
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Background: In birds and mammals, most mature vestibular nucleus neurons require both spontaneous spike activity and repetitive firing to transmit faithfully the temporal characteristics of vestibular stimuli. These two features may appear gradually during development, since vestibular stimuli are changing at birth. At embryonic day 16 (E16), chicks reside in ovo, so persistent vestibular reflex activity is not needed. While chicks can stand and move at birth (H1), it is not until 5 days after hatching (H5) that the chick's motor skills are rigorous and stable.
Objectives: The emergence of neuronal excitability was studied in the chick tangential nucleus (TN), whose principal cells (PCs) participate in the vestibular reflexes.
Methods: These studies were performed on PCs in brain slices using whole-cell patch-clamp recordings and immunolabeling combined with confocal imaging at 3 ages: E16, H1, and H5-H9.
Results: At E16, none of the PCs showed spontaneous spike activity, and most neurons generated single spikes on depolarization. By H1, half of the PCs showed spontaneous

spike activity, which depended on synaptic transmission. On depolarization, >90% of PCs showed repetitive spike firing. By H5, most PCs generated spontaneous spike firing, independent of synaptic transmission, indicating that PCs had acquired new intrinsic membrane properties. Moreover, by H5, all PCs generated multiple spikes on depolarization. Coincident with the switch in firing pattern from E16 to H1, a dendrotoxin-sensitive (DTX) potassium (K) current was down-regulated(Gamkrelidze et al., 1998; 2000). Immunolabeling for DTX-sensitive Kv1.1 and Kv1.2 K channel subunits confirmed that they were expressed highly in PC bodies at E16, but significantly reduced after birth. In the brain, an astrocytic syncytium contributes to maintain the extracellular K ion balance. Changes in astrocytic communication can be detected by the level of expression of Cx43, a gap junction protein mainly expressed in astrocytes. In the TN, Cx43 was developmentally regulated, with a peak at H1 when PC excitability increased dramatically. Finally, AMPA sEPSCs showed faster kinetics at H1 than at E16, and AMPA receptor subunit immunolabeling increased steadily from embryo to hatchling. Also, GluR3 and GluR4 receptor subunits, composing AMPA channels with fast kinetics, are present at high levels in PCs after birth.

Conclusion: There are 3 major steps for setting the firing pattern of these vestibular nucleus neurons: (1) repetitive spike firing on depolarization appears first, followed by (2) spontaneous spike activity which depends on synaptic transmission, and then(3)spontaneous spike activity which depends on intrinsic membrane properties. In summary, important cellular features and functional rules have been deciphered for vestibular nucleus neurons to establish their mature firing pattern. These rules might also be followed by these vestibular neurons during recovery of function after vestibular lesions and contribute to vestibular compensation.

O104

Properties of Vestibulospinal Neurons Receiving Inputs from Horizontal Semicircular Canal in Cats

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Background: The vestibulospinal reflex is important for the control of proper body posture and movement. In previous work from our group, we selectively stimulated the otolith nerves and described features of the utricular and saccular nerve-activated vestibulospinal neurons using electrophysiological techniques. Although some aspects of semicircular canal-activated vestibulospinal neurons have been documented previously, in particular the strong connections between the canals and neck motoneurons, little is known about the spinal projection levels of canal-activated vestibular neurons.

Objectives: The present study was designed to clarify the projection level and the pathway of the horizontal semicircular canal (HC) nerve-activated vestibulospinal neuron. We also investigated whether there were any differences between the neurons that projected solely to the cord and those that additionally sent ascending collateral branches to the oculomotor nucleus.

Methods: Experiments were performed on seven adult cats. The horizontal semicircular canal nerve was selectively stimulated. Vestibulospinal neurons were activated antidromically with four stimulating electrodes, inserted bilaterally into the lateral vestibulospinal tracts (LVST) and medial vestibulospinal tracts (MVST) at the C1/C2 junction. Stimulating electrodes were also positioned in the C3, T1, and L3 segments and in the oculomotor nuclei.

Results: HC nerve-activated vestibulospinal neurons were mainly located in the ventral portion of the medial and lateral vestibular nuclei. Almost all the vestibulo-oculospinal neurons had axons that descended through the contralateral (c-) MVST, whereas most vestibulo-spinal neurons had axons that descended through the ipsilateral (i-) MVST. Almost all those neurons were activated antidromically only from the cervical segment. Only one neuron was activated from the T1 segment of the i-LVST. No neurons were activated from the L3 segment.

Conclusion: 1. The majority of vestibulospinal neurons with axons descending through the c-MVST were also antidromically activated from the oculomotor nucleus, whereas almost all vestibulospinal neurons with axons descending through the i-MVST were not.

2. It is likely that the majority of HC nerve-activated vestibulospinal neurons terminates in the cervical cord and has strong connections with neck motoneurons.

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O105

Alterations in Human Rectus Extraocular Muscle (EOM) Actions by the Torsional Vestibulo-Ocular Reflex (VOR)

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Background: Gravitational stimulation of the otoliths by head tilt induces ocular counter-rolling (OCR) around the visual axis, constituting a torsional VOR. Sustained 90 deg tilt induces 3–7 deg OCR in humans(1), and in monkeys alters preferred directions of saccadic burst neurons(2). The VOR violates Listing's Law (LL) , which otherwise confines ocular torsion to a planar surface, so that the 3-D ocular velocity axis shifts by half of eye position. LL is hypothesized to arise from mechanical configuration of the connective tissue pulleys that determine EOM force directions(3).
Objectives: We sought to determine if VOR violation of LL is due to otolith-mediated reconfiguration of rectus EOM pulleys.
Methods: Tri-planar gadodiamide contrast magnetic resonance imaging (MRI) was obtained in 10 humans during central target fixation while positioned in right (RD) and left (LD) lateral decubitus positions. EOM cross sections and paths were determined from area centroids in normalized coordinates. EOM paths were used to locate connective tissue pulleys in 3-D. Correct head orientation was verified from MRI images.
Results: Significant ($P < 0.01$) binocular counter-rotational repositioning in the coronal plane averaging 4.1 (max 8.7) deg from RD to LD was observed for the inferior, medial, and superior rectus pulleys, with a trend for the lateral rectus pulley averaging 1.4 deg. This effect varied inter-individually. Pulley array incyclorotation was associated with significant contractile thickening of the superior oblique and thinning of the inferior oblique EOMs, while excyclorotation was associated with superior oblique thinning and inferior oblique thickening.
Conclusion: Since rectus EOM paths are determined by their pulley locations, observed path shifts during static head tilt indicate rectus pulley re-positioning by the torsional VOR. This pulley reconfiguration is associated with appropriate contractile changes in oblique EOM cross sections. Rectus pulley shift during the VOR, changing pulling directions of the rectus EOMs, is probably an active process mediated by known insertions of the orbital layers of the oblique EOMs on rectus pulleys. The amount of pulley reconfiguration is comparable to OCR, suggesting coordinated shifts of rectus pulleys and insertions that would simply offset Listing's plane without disturbing the half angle ocular kinematics necessary for neural control. Inter-individual variation in this pulley reconfiguration may relate to known individual variability in torsional VOR. Shifted rectus pulleys during head tilt would re-direct concurrent pursuit and saccades, and explain observed directional alterations in saccadic burst neuron firing(2). Larger rectus pulley repositioning would be expected during the higher-gain dynamic torsional VOR mediated by the semicircular canals. Grant support: USPHS EY08313 & RPB.
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O106

Visual and Vestibular Responses of Pursuit Neurons in the Caudal Frontal Eye Fields (FEF)

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Background: To maintain optimal clarity of objects moving slowly in three dimensional (3D) space, frontal eyed-primates use both smooth pursuit and vergence eye movements. Both systems must interact with the vestibular system to maintain foveal images. The caudal FEF contains smooth pursuit neurons (e.g. MacAvoy et al. 1991), and the majority of them discharge for retinal image-slip-velocity, gaze-velocity during whole body rotation, and vergence tracking (Fukushima et al. 2000, 2002).
Objectives: To understand the role of the caudal FEF in vergence tracking and its interaction with linear vestibular inputs, we examined visual responses induced by spot- or pattern- motion in depth and vestibular responses induced by linear motion.
Methods: Three head-stabilized Japanese monkeys were seated facing a 22-inch computer display placed 65 cm away from their eyes. Visual stimuli were generated as two alternating images viewed by left or right eyes through polarization shutter glasses at 0.5 Hz. Vestibular responses were tested by moving the whole body sinusoidally backward and forward at 0.3 Hz (±10 cm).
Results: About half of caudal FEF pursuit neurons discharged for movement of another spot in-depth and also for pattern-motion-in-depth. Their preferred directions for visual responses were similar to those during vergence tracking. Neurons that exhibited visual response in depth were mostly separate from neurons that showed visual response in frontal planes. During back-and-forth whole body translation, the majority of pursuit neurons exhibited robust discharge modulation, particularly when the spot moved in space together with the chair so that the animals were required to maintain the foveae of both eyes on the spot by canceling their linear VOR. There was no correlation in neuronal responses during vergence tracking and linear VOR cancellation, suggesting that direction preference and response for vergence and linear vestibular inputs are independent. The majority of pursuit neurons also responded to linear motion in complete darkness without a target.
Conclusion: These results indicate the existence of otolith signals in the caudal FEF and suggest that the caudal FEF integrates frontal- and depth- visual and otolith signals to code smooth tracking eye movements in 3D space. The independence of vergence and otolith inputs to caudal FEF pursuit neurons may be related to the characteristics of the linear VOR, which requires control of otolith inputs independent of vergence eye movements.
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O107
Multiple Reference Frames for Motion in Primate Cerebellum

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Background: The otolith organs measure linear acceleration. However, the corresponding sensory signals, being in head-fixed coordinates, do not provide information about the body-motion. As this information is necessary for detection of self-motion, voluntary motor tasks and control of vestibulo-spinal reflexes, a reference frame transformation might take place centrally. The brain could construct an internal estimate of body motion by combining otolith signals with neck proprioceptive information. Extensive convergence of vestibular and somatosensory signals have been reported in vestibular nuclei (VN), the fastigial cerebellar nuclei (FN) and the cerebellar cortex. Yet it is not known if this convergence reflects an underlying reference frame transformation to compute body motion in space.
Objectives: To test if there exist central neurons that encode body translation through space, the head and body coordinate systems were dissociated by systematically varying both the direction of motion and the static orientation of the head relative to the body. The neural tuning and underlying motion reference frame for FN neurons were compared with those in VN.
Methods: Single unit activities were recorded as monkeys were translated along different directions defined relative to their body. The head-on-body orientation was fixed such that the animal faced either straight-ahead or 30˚ to the left or to the right, in relation to their body. A spatio-temporal tuning model was fitted to the neural response gain and phase for all of the three head-on-body orientations. The effect of altered head-on-body orientation on the spatial shift of the tuning curves was quantified to determine the reference frame for motion detection.
Results: A subpopulation of FN neurons (43%) encoded the translation of the body through space. In contrast, 34% of FN and 80% of the VN neurons maintained a head-fixed reference frame for encoding motion. An intermediate coordinate frame was observed in about 20% of FN and VN neurons.
Conclusion: The fact that more FN then VN neurons encoded motion of the body through space, raises the possibility that the coordinate transformation might take place in the cerebellar cortex. The rostral fastigial nucleus represents the main output of the medial zone of the anterior vermis, whose role in vestibular/somatosensory interactions has received strong experimental support. The present results show that these interactions implement a coordinate transformation to estimate motion of the body through space. Interestingly, FN represents a main cerebellar outflow to the spinal cord, premotor brainstem centers and the thalamocortical system.

O108
Spatio-Temporal Characteristics of Saccades, Vergence and Combined Movements in Children with Vertigo

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Background: Clinicians reported the existence of a children population with symptoms of vertigo, headache, in the absence of vestibular dysfunction; interestingly orthoptic evaluation showed vergence abnormalities (Anoh-Tanon et al., 2000).
Objectives: This study examines in such children the speed-accuracy characteristics of vergence and saccades, and the effect of orthoptic vergence training on these parameters.
Methods: LEDs were used to stimulate saccades, pure vergence along the median plane and combined saccade - vergence movements. Movements from both eyes were recorded with a photoelectric device (BOUIS) before and after orthoptic training.
Results: Similarly to normals, latency of convergence was longer than that of divergence and of pure saccades; combined movements showed longer latencies than pure movements. In contrast to normals, these differences were more accentuated. Particularly convergence latencies were 100 ms longer than that of divergence while in normals this difference is only 30 ms. Convergence duration was abnormally long in children with vertigo (573 ms versus 360 in normals); divergence and convergence along the median plane as well as convergence combined with saccades were highly hypometric in children with vertigo (the percentage of hypometria was 21%, 36% and 42% respectively). The well-known reciprocal interaction between the saccade and the vergence during saccades combined with convergence is abnormal: the saccade is slowed down by the convergence but the convergence is not accelerated by the saccade. Orthoptic training eliminates vertigo symptoms and improves the latency, the accuracy and the duration all eye movements; however convergence remains abnormal and the lack of acceleration by the saccade persists.
Conclusion: These specific convergence deficits could be of both subcortical and cortical origin. The improvement after orthoptic training could be due to increased visual attention; however, such mechanism cannot eliminate completely convergence deficits. We suggest that abnormality of vergence can lead to inappropriate VOR adjustment and thereby poor gaze stabilization and vertigo, but this needs further investigation.

O109

Latency of Saccades and Vergence in Children, in Adults and in Old Subjects With or Without Falling History

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Background: When exploring the 3D visual space we perform saccades, vergence and most frequently combined movements.

Objectives: This study compares the characteristics of the three types of movements in children and in adults.

Methods: Fourteen normal children (4.5-12 years) and 14 normal adults (22-44 years) were studied. LEDs were used to elicit horizontal saccades of 20°, pure convergence or divergence along the median plane (between 20 et 150 cm), and saccades combined with vergence. Eye movements were recorded binocularly with a photoelectric device.

Results: For both children and adults, convergence latency is the longest; combined movements have longer latency than pure movements. All latencies are significantly longer in young children and reach adult levels at 10-12 years. Initiation of combined movements: the rate of asynchronous initiation of the two components is higher in children than in adults (77% vs. 66%). Preliminary data in old healthy subjects (>70 years) show increased latencies for all three types of eye movements; the values are similar to those exhibited by children of 7-8 years. Combined eye movements showed high rates of asynchronous initiation, namely the saccade component started first. Latency and asynchrony were dramatically increased in old subjects with falling history.

Conclusion: Long latency of saccades in children could be due to progressive maturation of the cortical circuitry involved in the control of these parameters (parietal-frontal network). In old subjects the increase of latencies relative to adults could be due to hypo-function of such circuit. Slow eye movement initiation particularly of vergence could be involved in the aetiology of falling in elderly subjects.

O110

Suppression of Saccades Controlled by the Monkey Frontal Eye Field (FEF) and Visual Fixation

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Background: When an interesting object appears in the visual field and a saccadic eye movement occurs to that object, visual fixation holds its image on the fovea and suppresses saccades to other objects appearing in the visual field. Therefore, the act of the fixation must make the brain stem saccadic generation system less susceptible to the effects of extraneous commands to make a saccade.

Objectives: To understand the neural mechanism of visual fixation, we investigated effects of electrical stimulation of the frontal eye field (FEF) on the generation of electrically–evoked saccades (Esacs) and the suppression of saccades.

Methods: Experiments were performed in trained monkeys.

Results: While we examined properties of the electrically-evoked suppression of visually-guided (Vsacs) and memory-guided saccades (Msacs), we found that there are two types of the suppression. Stimulation of a wide area of the FEF suppressed only ipsiversive Vsacs and Msacs at stimulus intensities lower than those for eliciting Esacs, whereas stimulation of a localized area of the FEF suppressed the initiation of both Vsacs and Msacs in any direction during and ~50 ms after stimulation. However, neither stimulation did affect the vector of these saccades. Thresholds for the suppression were usually less than 50 μA. Suppression sites of bilateral saccades usually did not evoke any saccades at 80 μA, indicating that the bilateral suppression area was different from the unilateral suppression area where stimulation evoked saccades at less than 50 μA. The most effective stimulus timing for the suppression of ipsiversive and contraversive Vsacs was ~130 ms after the target onset, which corresponds to ~40-50 ms before saccade onset. Therefore, the suppression occurred in the efferent pathway for Vsacs at the premotor rather than the motoneuronal level, most likely at the superior colliculus and/or the paramedian pontine reticular formation.

Conclusion: Our results suggest that these suppressions in the FEF may play roles in maintaining visual fixation by suppressing saccades in all directions. Neural circuits to convey suppression signals from the FEF to ocular motoneurons will be discussed in relation to the above-mentioned suppressions of saccades evoked by electrical stimulation of the FEF.

O111

Changes in Firing Behavior of Saccadic Burst Neurons Induced by Iontophoretic Application of Strychnine in Alert Cats

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Background: Excitatory and inhibitory burst neurons (BNs) in the paramedian pontine reticular formation carry the final output signals for horizontal saccades. They exhibit a high frequency burst of spikes that determines the velocity and amplitude of saccades. During intersaccadic intervals, BNs are kept silence due to a tonic inhibition from omnipause neurons (OPNs). However, exact reason for the need of OPN inhibition upon BNs is not clear.

Objectives: In the present study, we investigated how the blockade of OPN inhibition influences the firing characteristics of BNs. Since the somata of OPNs are glycine immunoreactive (Horn et al. 1994), we examined the effect of

strychnine, the glycine receptor antagonist, on the behavior of BNs during fixations and saccadic eye movements.
Methods: Using three-barrel micropipettes, extracellular recordings were made from BNs in the area mediocaudal to the abducens nucleus in the alert cat. Strychnine was applied iontophoretically by passing currents through the two barrels containing the drug and NaCl solutions.
Results: After application of strychnine, BNs showed spontaneous discharge during intersaccadic intervals. Single-pulse stimulation of the contralateral superior colliculus became effective and evoked spikes with monosynaptic latencies. Visual stimuli also elicited spike responses. While the profile of bursts during ipsiversive saccades was similar to that of saccadic eye velocity, the bursts were followed by a gradually decreasing activity that lasted well beyond the end of saccades. In addition, strychnine affected the relationship between the number of spikes in the burst and the amplitude of horizontal component of saccade, i.e., firing activities during both ipsiversive and contraversive saccades were significantly increased after application of strychnine.
Conclusion: Results suggest that inhibitory action of OPNs on BNs is glycinergic and plays an essential role in suppressing BN responses to visual stimuli during intersaccadic intervals and in terminating bursts at the end of saccades. Results also suggest that BNs receive glycinergic inhibition of non-OPN origin during saccades, which may control the intensity of bursts and consequently the amplitude and velocity of saccades.

O112

Spatial Memory Deficits and Hippocampal Atrophy in NF2 Patients with Bilateral Vestibular Failure

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Background: The role of the vestibular system in navigation and spatial memory was demonstrated earlier in animals. Vestibular signals are necessary for location-specific "place cell" activity in the hippocampus, which provides a putative neural substrate for the spatial representation involved in navigation.
Objectives: To investigate the spatial memory in patients with bilateral vestibular failure due to NF2 with bilateral neurectomy.
Methods: A virtual variant (on a PC) of the Morris water task adapted to humans was used. The pre-morbid intelligence was also estimated, and the revised Wechsler Memory Scale was used in full to calculate several indices (general memory, attention / concentration, visual memory, verbal memory, delayed recall). The volumes of the hippocampus and of the whole brain were quantitatively measured by MRI volumetry.
Results: Significant spatial learning and memory deficits were shown in 12 patients as compared to 12 age- and sex-matched healthy controls. All patients had an average to above average pre-morbid intelligence level and normal or even above average range values on the revised Wechsler Memory Scale. MRI volumetry detected a significant atrophy of the hippocampus in the patients but no atrophy of the whole brain. Furthermore, there was a significant correlation between the deficits in spatial memory and atrophy of the hippocampus.
Conclusion: These data suggest that selective functional hippocampal deficits with structural atrophy manifest due to a chronic lack of vestibular input in these patients. Spatial memory deficits, which were even demonstrated when the subjects remained stationary, e.g., without any actual vestibular or somatosensory stimulation, were not associated with general memory deficits, i.e., there was a selective deficit of spatial memory.

O113

The Superior Temporal Gyrus, the Retrosplenial Cortex, and the Hippocampal Formation: A Fundamental Network for Vestibular Induced Spatial Orientation and Disorientation and for Compensation of Vestibular Deficits

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Background: The compensation of vestibular deficits is not necessarily produced by low-level brain stem mechanisms but is also dependant upon higher (cortical and limbic) cognitive mechanisms that are involved in spatial orientation.
Results: a) We have identified the vestibular cortex in humans close to the temporo-parietal junction and the cortical vestibular related areas. However in addition to what could be called the "primary vestibular cortex", a series of areas located in the superior temporal gyrus (STG) are involved in the construction of a multisensory representation of the orientation of the body in space. This higher vestibular cortex is also now suspected to be involved in some aspects of spatial neglect and in other multimodal spatial processing. b) With neuronal and fMRI studies we have shown that the hippocampal formation is also involved in vestibular processing in relation with allocentric (right) and egocentric (left) spatial memory during navigation. c) In addition with fMRI studies we have also shown that the retrosplenial cortex (Schmidt et al FENS 2002; Commiteri et al in Press) is involved in tasks requiring not only egocentric motion perception but also the changes in reference frames and perspective in spatial tasks, compatible with its belonging to the head direction cell system.
Conclusion: The challenge is now to understand how these structures contribute to vestibular deficits and their compensation. For example, a modification of the symmetry of

the vestibular organs, such as found in cranio-facial asymmetries, could create an unbalance in this network which would induce a distortion not only of the body schema but also of the perceived orientation in space and explain, with a "top-down " model, various symptoms (eye deviation, head tilt, scoliosis, anxiety and even agoraphobia found in these patients

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O114

Brain Activation Studies in Patients with Vestibular Neuritis and Bilateral Vestibular Failure

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Background: During caloric or galvanic vestibular stimulation healthy volunteers show bilateral activation of the vestibular cortex in the posterior insula and retroinsular region, which represent the human homologue of the parieto-insular vestibular cortex in monkeys (PIVC). A recent human PET study during warm water caloric irrigation showed that two factors affect this cortical activation pattern: (1) the handedness of the subjects and (2) the side of the stimulation. There is vestibular dominance in the non-dominant hemisphere, and stronger activation occurs in the hemisphere ipsilateral to the stimulated ear. The finding of concurrent deactivation of visual cortex areas bilaterally was the basis for the concept of a reciprocal inhibitory interaction between the vestibular and the visual systems.

Objectives: Aim of these two studies was to determine how the activation-deactivation pattern is modulated in patients with acute unilateral vestibular loss and chronic bilateral vestibular failure (BVF).

Methods: I) Regional cerebral glucose metabolism (rCGM) in FDG-PET was measured in five right-handed patients with acute vestibular neuritis (lying supine, eyes closed, no stimulation): A) in the acute phase 6.6 days (mean) after symptom onset and B) after clinical recovery due to central compensation 3 months later. II) Regional cerebral blood flow (rCBF) in PET was measured in nine patients with BVF during caloric vestibular stimulation of the right or left ear. For both studies categorical comparisons were done using SPM99b and statistical group analyses.

Results: I) During the acute stage of vestibular neuritis rCGM was significantly increased in multisensory vestibular cortical and subcortical areas (PIVC, posterolateral thalamus, anterior cingulate gyrus, ponto-mesencephalic brainstem, hippocampus). Simultaneously, there was a significant rCGM decrease in the visual, somatosensory, and auditory cortex areas.

II) The group analysis of patients with BVF showed only one small activation in the posterior insula contralateral to the stimulated ear, whereas the other areas correlating with vestibular, autonomic, and ocular motor function were not activated. The concurrent rCBF decreases of the primary visual cortex seen in healthy volunteers were not found in these patients. Thus, activation and deactivation were significantly reduced.

Conclusion: The modulations of the activation-deactivation pattern in patients with acute unilateral loss or chronic BVF fit the concept of a reciprocal inhibitory visual-vestibular interaction. In the acute stage of vestibular neuritis a visual-vestibular activation-deactivation pattern was exhibited at cortical level similar to that in healthy volunteers during unilateral labyrinthine stimulation. In chronic BVF the visual-vestibular interaction occurs at a significantly lower level, i.e., with less activation and less deactivation. Thus, peripheral vestibular disorders modulate the interaction of sensory systems at the cortical level, but the reciprocal inhibitory interaction between the visual and vestibular systems is maintained.

O115

Arguments for Conservative Intratympanic Gentamicin Regimens: Human and Animal Data

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Background: Intratympanic (IT) gentamicin is effective in the control of vertigo due to unilateral Ménière's disease. Because the effects of IT gentamicin on labyrinthine function can be delayed for weeks, we have adopted a conservative protocol of single injections followed by later injections as needed to control vertigo. Success with this approach has motivated both human and animal studies on the effects of a single dose of IT gentamicin.
Objectives: To determine the effects of a single dose of IT gentamicin on the structure and function of the labyrinth.
Methods: The effects of a single dose of IT gentamicin in human subjects were assessed with quantitative angular vestibulo-ocular reflex (aVOR) testing using rapid rotary head thrusts in the planes of the semicircular canals. Vestibular nerve afferents were recorded in chinchillas after a single dose of IT gentamicin, and vestibular endorgans were examined with light and electron microscopy.
Results: The head-thrust aVOR was measured in 18 subjects pre- and post-IT gentamicin. Complete or substantial vertigo control during one year of follow-up was achieved in 11 subjects with only one injection. Seven required further injections for vertigo control. Gain decreases after one injection were significantly greater in subjects who had vertigo control with one injection than in those who did not. However, aVOR gain decreases induced by IT gentamicin were not as great as those induced by labyrinthectomy, suggesting that vertigo control requires only partial ablation of labyrinthine function.
A single IT gentamicin treatment reliably eliminated the increase in aVOR gain caused by vergence. The effect was only seen for head thrusts exciting the treated labyrinth. This is similar to the results obtained in primates with galvanic silencing of irregular vestibular afferents (Chen-Huang and McCrea 1998) and suggests that IT gentamicin may have a preferential effect on the hair cell inputs to irregular afferents.
The effects of a single dose of IT gentamicin have been further studied in a chinchilla model. Vestibular nerve afferents continue to fire spontaneously after IT gentamicin, but responses to vestibular stimulation are severely reduced. Histologically, type I vestibular hair cells appear to be eliminated. Type II hair cells are not significantly reduced, and they bear the synaptic specializations needed to support baseline neurotransmitter release to the afferents.
Conclusion: Conservative use of IT gentamicin can control vertigo in Ménière's disease while minimizing the risk of hearing loss. A single treatment appears to have selective toxicity to type I hair cells and perhaps to irregular vestibular afferents. Preservation of spontaneous afferent firing via preserved baseline neurotransmission may reduce the adaptive burden for the central vestibular nuclei in comparison to surgical labyrinthectomy.
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O116

Intratympanic Gentamicin Injections in Patients Suffering from an Intractable Meniere's Disease: Vestibular Hair Cell Impairment and Regeneration

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Background: Intratympanic gentamicin injections are an interesting alternative treatment in patients suffering from an unilateral and intractable Meniere's disease.
Objectives: The vestibular function of 22 Meniere's disease patients submitted to intratympanic gentamicin injections was probed using a variety of tests over a period of two years following the injections. Our aim was two fold: first, to assess the extent of the deficits induced by the injections and second, to detect their eventual recuperation.
Methods: Caloric and head impulses tests were used to appreciate the function of the horizontal canal ampulla. The vestibular evoked myogenic potentials (VEMPs) induced by high level clicks allowed us to determine the functionality of the sacculus and the sacculo-spinal pathways. Finally, the potential toxicity of gentamicin on the first order vestibular neurons was investigated by means of the vestibular evoked myogenic potentials evoked by short duration galvanic currents (VEMPg).
Results: At one month following gentamicin injections, 76,2% of patients showed a strong canalar paresis superior than 80% to the caloric test on the injected side. At six month, this number increased to 85,7%. However, at one and two years, the caloric response was abolished in only 57,1% and 47,6% of the patients, respectively. Hence, 38% of the patients had recovered an excitability of the injected side to cold and warm water at two years following the lesion. Interestingly, this recovery was associated with a reappearance of normal compensatory eye movements in response to head impulse towards the injected side. VEMPc were abolished at one month in 11 out of the 12 patients who had normal saccular test before the treatment. This deficit persisted over a period of two years. Finally, 31,8% of the patients exhibited an abolition of the responses to short duration galvanic currents as soon as at one post-injection month on the injected side. VEMPg recovery was not observed in these patients during the two years follow-up. Patients with abolition of VEMPg on the injected side never complain of vertigo recurrence.
Conclusion: These data suggest that intratympanic injections induced a differential and time-dependant effect on the horizontal canal ampulla, the sacculus and the trigger zone of the first-order vestibular neurons. More importantly, our results suggest that the horizontal canal ampullary cells began to regenerate one year following gentamicin injections, which led to a recovery of compensatory eye movements in response to low and high frequency

stimulations. Finally, galvanic test was found to be crucial to monitor the effect of gentamicin on the vestibular afferents and to predict the risk of long-term recurrence of vertigo attacks.

O117

Potential Stem Cells in Adult Mammalian Inner Ear

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Background: A number of factors including traumas or antibiotic treatment will cause irreversible loss of sensory hair cells and of neurons in the inner ear, leading to definitive impairment of the auditory and balance senses. Inner ear borne sensory disorders affect both communication and autonomy and are thus strongly disabling. They touch more than 10% of the active population and are a major health problem among senior citizens.
Objectives: Repair or replacement of inner ear sensory organs has become a very active research area. We have addressed this issue by focusing on the detection of possible stem cells or progenitor cells in adult mice inner ear and to identify factors that could instruct the resumption of hair cell differentiation.
Methods: We have isolated and cultured in vitro hair cells and supporting cells collected from sensory patches of 8 weeks-old mice inner ears. In normal conditions these cells can be maintained for several weeks in culture with little, if any, proliferation. When the same cells were cultured in the presence of the growth factors EGF and FGF2, proliferation occurred in such a way that the cells soon filled the Petri dishes in which they were placed and could be passed to new dishes. Cells that were grown for at least 5 weeks and passed at least once were transferred to coated cover slips. Proliferation was stopped by withdrawal of growth factors and cells were maintained in culture for an additional week. The cells were fixed and immunocytochemistry was used to look for expression of neuronal, glial and hair cell markers (neurofilaments, GFAP or MyosinVII respectively). Only cells whose nuclei had incorporated BrdU -a synthetic nucleic acid that serves as a marker of cell division- were considered in our analysis.
Results: Addition of serum during the last culture week triggered the differentiation of newly generated cells into neurons and glial cells but not in hair cells. Supplementation with the vitamin A derived gene-expression controlling hormone, retinoic acid, did induce new cells to express the hair cell marker. These results show that the capability to generate new cells exists within the sensory patches of the inner ear in adult animals. Given the appropriate stimuli the newly generated cells can be triggered to become neurons, glial cells or hair cells and thus to replace damaged components of the sensory pathway. Of these only hair cells are present in the mature sensory patches that were originally collected. This points out to the presence of previously unknown pluripotent progenitors in adult sensory epithelia or to the reversal to pluripotent state of a known cell population. Whether these are "bona-fide" stem cells remains to be investigated i.e. via clonal cultures.
Conclusions: These results point out to previously unexplored pathways for repair mechanisms in the inner ear.
This work is a collaboration between three laboratories in France and Sweden and has been made possible by the European Commission RTD Contract: "Bionic Ear" (QLG3-CT-2000-1343). ES is scientific coordinator for this contract.
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O118

Dispersal Characteristics of Drugs in the Inner Ear

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When drugs are applied to the round window membrane, their influence on the inner ear will depend on the applied dose, the spatial distribution of the drug produced in the inner ear fluids, and on the time course of drug reaching specific target regions of the ear. Understanding the effects of drugs thus requires knowledge of the kinetics and dispersal characteristics of the drugs in the fluid spaces of the ear. Simulations of drug dispersal have been performed with an established finite-element model of the cochlear fluids that is available from our website at http://oto.wustl.edu/cochlea/. The model takes into account the anatomy and dimensions of the scalae and round window membrane. It has been validated by comparison of the results with numerous studies in which the spread of chemical markers have been documented in the cochlear fluids with ion-selective microelectrodes. These analyses have suggested that drug dispersal in the ear is dominated by passive diffusion. Diffusion occurs extremely slowly over distances comparable to the length of cochlear scalae. Longitudinal spread of drug is further impeded by local clearance mechanisms, such as the loss of marker to other cochlear compartments or to the blood. It has been shown that drugs can cross radially between the cochlear compartments, either by entering endolymph or by passing through the fluid spaces of the spiral ligament. This allows high drug levels present in the basal turn of the cochlea to reach the vestibular fluid spaces. The ability of gentamicin to reach vestibular spaces by radial communication, in the presence of limited spread towards apical regions by longitudinal diffusion, may account for the predominantly vestibulotoxic effects of gentamicin while mid and lower-frequency hearing is preserved. The ability to simulate drug movements also permits drug dispersal characteristics in

the human ear, or the effects of different drug delivery protocols, to be calculated.

O119

Auditory Function After Intratympanic Gentamicin

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Background: Clinical hearing assessment includes several aspects of auditory function of which some are purely subjective and others can be objectively evaluated. In reporting the effects of a drug to hearing both aspects should be differentiated to gain insight not only into the knowledge of specific drugs action but also some aspects of cochlear or auditory nerve function.
Objectives: The intend of this study was to report the selective cochleotoxic effect of the intratympanically administered gentamicin, and compare it with the audiogram results, before and after the application
Methods: The 41 patients included in the study had been diagnosed with unilateral Meniere's disease as defined within the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) guidelines (1995), and were refractory to medical treatment for at least one year.
Intratympanic injections of gentamicin at a concentration of 27 mg/ml were performed at weekly intervals until indications of vestibular hypofunction appeared in the treated ear.
Before beginning the treatment and three months after ending it pure tone and speech audiometry were performed and results are expressed in terms of pure tone average (0.5, 1, 2 and, 3 kHz) and speech discrimination score respectively.
At the same time a distortion product otoacoustic emission study was performed and results are expressed in terms of its presence or absence and, in amplitude and threshold of the evoked response.
Results: There was a significant increase in mean audiometric threshold after treatment at frequencies 0.25, 3, 4 and, 6 kHz, but in all those frequencies it was lower than 10 dB HL. At all the frequencies studied (unless 3kHz) DPOAE threshold was reduced after treatment but it was significant only at 1 kHz. DPOAE amplitude was more frequently reduced but the change was only significant for 1 kHz. Mean PTA and SRT before and 3 months after treatment and mean threshold and amplitude at maximum intensity of the primaries of DPOAE will be detailed; none of the data before treatment shows significant differences when the patients are grouped by the number of injections received. None of the changes shown at three months follow-up is significant. Only 8 patients were considered to have DPOAE present; the change after treatment is not significant. 13 patients (31.7%) were considered to present a significant hearing reduction. None of the data before treatment shows significant differences when the patients are grouped by the existence of hearing loss after treatment. After treatment in the group who showed hearing loss the increase in PTA and, SDS of audiometry and DPOAEam at 1 kHz are significant.
Conclusion: In patients with Meniere's disease it can be concluded that in the short-term, three months after treatment, the procedure with intratympanic gentamicin here used generates little damage to cochlear function as analyzed with otoacoustic emissions.

O120

A New Countermeasure for the Prevention of Motion Sickness and Space Motion Sickness

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Background: Space motion sickness (SMS) remains a significant problem given that 80% of all astronauts experience some degree of motion sickness (MS). Current countermeasures available today include medications and preflight adaptation. The pharmacological management of motion sickness symptoms has several disadvantages: (a) Drugs can only be used at specific times during a flight, (b) they cannot prevent the appearance of SMS symptoms, and (c) they have undesirable side effects. Preflight adaptation requires: (a) Substantial investments in crew time and, (b) that crewmembers experience some level of MS if the preflight adaptation environment is an analog of flight.
Objectives: It was our intention to develop a MS countermeasure using stroboscopic vision and to investigate the effect of stroboscopic vision on the behavior of the central neural integrator.
Methods: Thirty-five Ss participated in this investigation; 19 in Study 1, 14 in Study 2 and 2 Ss in Study 3. Studies 1 and 2 exposed subjects to left-right vision reversing prisms either under normal or stroboscopic (4 Hz with a 3 μsec on time) illumination while they made sinusoidal horizontal head movements (±20° @ 0.33 Hz) and read a passage from Treasure Island located 1 m directly in front of their eyes. In Study 1, stroboscopic illumination was provided with a stroboscopic lamp, while in Study 2 stroboscopic vision was driven with liquid crystal shutters (LCS) in eyeglass frames. Motion sickness was scored using a modified version of the Miller-Graybiel scale. Testing was stopped at the MIIa level of nausea or 30 min had elapsed. In Study 3, eye movements were obtained with search coils. Ss made a series of visually guided saccades and engaged in pursuit of a predictable sinusoidal target under LCS illumination.
Results: Study 1: Five of 19 Ss had no symptoms regardless of illumination. The remaining 14 completed testing with only minor symptoms under stroboscopic illumination. Without stroboscopic vision these 14 Ss all experienced significant symptoms and 8 ended testing prior to the 30 min test criteria. Study 2: Twelve of 14 Ss had symptoms without stroboscopic vision, 10 stopping the test prior to the 30 min criteria. With stroboscopic vision all 14 Ss completed the test with minor symptoms. Study 3 showed that the velocity of visually guided saccades with LCS vi-

sion was reduced by 50% while saccade duration increased (60%), and smooth pursuit movements were partly saccadic with epochs of smooth pursuit.
Conclusion: Stroboscopic vision, including that provided with LCS, is successful in preventing motion sickness. Aside from a reduction in retinal slip, the results also suggest that modification of the central integrator may be an important factor in the success of stroboscopic vision in treating motion sickness.

O121

Effect of an NK1 Receptor Antagonist on Motion Sickness in Rats and Its Putative Sites of Action

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Background: The tachykinin NK1 receptor antagonist, i.e. substance P antagonist, is known to have the antidepressant and anti-emetic effects. As effective sites of the action, the amygdale for the former action and the solitary tract nucleus for the latter are supposed [1]. We previously showed that bilateral lesions of the amygdala suppressed hypergravity-induced motion sickness in rats using pica behavior as an index, suggesting that the amygdala plays an important role in the development of motion sickness [2,3].
Objectives: In the present study, we examined the hypothesis that substance P neuronal system in the amygdala is involved in motion sickness.
Methods: Rats were subjected to a gravito-inertial force twofold higher than Earth's gravity by centrifugation. Effects of an NK1 antagonist, CP99,994, and its inactive enantiomer CP100,263 were compared on hypergravity-induced pica behavior. In the second experiment, real-time quantitative RT-PCR methods were used to assess the changes in mRNA expression of preprotachykinin, a precursor of substance P, in the amygdala and the solitary tract nucleus in rats exposed to hypergravity.
Results: CP-99,994 (60mg/kg), but not CP-100,263, significantly attenuated the hypergravity-induced pica behavior. These two compounds did not influence the normal food consumption. The mRNA expression of preprotachykinin in the basolateral nucleus of amygdala was increased as well as in the solitary tract nucleus after 3 hours load of hypergravity.
Conclusion: The NK1 receptor antagonist is effective for motion sickness in rats. The substance P neuronal system in the amygdala and the solitary tract nucleus may be involved in the development of motion sickness.
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O122

Interaction of Alcohol and Nicotine on Postural Stability Scores and Long-Loop Motor EMG Latency Responses

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Background: In previous studies we have demonstrated subtle but significant effects of ethanol ingestion on postural stability and long-loop motor latencies to support surface movement. [1,2] Such effects were clearly identified at sub-intoxicating levels of alcohol.
Objectives: Current efforts are directed at the interactive effects of ethanol and nicotine, often consumed jointly, upon posture control with particular interest in motor latency measurements. Our main objective is to characterize any nicotine-alcohol interaction that may help explain the 90% incidence of smoking amongst heavy drinkers.
Methods: In the present study, we examined the effects of cigarette smoking and oral ethanol ingestion in 28 subjects (ages 21-30 years) in a placebo-controlled, randomized, single-blinded design using Computerized Dynamic Posturography (CDP- NeuroCom Intl, Inc. Clackamas, OR, USA). Outcome measures included Sensory Organization Test (SOT) Equilibrium Scores, frequency analysis of sway data and surface EMG latency measurements.
Results: Results of this study reconfirm the deleterious effects of ethanol on postural control and reflex latencies at moderate doses (producing blood alcohol concentrations of 0.05 to 0.06%). Moreover, concurrent smoking significantly reduced the postural sway induced by ethanol while offsetting the prolongation of long-loop EMG latency responses, towards baseline levels.
Conclusion: This study clearly demonstrates a physiological interaction of cigarette smoking and ethanol upon postural control. By blunting the intoxicating effects of ethanol, and thereby promoting increased ethanol consumption, cigarette smoking may contribute causally to the close association between ethanol drinking and smoking.
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O123

Higher Visual Contribution in Balance Control Favours Risk of Falls in Adult at Work

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Background: Falls represent a major public-health problem and are responsible for 20 % to 25 % of occupational accidents for all sectors of industries combined. Among all fall-related contributive factors, those concerning intrinsic balance control have received little attention in adult at work.
Objectives: Yet, an explanatory hypothesis could be that workers who fall have greater difficulties in sensing and adjusting postural control to new control tasks and to the new environmental constraints that they continuously face in their occupational activities. The purpose of the study was to investigate whether postural regulation in workers having fallen might have specificities in terms of sensorimotor strategies and neuromuscular responses and whether the recurrence of a fall might be the result of a particular neurosensorial organization.
Methods: Nine multi-fall victims (MF: 44.9 ± 7.4 years of age), 43 single-fall victims (SF: 45.5 ± 8.1 years of age) and 52 controls (C: 44.6 ± 6.7 years of age) were compared on performance measurements of static and dynamic postural control. Each control subject was chosen to be the closest to a fall victim (age, grade, hospital care unit, working hours). All subjects were submitted to static and slow dynamic sinusoidal posturographic tests both in eyes open and eyes closed conditions (Toennies GmbH, Freiburg, Germany) and sensory organization and motor control tests (EquiTest, NeuroCom, Clackamas, OR).
Results: MF and SF had the worst postural performance both in the static and slow dynamic tests, particularly in eyes closed conditions, suggesting a high dependency on visual cues and a lower use of proprioception. Moreover, the sensorial analysis showed that MF and SF relied less on vestibular input in the development of balance strategy and had more difficulties in maintaining a correct upright stance when proprioceptive input was altered. Finally, MF showed longer latency responses to unexpected external disturbance. Postural control quality increased in the order MF, SF and C.
Conclusion: Strategies incorporating visual information involve using the cognitive processes causing delayed and less accurate fall avoidance responses, in contrast to adaptive strategies based on proprioceptive and vestibular information. The reweighting of the different cues controlling balance, which workers frequently have to deal in the workplace, is less efficient in fall victims, and particularly in multi-fall victims. This difficulty in adapting and adjusting motor control performance correctly and rapidly to changing external and internal constraints produces instability, which often results in a fall. As impaired balance is a good predictor of falls, the early detection of a particular sensorimotor organization promoting visual information to the detriment of proprioceptive and vestibular cues could limit the risk of occupational accidents, possibly by the development of a prevention approach aimed at adapting task to worker.

O124

Neurootology in Neck Trauma Patients

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Background: Head and neck trauma may cause inner ear and brain and brainstem damage but also lesions to the cervical vertebrae, ligaments, discs, roots and muscles. Thus, many causes for vertigo and balance problems are present.
Objectives: To increase knowledge for this haunted patient group.
Methods: Patients with whiplash injuries, 43 men and 87 women, were referred to the University hospital for investigation and expert statement eight months to several years after the accident. They were investigated with the full ENG protocol, and also broad frequency rotatory and ocular pursuit testing. Dynamic posturography was performed in the standard Neurocom fashion and also in 45 of the patients with neck provocation using six different head positions. The results were compared with normative data and findings in healthy controls.
Results: In the whiplash patients vestibulooculomotor disturbances were frequent, especially concerning smooth pursuit (31%) and visual suppression of VOR (18%), even more in the broad frequency testing. Positional nystagmus and nystagmus with head turned in lying position was present in 13–19% of the patients. The posturography showed pathology in 25% of the patients, and provoked posturography in 65–93%. Smooth pursuit with the neck 45 degrees turned was pathological on a group level but only a few patients could be singled out.
Conclusion: Head and neck trauma may disturb the inner ear with a function loss or BPPV. There may be concussion or contusion of the brain. Cervical vertigo may appear. Also in severe cases the brainstem can be lesioned with disturbances of the structures concerned with balance and oculomotor control. A neurootological investigation is of value. Besides an inner ear disturbance, oculomotor and balance findings may unveil a CNS function disturbance, presumably located to the brainstem. The knowledge is important for treatment strategies, prognosis and legal decisions.

O125

Unrestricted Arm Movement Speeds Up Balance Task Adaptation

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Background: Anecdotally arm movements appear to be an intrinsic component of strategies that serve to maintain upright posture. The importance for such arm movements appears to be heightened in situations of balance perturbation or uncertainty.
Objectives: The purpose of this study was to investigate the role of arm movements whilst performing a moderately difficult balance task.
Methods: Ten healthy subjects (8 male; mean 35.6 years old) were asked to maintain their balance when adopting the Romberg position upon a wooden beam with a width of 85mm and a height of 50 mm. The beam was placed on a block of foam (with a width of 270 mm and a height of 85mm) thereby creating balance uncertainty. Subjects were requested to look ahead with their eyes open and use the handrail surrounding them only when their balance was compromised. The task was performed in 3 trials lasting 60s each, with two conditions (balanced order). Subjects were instructed to either cross (restricted) or to use their arms (unrestricted) in order to maintain balance upon the beam. Measures of XY body sway were obtained using a force platform (Amt Inc. USA) and at the level of C7 and the head using Fastrak (Polhemus Inc. USA). The number of touches made by the subject onto the handrail was recorded as task failure.
Results: We found no significant differences of XY position measures (stability) in either condition. In addition, there was no difference in task failure between conditions for trial 1. Task failure became significantly reduced with practice (i.e. order effect) for both restricted (Chi-Square = 1.9347; $p < 0.0032$), and unrestricted arm movement (Chi-Square = 2.0534; $p < 0.0041$) (see Table.). However, when arm movement was restricted; the rapidity of task learning i.e. reduction in task failure was slowed, producing a significant condition effect (Chi-Square = 2.6272; $p < 0.0001$).
Table:

Task Failure Frequency (per trial)			
Arm Movement	Trial 1	Trial 2	Trial 3
Restricted	0.4	0.3	0.1
Unrestricted	0.4	0.0	0.0

Conclusion: In conclusion, whilst free arm movements failed to improve overall stability in sway parameters it did significantly speed up balance task adaptation compared to when arms were restricted. The increase in task failure during restricted arm movement supports the observation that arm movements are a useful component in balance rescue reactions.

O126
The Effect of Inaccurate Modulation of Arm and Knee Movements on the Roll Instability of Vestibular Loss Subjects

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Background: One of the signatures of balance deficits in vestibular loss subjects is a later but larger instability in the roll compared to pitch planes. This is surprising because trunk roll movements begin earlier than those of trunk pitch. However, this effect does lead to a propensity for lateral falls.
Objectives: We therefore sought to identify differences in the directional sensitivity of vestibular information generated by head accelerations compared to proprioceptive information. Furthermore, we sought to quantify the effect of absent vestibular modulation on the directional and amplitude tuning of balance correcting movement synergies that may underlie lateral falls.
Methods: We compared biomechanical and EMG reactions to 8 directions of pitch and roll support-surface rotation in 6 subjects with absent bilateral vestibular function and 12 healthy subjects of the same mean age (42 years). Rotations had an amplitude of 7.5 deg and velocity of 60 deg/s. Subjects were tested under eyes open and eyes closed conditions. Body segment movements were recorded with an Optotrak motion analysis system and head accelerations with accelerometers.
Results: Pitch responses were well coded by stretch reflexes in soleus muscles some 50 ms after stimulus (and ankle rotation) onset. For off-pitch perturbations, hip adduction was the earliest joint angle change observed in the roll plane at 15 ms and was accompanied by directionally specific stretch reflexes in the uphill gluteus medius muscles with onsets of 10ms later. Vertical and pitch accelerations of the head were most sensitive to pitch plane head movements, with acceleration onsets at 10ms, and time to peak acceleration at 35 msecs after stimulus onset. Roll and lateral acceleration of the head were most sensitive to roll plane head movements, with acceleration onsets at 40 msecs and time to peak acceleration at 100 msecs. Thus roll-sensitive vestibular information was delayed with respect to both proprioceptive and head pitch information. The absence of vestibular information in the vestibular loss subjects resulted in a characteristic difference with respect to control subjects. The uphill flexion and downhill extension of the leg as observed in knee and ankle angle changes was less in vestibular loss subjects even though directional tuning was maintained. This difference was larger under eyes closed conditions and led to excessive trunk roll and falling after 400 msecs.
Conclusion: These results indicate that hip proprioceptive inputs in man encode the lateral direction of a disturbance to stance and may well trigger balance responses but that vestibular inputs provide critical information necessary for appropriate modulation of responses. The shaping of the roll directed postural responses in the legs are similar to those expected based on animal studies with flexion of the uphill leg. Roll response instability may be greater due to the delay between proprioceptive and vestibular information not observed with pitch plane disturbances.

O127

Vibration to the Posterior Neck Evokes Fast EMG Responses of the Lower Leg, but Mastoid Vibration Does Not

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Background: Vestibular and cervical proprioceptive information have to be coordinated to provide a viable base for postural information. Also motion perception seems to depend on interaction between vestibular and cervical proprioceptive input. (3,4). After galvanic vestibular stimulation, there is fast 50-60 ms activation of muscles of the lower leg reflecting the importance of such vestibular postural control.

Objectives: To study the postural effect and the response time of cervical proprioceptive inputs and to discriminate these responses from vestibular inputs as well as startle responses.

Methods: Two series of ten otherwise healthy and naive subjects were exposed to vibration either towards the posterior cervical segment alone or to the mastoid when standing on a force plate. EMG recordings were simultaneously made from tibialis anterior and gastrocnemius muscles. Vibrators were attached with elastic straps either to the neck or to the mastoid, delivered either 800 or 160 mW stimulation of 1.0 or 0.4 mm peak-to-peak amplitude. Stimulation trains with pulses of a duration of either 1 or 4 seconds were used to perturb the subjects who stood with eyes either open or closed in a randomized order.

Results: When exposed to vibration towards neck muscles, there was an activation of gastrocnemius at 70-90ms followed by postural movements at 200-300 ms after an onset or offset of vibration towards the neck muscles. In offset, i.e. cessation of vibration, there was a strong activation of the gastrocnemius with a similar latency of about 80 ms and, followed at about 20 ms later by slight inhibition of the tibialis anterior muscle. The responses were generally larger with the 1.0 mm amplitude stimulus than with the 0.4mm. In mastoid vibration there was no coordinated activation visible in either tibialis or gastrocnemius and no systematic postural movements. Occasionally, initial startle responses characterized by a co-activation of both tibialis anterior and gastrocnemius muscles were seen.

Conclusion: Vibration toward the mastoid did not evoke muscle activation or postural responses in healthy normals. This suggests that there are fast, and considering the time lag, polysynaptic but subcortical postural responses to cervical proprioceptive information in normal subjects that are not of vestibular origin. There exists a short latency postural responses triggered by cervical proprioceptors in the standing human.

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O128

The Flocculus in Hereditary Ataxia Syndromes

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Background: Spinocerebellar ataxia type 2 (SCA2) is a slowly progressive ataxia characterized by dysarthria, gait and limb ataxia, and characteristic eye movement abnormalities. Inheritance is autosomal-dominant, via a CAG repeat expansion in the gene for ataxin-2. Ocular motor findings include slow saccades but apparently preserved smooth pursuit and gaze holding. However, the integrity of smooth pursuit or gaze holding can be difficult to assess clinically in the absence of catch-up saccades or fast phases of nystagmus. In order to address possible functional masking of pursuit abnormalities by saccade abnormalities in ataxin-2 mutations, further structural comparison was made to patients with mutations in the gene encoding for Ca(V)2.1. These patients are genetically classified by mutation type to have spinocerebellar ataxia type 6 (SCA6) or episodic ataxia type 2 (EA2). These patients show ataxia disability commensurate to that of SCA2 patients, but exhibit a complementary ocular motor phenotype, with normal saccade velocities and fast phases but markedly impaired smooth pursuit movements, associated with atrophy of the flocculi.

Objectives: Our goal was to study the structural abnormalities underlying the eye movement abnormalities characteristic of SCA2.

Methods: Ten patients with ataxin-2 mutations were compared to eight patients with Ca(V)2.1 mutations, age- and gender-matched controls. Clinical, eye movement, and structural MRI data were collected from each subject. Subjects were scanned with a 3D-SPGR sequence (TR=24 ms, TE=4ms, slice thickness=1.2mm, FOV=24 cm, matrix 256x256). Regions of interest were manually identified and individual volumes were calculated.

Results: Comparison of volumetric phenotype against genotype showed slowed saccades and significant atrophy of the pons ($p<0.001$) and the flocculi ($p=0.025$) in the cohort with mutations in ataxin-2 as compared to normals. On the other hand, the cohort with mutations in Ca(V)2.1 showed significant atrophy of the flocculi but not of the

pons as compared to normals. Total ataxia disability and total cerebellar atrophy were statistically indistinguishable between the two disease categories.
Conclusion: Morphology was highly correlated with ocular motor profile in these two disease categories. This suggests that pontine atrophy specifically underlies diminished saccade velocities in ataxin-2 mutations and may be useful for diagnosis, prognosis, or indication of disease severity. Additionally, the finding of floccular atrophy to the degree seen in patients with Ca(V)2.1 mutations is consistent with possible smooth pursuit and gaze holding abnormalities, which have previously not been reported. Further careful quantification of smooth pursuit and gaze holding in SCA2 is warranted.

O129
Vection Induced Neural Activity in Insular Cortex
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Background: While the pathologic mechanism of disorders causing vertigo usually resides in the vestibular labyrinth or the brainstem, the actual sensation of self-motion is a cortical phenomenon. Understanding of central mechanisms of motion sensation is an important step in development of treatment of vertigo.
Previous studies (Zalewski-Zaragosa, 2003) have shown that vertigo sensations may have a characteristic frequency and orientation, suggesting there are specific representations for both those characteristics. Further, Grusser (1990) found suggestions that there were cells in vestibular cortex in primates that had responses to preferred directions and orientations of vestibular stimulation. Is there a characteristic segregation of responses in human cortex?
Measurement of controlled multiaxis-multifrequency acceleration responses in vestibular cortex in the intact human is not yet feasible. However, vection responses have been used to effectively inhibit the parainsular vestibular cortex (PIVC) (Brandt, 1998).
Objectives: We wished to verify that we observed similar deactivation of the vestibular cortex to vection stimuli as previously observed. Then we wanted to determine if there was differential activation of PIVC depending on the vection stimulus direction.
Methods: Vection was induced by display on a screen 10 cm from the subjects' eyes. Though it was slightly out of focus, there was substantial vection induced by both a left to right oscillating visual field (sinusoidal, ±50 , total stimulus extent > 110 wide) as well as an up/down oscillating display. Localizer functional MRI scans at 3T were done using comparisons between flow fields and scrambled visual motion with the same local velocities. The two vection stimuli were directly compared in a two-condition block design. In one subject, vection with left to right motion (yaw) was presented alternating with up and down motion (pitch). Neural responses were recorded with fMRI in a 3T magnetic field (3.75 x 3.75 x 3.75 mm voxels, TR=2000 ms). Results were aligned with and displayed on cortical surface reconstructions made using FreeSurfer.
Results: There is a region in the posterior insula that is activated by flow fields relative to scrambled flow fields. This region was also active in the vection conditions. The direct comparison between left/right and up/down vection showed that the activations in this posterior insular area were not completely overlapping.
Conclusion: Recording with fMRI suggests that the vestibular cortex is deactivated by vection stimuli and pilot data suggests that the areas activated by different directions may be somewhat segregated. Further research with more subjects, controlled vection amounts and canal-specific vection directions will be needed to confirm these results.
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O130
Otoneurological Findings in Patients with Fabry Disease
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Background: Fabry disease corresponds to an inherited disorder transmitted by an X-linked recessive gene. It generates a dysfunction of the glycosphingolipid metabolism due to an enzymatic deficiency of a-galactosidase activity, resulting in glycosphingolipid deposits in all areas of the body. In hemizygous boys, the clinical (heart, kidney and central nervous system) manifestations are more severe than in heterozygous girls. They appear during childhood or adolescence: acroparesthesia, joints pain, angiokeratoma, corneal dystrophy, hypo- or anhydrosis, renal failure. Otoneurological symptoms are fluctuation of hearing, progressive uni or bilateral hearing loss, episodes of vertigo simulating the Menière disease.
Objectives: We present the otoneurological findings of 9 out of 13 members of a same family: the heterozygous mother and 8 of her 12 children (2 females and 6 males aged from 34 to 48 years old). In the children, 1 sister was heterozygous, the other was healthy; 3 brothers were hemizygous the 3 others were healthy.
Methods: All family's members underwent a complete otoneurological examination including pure-tone audiogram, reflex decay, auditory evoked potentials and electronystagmography.
Results: The 3 hemizygous brothers suffered from fluctuation of hearing, sudden hearing loss, episodes of vertigo and dizziness. The otoneurological examination showed a bilateral cochleo-vestibular deficit (n=1), a right cochleo-vestibular deficit (n=1) and a bilateral hearing loss with a right vestibular deficit in the third brother.
Conclusion: Histopathological works of the inner ears demonstrate alterations of the stria vascularis, semi-circular

canals and accumulation of glycosphingolipids in the endothelial cells of vessels. Fabry disease is a rare sphingolipidosis with an incidence of 1:40'000 individuals without specific ethnic distinction. The cochleo-vestibular abnormalities seem to be more frequent in hemizygous than in heterozygous patients.

O131

The Location and Capability of CPG Revealed with Spinal Electrical Stimulation in Human Paraplegics

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Background: The findings obtained by different research groups during last decade suggest the existence of a CPG in humans but it is still unknown how such neuronal structures are organized. It can be studied indirectly in completely paralyzed patients by analyzing the characteristics of motor activity induced by spinal cord (SC) electrical stimulation (ES) applied with therapeutic purpose (Shapkova,1995-2003).
Objectives: The aim of study is to analyze our observations of SCES-induced motor activity in paraplegic patients with respect to the CPG location and possible organization in humans.
Methods: The cervical, thoracic and lumbar cord were tested by rhythmic epidural or surface ES (0.5-100Hz) with the aim to initiate locomotor-like activity, the level of lumbar enlargement was stimulated for locomotor training. The SCES-induced movements were documented with EMGs, video- and goniograms of hip or knee joints. The completeness of lesion was tested clinically, by transcranial magnetic stimulation and by supraspinal influences on H-reflex amplitude. An optimal electrodes position was controlled by X-rays.
Results: The rhythmic movements with locomotor signs were obtained by ES of the lumbar enlargement, applying of ES to the other levels evoked no coordinated movements but the direct muscle answers correspondingly to the spinal segments. Well-coordinated alternating run-like and walk-like 'stepping' was obtained at the mid-lumbar enlargement (about L3-L5 segments; vertebrae T12-L1), upper or lower this 'locomotor' zone unilateral or bilateral in-phase 'stepping' can be evoked. The frequency of 'stepping' was often independent of the SCES rate. After the end of stimulation, rhythmic movements could continue for many cycles. ES of the 'locomotor' zone could also evoke a wide diversity of stereotyped patterns including 'stepping' with atypical leg interaction (in-phase or with shift co-activation, coupling of 'stepping' with different rates) and reduced (alternating in pairs of homonymous joints) or asymmetric (with difference to one joint) cycle pattern. A transition from one pattern to another could occur with or without changes in SCES parameters.
Conclusion: The possibility to evoke locomotor-like movements by SCES in completely paralyzed patients suggests the existence of a CPG in the human lumbar enlargement. The independence between frequency of induced movements and SCES rate, as well as continuing activity after the end of SCES, indicate that these movements are centrally generated. A 'locomotor' zone containing CPG or its part responsible for bilateral alternating movements is likely located at mid-lumbar enlargement. Cases of atypical inter-limb coordination suggest the existence of separate CPG for each leg; movements with atypical cycle show one joint movement as a unit of pattern.
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O132

Gait Disorders in Patients with Parkinsonian Syndromes: Defective Braking of the Fall

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Background: Postural equilibrium must be controlled during gait. As the body progresses there are periodical vertical oscillations of the center of gravity (CG), i.e. periodic sequences of falling phases followed by balance recovery phases. The mechanisms underlying body progression, including propulsive force generation, successive placements of one foot in front of the other and the transition from double to single support phase, have been widely investigated. The initiation of gait challenges the balance control as it moves from stable static balance to continuously unstable gait. During the single stance phase, the CG position lies outside the base of support and the body is thus in a state of disequilibrium. Due to the force of gravity, there is a fall of the CG. From an ecologic point of view, i.e. the continuation of the movement, a brake of the fall of the CG must be operated avoiding the collapse of the body to the ground. The fall of the CG can be arrested by the swing limb hitting the ground ('passive or mechanical' mode). It can also be braked by the active control of anti-gravity muscle activity, such as that of the ankle plantar flexors, prior to foot landing of the swing limb ('active' mode). The kinematic differences between these two modes of braking would be an absence of slowing down, i.e. deceleration, of the speed of the fall in the 'passive' mode and a slowing down of the speed of the fall prior to foot-landing in the 'active' mode. The 'active' mode is used by normal adults walking at self-paced and fast speeds, implying that, in adults, the 'passive' mode is a non-normal mode, which may reflect an impairment of balance control. Few studies have specifically dealt with the question of balance control

during gait initiation in normal subjects and none, to our knowledge, in parkinsonian patients

Methods: The length, maximal velocity and capacity to brake the fall of the center of gravity (CBF), of the first step were measured in 49 patients with Parkinson's disease (PD), 10 patients with progressive supranuclear palsy (PSP), 8 patients with multiple system atrophy and 35 control subjects, at both self-paced and fast speeds.

Results: The step length and maximal velocity were increased in the fast gait condition compared to the self-paced gait condition in all subjects. In controls, the CBF was independent of both step length and maximal velocity. When controls performed step length under 40 cm, the CBF was zero. In all patients the step length and maximal velocity were reduced compared to controls. In PD patients, the step length and maximal velocity were improved by levodopa treatment. The CBF was slightly reduced and improved by levodopa treatment in half of patients. In PSP and MSA patients, the CBF was dramatically reduced compared to control subjects.

Conclusions: Gait disorders in parkinsonian patients are characterized not only by a decrease in both step length and maximal velocity but also by defective braking of the fall. The decreased step length and maximal velocity during the initiation of gait result mainly from the dysfunction of brain dopaminergic neuronal systems, whereas the defective braking of the fall results mostly from the dysfunction of brain non-dopaminergic neuronal systems. However, the selective action of levodopa on the CBF, in PD patients, supports the hypothesis that postural responses are organized separately in the nervous system, with at least two (dopaminergic and non-dopaminergic) components.

O133

Cerebellar Control and Adaptation of Human Locomotion

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Background: The cerebellum is important for movement control and plays a particularly crucial role in balance and locomotion. As such, one of the most characteristic signs of cerebellar damage is walking ataxia.

Objectives: Different cerebellar regions participate in balance control and voluntary limb coordination, both of which might be important for normal bipedal walking. I will review our recent work on the role of different cerebellar circuits for control of locomotion, showing that balance deficits are more closely related to cerebellar gait ataxia than leg placement deficits.

Conclusions: These findings are consistent with animal literature, which has suggested that cerebellar control of balance and gait are interrelated, and dissociable from cerebellar control of voluntary, visually guided limb movements. I will also discuss new studies on adaptation of inter-limb coordination using a novel split-belt treadmill paradigm where one leg is made to walk faster than the other. Our work suggests that this type of inter-limb adaptation is most dependent on cerebellar-brainstem interactions and not on cerebral cortical structures. This suggests that individuals with neurological damage, but intact cerebellar function, (e.g. hemiparesis) could benefit from adaptive split-belt treadmill training to correct abnormal, asymmetric walking patterns.

O134

Verticality Misrepresentation And Postural Disorders In Stroke Patients

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Background: Postural control is a complex function that involves most brain areas (Horak and MacPherson, 1996); many brain lesions cause postural disorders that represent a primary disability after stroke. Postural disorders of stroke patients are cause either by a misrepresentation of verticality (Brandt et al., 1994; Pérennou et al., 1998a; Kerkhoff, 1999), by an impaired postural stabilization (Pérennou et al., 2000), or by a combination of these two impairments.

Objectives: Here we present facts and concepts leading to think that, in some stroke patients, verticality misrepresentation may be one of the primary cause of postural disorders. We review the literature and present a study aiming at clarifying the relationships between the perception of verticality, verticality representation (supramodal bias in the perception of verticality), lateropulsion (lateral body tilt in sitting and standing), pushing (resistance to correction), and general postural impairments.

Methods: We studied 14 subjects without lateropulsion (8 healthy controls and 6 hemispheric stroke patients with symmetrical sitting and standing postures) and 14 stroke patients with lateropulsion; this latter group comprising 3 brain stem strokes with ipsilesional lateropulsion, 6 hemispheric strokes with severe contralesional lateropulsion without pushing, and 5 hemispheric strokes with lateropulsion and pushing. Lateropulsion and pushing were diagnosed according to the Scale for Contraversive Pushing (Karnath et al , 2000). We investigated: 1) the three modalities of the subjective vertical; the visual vertical (VV), the postural vertical (PV) and the haptic vertical (HV); 2) patients' postural disability using the PASS.

Results: Postural disability was correlated with PV and HV but not with VV. When present, tilts of the subjective vertical were always ipsilesional in brain stem strokes and contralesional in hemispheric strokes. In brain stem strokes only the VV was tilted, whereas all modalities could be affected in hemispheric strokes. PV and HV were always normal in patients with hemispheric stroke without lateropulsion whereas three had a VV tilt indicating that VV tilt does not cause lateropulsion per se. Consequently lateropulsion observed in brain stem strokes does not result from

a cognitive disorder but more likely from reflex-mechanical dysfunction such as vestibulo-spinal tone asymmetry. In contrast, a strong PV tilt around 10° (HV tilt 6°, VV tilt variable) was systematically found in hemispheric stroke with lateropulsion suggesting that these patients implicitly align their erect posture on a tilted postural vertical. A transmodal bias (PV, HV, VV) was found in all pushers, indicating the existence of a generalized disorder of verticality representation but this alone was not the cause of pushing since a severe transmodal bias was also present in two patients with lateropulsion but no pushing.
Conclusions: This study showed a close relationship between perception of and behavioural response to gravity. PV and HV are useful assessments of the anti-gravity behaviour of stroke patients which could be used in addition to the less precise ratings of lateropulsion and pushing and give more relevant information than the VV.

O135
Postural Instability in Amyotrophic Lateral Sclerosis
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Background: Amyotrophic Lateral Sclerosis (ALS) is a multisystem degenerative disorder involving most components of the motor system both in the cortex and in the subcortical motor nuclei. It is our experience that postural instability (PI) is a frequent feature in ALS, but its pathophysiology remains unclear.
Methods: We reviewed the clinical parameters of a cohort of ALS patients to determine whether PI is associated with observed clinical patterns such as severity of the muscular strength loss, pyramidal or extrapyramidal features, and ocular motor abnormalities. Clinical examination included Berg Balance Scale, muscle testing of the limbs and neck, evaluation of pyramidal and extrapyramidal clinical involvement, and eye movements' examination.
Results: In a large majority of patients, PI was present. It occurred more frequently in patients with limb-onset compared with bulbar-onset. Loss of strength was significantly higher in patients with PI, but most of them had normal or subnormal muscle strength of the lower limbs. The Berg Score was significantly lower in patients with PI. PI was significantly associated with a higher frequency of pyramidal and extrapyramidal signs, and particularly of muscle stiffness ("contracture"). Correlations of lower limb functional score with SPECT perfusion showed that most of the primary motor cortex was spared, but most of the modifications were observed in the prefrontal and premotor parts of the cerebral cortex.
Conclusions: From our data, PI can be attributed to a significant weakness of the lower limbs only in a minority of cases. In most patients, PI seems correlated with the pyramidal and extrapyramidal central nervous system involvement. Thus, PI appears to be a marker of the central nervous system involvement in ALS, and could therefore be a prognostic factor, as it has been shown for stiffness.

O136
Vestibular Signals and Self-Motion Perception: Discrimination between Active and Passive Movement
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A number of vital functions in everyday life involves moving through the environment while orienting and grabbing objects. These functions involve precise coordination of locomotion, eye-head movements, and manipulations via arm and finger operations. In this symposium, we will explore the role of a number of cortical, cerebellar and brain stem sites in the combined tasks of eye-head-hand coordination, and the multisensory inputs, in particular from the vestibular system guiding this behavior. We will introduce specific areas around the intraparietal sulcus, that are classically thought to be involved in particular behaviors, e.g., LIP (eye movements), VIP (head movements), AIP, MIP (arm movements), and show neurophysiological correlates, and how these areas are related to the motor output side via involvement of cerebro-cerebellar loops, cerebellar and brainstem sites. All in all, we should arrive at a near-complete picture of the sites necessary to coordinate and control the complicated ensemble of goal-directed eye, head and hand movements, using classical neurophysiology and neuroimaging approaches, as well as clinical data from patients with specific brain lesions.

O137
Posterior Parietal Cortex Neurons Encode Target Motion in World-Centered Coordinates
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The motion areas of the posterior parietal cortex extract information on visual motion for perception as well as for the guidance of movement. It is usually assumed that neurons in the posterior parietal cortex represent visual motion relative to the retina. Current models describing action guided by moving objects work successfully based on this assumption. However, here we show that the pursuit-related responses of a distinct group of neurons in area MST of monkeys are at odds with this view. Rather then signaling object image motion on the retina, they represent inferred object motion in world-centered coordinates. This representation may simplify the coordination of object-directed action and ego-motion invariant visual perception.

O138
The Primate Pontine Nuclei Contribute to Visually Guided Eye as Well as Hand Movements
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The primate pontine nuclei are commonly thought to be a key link in a cerebro-cerebellar pathway for smooth pursuit eye movements, a pathway assumed to be anatomically segregated from the tegmental circuits subserving saccades. However, the existence of afferents from several cerebrocortical and subcortical centers for saccades as well as for visually guided hand movements suggests that the pursuit-related dorsolateral part of the pontine nuclei, the DLPN and neighboring parts of the dorsal pontine nuclei (DPN) might contribute to a much broader spectrum of visually guided behavior. In order to test this hypothesis, we recorded from the DPN of two monkeys trained to perform smooth pursuit eye movements as well as visually and memory-guided saccades and a third one, trained to carry out alternatively memory guided eye or hand movements. Out of 281 neurons isolated from the DPN of the first two monkeys, 138 were responsive in oculomotor tasks. Forty-five were exclusively activated in saccade paradigms, 68 exclusively by smooth pursuit and 25 neurons showed responses in both. Pursuit-related responses reflected sensitivity to eye position, velocity or combinations of velocity and position with minor contributions of acceleration in many cases. When tested in the saccades-to-remembered-locations paradigm, 65 out of the 70 neurons activated in saccade paradigms showed significant saccade-related bursts and 20 significant activity in the memory period. In on-going recordings from the DPN of the third monkey, we could reveal a population of 84 neurons so far, discharging immediately before and/or during a hand movement towards memorized spatial positions in complete darkness, most of them in a directionally selective manner. Hand movement related neurons are found in a region of the DPN that seems to be segregated from the oculomotor DPN by being more rostral. Correspondingly, we have so far not found a single DPN neuron which would have shown sensitivity to both eye and hand movements. Our findings support the view that DPN serve as a major precerebellar relay for all types of target directed behavior.

O139

Neural Substrates of Coordinated Eye-Head Gaze Shifts

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Background: When the head is prevented from moving, saccade duration, peak velocity and velocity as a function of time are all predictable based on knowledge of movement amplitude. As illustrated in Fig. 1, during saccades of the same amplitude, none of these parameters are predictable if saccades are accompanied by head movements. As head movement amplitude and velocity increase, peak saccade velocity decreases, and velocity profiles develop secondary peaks (Freedman and Sparks 2000). The timing and degree of head movement effects on saccade velocity may preclude sensory-mediated reflexes (i.e. VOR or COR) as a source of the observed interaction. We proposed an interaction at the level of separate command signals used to drive the eyes and head during gaze shifts. The proposed interaction replaced the traditional non-linear equation describing the saccadic burst generator ($V_e = (B_m)*(1 - e^{-((ME+1.5)/10)})$ after Becker and Jürgens (1990) with the following equation: $V_e = (B_m - V_h)*(1 - e^{-((ME+1.5)/10)})$. In the modified function, a signal proportional to head velocity (V_h) is subtracted from the maximum burst rate (B_m), dynamically altering the asymptotic value of the exponential (V_e = eye velocity, ME = motor error). This is sufficient to account for the observed changes in saccade kinematics as a function of associated head movement (Freedman 2001).
Methods: We tested two critical predictions of this hypothesis by electrically stimulating in the nucleus reticularis gigantocellularis (NRG) during gaze shifts to briefly flashed targets.
Results: When the head velocity command was transiently increased (by stimulation in the NRG) saccade velocity was reduced and then increased after the end of the stimulation train. In addition our hypothesis does not assume that gaze shift amplitude is controlled via feedback and therefore predicts hypermetric gaze shifts. When gaze position is plotted as a function of time during control (gray) and NRG stimulation (black) trials, gaze shifts were 140% hypermetric when the NRG was stimulated during gaze shifts to flashed targets displaced by 30°.
Conclusions: The results of this experiment are *not inconsistent* with the gaze control hypothesis instantiated in the model of Freedman 2001.

O140

Cortical And Cerebellar Network Processing of Eye-Hand Coordination

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Cortical, in particular the posterior parietal cortex, and cerebellar networks provide overlapping and dissociating processing for controlling isolated and combined fast goal-directed eye and hand movements (saccades and reaching). The interrelationship and processing mechanisms in these systems will be demonstrated from f-MRI data, and clinical lesion studies in patients with unilateral or bilateral lesions of the posterior parietal cortex.

O141

The Role of the Ventral Premotor Cortex in Choosing Targets for Gaze Shifts and Hand Movements

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When multiple equivalent targets are available, the brain typically chooses to interact with one at a time. Gaze becomes directed at one target, and one hand reaches out to grasp that target. In this situation, the ventral premotor cortex (PMv) may participate in choosing where to turn the head and which hand to use. We reversibly inactivated the

PMv with intracortical injections of muscimol. During unilateral PMv inactivation, when two equivalent food morsels were presented simultaneously to the monkey's right and left, the monkey was less likely to turn its head initially toward the food morsel contralateral to the inactivated PMv. Although the monkey then might look back and forth between the two food morsels, the monkey still was less likely to take the contralateral food morsel, and less likely to use its contralateral hand. Catch trials in which only one food morsel was present contralateral to the inactivated PMv revealed no deficit in the monkey's ability to notice the food morsel and reach out to take it swiftly and dexterously with the contralateral hand. We infer that when equivalent targets are present on either side the PMv participates in choices of where to turn the head and which hand to use.

O142

Correlation of VEMP and Vestibular Test Battery Results in Meniere's Disease

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Background: Toneburst-evoked VEMP demonstrates a significant difference in threshold and tuning between normal and Meniere's disease (MD) ears. VEMP threshold and tuning may be abnormal in the unaffected ears of patients with unilateral MD. VEMP does not correlate with ipsilateral audiometric thresholds. Correlation of VEMP and standard vestibular function tests in MD has not been previously reported.
Objectives: We explored the relationship of VEMP to other vestibular function tests in MD and tested the hypothesis that the side with poorer VEMP thresholds will be correlated with the side-of-disease.
Methods: Twenty adult subjects with unilateral MD underwent otologic and audiometric evaluation, conventional vestibular test battery and VEMP testing. Side-of-disease was assigned clinically based on symptoms, otologic exam, and audiometry. This assignment was compared to vestibular test battery and VEMP results. Vestibular test results were analyzed to make side-of-disease assignment by three different criteria: (1) 30% caloric asymmetry, 5% caloric asymmetry, and the multivariate method of Dimitri et al. (2002). VEMP interaural threshold difference was calculated for all 4 stimuli (250, 500, 1000Hz, click), with the higher threshold considered pathologic and symmetric thresholds scored as "indeterminate."
Results: The 30% caloric asymmetry criterion correctly identified side-of-disease in 55% of cases, with 45% indeterminate and none incorrect. The 5% caloric asymmetry criterion made correct assignment in 85% of cases, with 5% indeterminate and 10% incorrect. Multivariate statistical analysis made 70% correct assignment, with 30% incorrect and none uncertain. VEMP assignment accuracy varied by test stimulus. Best results were obtained for 250 Hz tone burst, which made 80% correct assignment, 5% uncertain and 15% incorrect. Worst VEMP results were for click stimulus, with 55% correct assignment, 15% uncertain, and 30% incorrect.
Conclusion: We conclude that VEMP is highly correlated with side-of-disease in unilateral MD, even though occult bilateral changes may diminish interaural asymmetry. VEMP is most informative when measured with tone burst stimuli rather than clicks. The capacity for the VEMP to identify side-of-disease is approximately equal to the best available analysis of conventional vestibular test battery results. VEMP is a robust measure of inner ear dysfunction providing information complementary to that of audiometry and conventional vestibular function testing in MD patients.

O143

Meniere's Disease Without Deafness

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Background: Can Menière's disease (MD) affect only the vestibular system, that is, cause only vertigo and not hearing loss and if so for how long? There is little in the literature to help answer this question, frequently asked by patients and doctors.
Objectives: To report clinical details of 7 patients who suffered recurrent attacks of acute spontaneous vertigo for 7 years or more before developing a unilateral fluctuating low-frequency cochlear-type hearing loss.
Methods: Retrospective review of electronic data records of about 26,000 patients seen in our Vertigo Clinic over a period of 10 years.
Results: Seven such patients were identified. Each had experienced vertigo attacks for between 7 and 22 years before developing a fluctuating, unilateral, low frequency, cochlear-type hearing loss. None had experienced consistent unilateral tinnitus and fullness until the hearing loss developed. Three had noticed unilateral hearing loss in some attacks which could not be confirmed by audiometry carried out days, sometimes weeks later. By the time the hearing loss had developed 5/7 patients had also developed a unilateral canal paresis on the same side.
Conclusion: It is possible in MD to have vertigo attacks for up 20 years or more before developing a unilateral hearing loss. However some MD patients might be too distressed during the vertigo attacks to notice a slight low-frequency hearing loss or their hearing loss might not have lasted long enough for an audiogram to be have been done. However the cases reviewed here show that it is possible in MD to have vertigo attacks for many years without developing a hearing loss.
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O144

Clinical Figures of Delayed Endolymphatic Hydrops

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Background: Delayed Endolymphatic Hydrops (DEH) is a syndrome which occurs to patients with pre-existent unilateral profound deafness, and gradually develops repetitive vertiginous attacks or fluctuating hearing loss of their only hearing ears. Clinically typical DEH cases are shown with a view to obtaining certain implications on their clinical features, and on their inner ear disorders such as vestibular functions or hearing prognosis.

Objectives: Nineteen consecutive patients with unilateral profound deafness (pure tone average (PTA)>90.0dB) who came to Mitsui Memorial Hospital between 1998 and 2003,complaining vertigo, tinnitus or ear fullness, were studied (10 males and 9 females, age ranging from 22 to 67 years old (mean 43), 10 right and 9 left side deafness, mean PTA of better hearing ear was 16.8dB (ranging from 2.5 to 35)).

Methods: Retrospective case series study. Pure Tone Audiogram, Auditory Brainstem Response (ABR), vestibular functional studies, and imaging study are performed.

Results: Profound deafness was thought to be congenital or unknown origin in 15 cases, caused by viral infection (mumps or meningitis) in 4 cases. Fourteen cases were ipsilateral type and 5 cases, having been detected cochlear symptoms on opposite side ears, were contralateral type. Initial symptoms of DEH were vertiginous attack, unsteadiness, or tinnitus. In their twenties or later, they happened to notice vertigo or unsteadiness. Mean age of the first attack which they had experienced was 37.7, ranging from 15 to 65, clearly drawing two peaks in younger age (twenties) and older age (forties) (Table). vestibular function of the hydropic ear was studied, and 8 cases showed Canal Paresis (CP) of the hydropic side. Hearing level of their better hearing ear got worse, as the initial symptoms occurs later in their age (mean PTA (dB); 12.6, 11.2, 19.0, 25.6, 23.8 in their teens, twenties, forties, fifties, sixties). Imaging studies were performed in 10cases, revealed inner ear anomaly of hydropic side in one case, slightly widened cochlear duct of hydropic side in another case, and normal in the other 8 cases.

Table:

Age of initial symptom	Number of patients	% having vertigo	% having CP
Teens	2	100 (2/2)	100 (2/2)
Twenties	6	100 (6/6)	60 (3/5)
Forties	8	50 (4/8)	33 (2/6)
Fifties	2	100 (2/2)	0 (0/2)
Sixties	1	0 (0/1)	100 (1/1)

Conclusion: Initial symptoms of DEH are likely to occur in patients with unilateral profound deafness in their twenties and forties. The difference of their initial symptoms and vestibular functions between 2 peaks implies that etiology of DEHs in younger generation may be different from that of older generations.

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O145

The Endolymphatic Sac Potential in Human

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Background: Amano first reported the existence of a direct current potential in the endolymphatic sac of guinea pigs (n=7) in 1983, which is now called endolymphatic sac potential (ESP) (Amano et al., 1983). Since then, the properties of ESP have been investigated in several species in detail. It is a undoubted fact that morphological observations have contributed to studies of the endolymphatic sac and Meniere's disease. However, there have been no studies on the human endolymphatic sac observed from the viewpoint of electrophysiology.

Objectives: In considering a potential derived from the human inner ear, although EP has already been measured in patients Menière's disease (Tran Ba Huy, 1984), to our best knowledge, there have been no studies measuring ESP in human. To determine the normal value of human ESP, and to compare it with those obtained from patients with Menière's disease might provide us a new aspect of the pathophysiology of Menière's disease.

Methods: ESP was measured in 8 patients with vestibular schwannoma during the translabyrinthine removal of the tumor, and in 5 patients with Menière's disease during endolymphatic sac surgery. ESP was measured with a glass electrode filled with 154 mM NaCl and with an outside tip diameter ranging from 2 to 3μm. The values of ESP were correlated with histological findings of the endolymphatic sac biopsied during the surgery.

Results: The mean value of human ESP in patients with vestibular schwannoma was + 13.3 ±1.9 mV. Since elec-

tron microscopy showed that the endolymphatic sacs of the 8 patients with vestibular schwannoma were normal in the ultrastructures, the value can be close to normal human ESP. While in Menière's disease, 3 cases showed low potentials and 2 cases showed almost the same values observed as in the 8 patients with vestibular schwannoma. In the 2 cases with Menière's disease, the epithelial cells of the endolymphatic sac were preserved.

Conclusion: Our study can be considered as the first successful measurement of human ESP and revealed the existence of Menière's disease having normal endolymphatic sac in function as well as morphology.

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O146

Pressure Treatment in Menière's Disease

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Background: Patients with active Menière's disease according to AAOO were studied either with hypopressure chamber or with local pressure pulses in the ear canal. They had not been subjected to surgery or gentamicin treatment.

Objectives: To study pressure treatment in active Menière's disease

Methods: In the first study 35 patients were subjected to hypopressure chamber treatment, exposed to 90 kPa, 80 kPa and 77 kPa, the time in each altitude ten minutes, followed by quick normalization of the pressure before returning to the next pressure level. The results were recorded by questionnaire and repeated PTA. In the second study 31 patients were treated for two weeks with pulsed overpressure in the ear using the Meniett method five minutes three times daily. For comparison 25 patients had been randomized to a placebo apparatus with the same instructions. The results were recorded with daily reports and a VAS scales. When possible ECoG was performed before and after the two weeks. All local pressure patients had a grommet in the eardrum. In the third study the procedure was similar but the treatment time 2 months and the number of patients 40, 20 treated with Meniett and 20 with the placebo machine.

Results: Out of the 34 recorded chamber patients, 23 experienced positive effects of the treatment, two had negative effects. Eleven had effects on hearing, tinnitus and vertigo and another eleven on two of the symptoms. In the two week Meniett study, a significant influence on frequency and intensity of vertigo, aural pressure and tinnitus and functionality was reported. PTA improved 5–10 dB in the low frequencies. ECoG showed a significant improvement. In the placebo group no changes occurred on any parameter. In the two-month study the functionality profile improved significantly compared to the placebo group, as was the VAS evaluation of vertigo. The frequency of attacks decreased in both groups but the difference was not significant, p= 0.090. Other parameters showed no significance. The PTA did not change. No side effects were recorded.

Conclusion: In the treatment arsenal, pressure treatment has a role, and it is reasonable to use it when information, life style changes and drugs have failed and before gentamicin is considered.

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O147

Effect of Betahistine on Spatiotemporal Response Properties of Vestibular Nuclear Neurons to the Labyrinthine Input

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Background: Betahistine (Bh) is a drug used in the treatment of vestibular disorders, with week agonist action on H1 and strong, antagonistic action on H3 histaminergic receptors. Besides improving cochleovestibular blood flow, Bh may directly affect the activity of vestibular neurons and their responses to the labyrinthine input.

Objectives: We verified whether Bh may modify the spatial (directional) and temporal properties of vestibular nuclear neurons to the labyrinthine input, as well as the convergence of different labyrinthine signals on single units.

Methods: The experiments were performed in adult, urethane anesthetized (1.3 g/Kg, i.p.), Winstar rats. Extracellular, single-unit activity was recorded from the spinal projecting regions of the vestibular nuclei during animal wobble in both clockwise and counter-clockwise direction. Recordings were performed in control condition as well as for 60-120 minutes following an i.p. injection of Bh (50 mg/kg). Analysis of the responses to wobble allowed to define the two orthogonal directions of maximal and mini-

mal response to tilt of the neuron, as well as the corresponding gains (Gmax, Gmin) and phases. The ratio of the minimal to the maximal response gain (tuning ratio, TR) measures the spatial selectivity of the neuron and the degree of convergence of vestibular signals endowed with different spatial and temporal properties (spatiotemporal convergence, STC). The minimal response of units with TR<0.1 is null and their degree of STC negligible. Pre and post-injection data were compared by ANOVA and FISCHER.

Results: Response properties were evaluated for 47 units before and 17 units following Bh. No significant differences were observed in the average basal activity and Gmax values between the two conditions. However, before Bh, two population of neurons, with high (1.67±0.47, SD, imp/sec/°, n = 10) and low (0.36±0.20, n=47) Gmax values were observed, while following Bh, only a population with intermediate (0.53± 0.25, n=17) Gmax values was present. Therefore, the standard deviation of Gmax was significantly reduced by Bh (FISCHER, P< 0.0005). Observation on individual units indicated that high gain values were reduced, while low gain values enhanced by Bh. On the other hand, Bh significantly raised the average Gmin value from 0.06±0.01 to 0.12±0.13 (ANOVA, P<0.05). The changes in Gmax and Gmin led to a significant decrease in the spatial specificity of the neurons, indicated by an increase in TR from 0.12±0.01 to 0.21±0.16 (ANOVA, P< 0.02) . No major changes could be found in the remaining response parameters..

Conclusion: The results suggest that Bh affects the process of STC at the level of vestibular units, leading to a reweighting of the converging inputs. The outcome of the process is a decrease in the spatial specificity of the neurons, which could be related to the drug effect on the symptoms of vestibular diseases. It may well be that activation of histaminergic H1 receptors and blockade of H3 receptors within the vestibular complex are involved in the observed effects.

O148

The Effects of Antioxidant on the Peripheral Vestibular Disorder Induced by AMPA or Streptomycin

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Background: Aminoglycoside antibiotics and excessive activation of glutamate have toxic effects on the inner ear. Evidence for a correlation between aminoglycoside antibiotics, glutamate and reactive oxygen species in the inner ear is accumulating.

Objectives: The aim of the present study was to investigate the effects of edaravone, a free radical scavenger clinically used, on the peripheral vestibular disorder induced by topical application of AMPA or streptomycin.

Methods: 1. A tiny hole was made adjacent to the round window in the guinea pig right ear, and 10 mM AMPA was infused through this hole by syringe pump at the rate of 0.6 ml/h for 5 minutes. In some animals, edaravon-soaked gelfoam (3 mg/ ml) was put on the round window membrane before wound closure. As a control, artificial perilymph was infused in the same manner. After treatment, spontaneous nystagmus was observed. At 1 week after treatment, caloric tests were performed to investigate peripheral vestibular function.

2. A tiny hole was made adjacent to the round window in the guinea pig right ear, and 30% SM was infused through this hole by osmotic pump for 24 h. Infusion rate was set at 0.5É l/h. Eight animals received edaravone at a dose of 3 mg/kg i.p. once a day for 7 days after treatment. Six animals received the same amount of saline i.p. in the same manner as a control. In another 6 animals treated with SM, edaravon-soaked gelform (3 mg/ ml) was put on the round window membrane before wound closure. After treatment, spontaneous nystagmus and yaw head tilt were observed.

Results: 1. AMPA-induced nystagmus was suppressed by edaravone. In the AMPA + edaravone group, animals showed a significant recovery of caloric response time close to the control level.

2. No statistical difference was observed in the spontaneous nystagmus number or yaw head tilt between the systemic application and saline groups. In the local application group, spontaneous nystagmus numbers were statistically smaller than those in the systemic application group at 6, 9, 12, 18 and 24 h after treatment. Furthermore, in the local application group, yaw head tilt was also statistically smaller than that in the systemic application group at 6 h after treatment.

Conclusion: These data indicate the possibility that topical application of edaravone may be useful to treat peripheral vestibular disorder induced glutamate excitotoxicity or aminoglycoside ototoxicity.

O149

The Effect of Promethazine on the Human Vestibulo-Ocular Motor System

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Background: Promethazine is used to treat vertigo. In monkey's it is known to affect Optokinetic Nystagmus (OKN) and Optokinetic After Nystagmus (OKAN) but not the Vestibulo-Ocular Reflex (VOR) [1].

Objectives: We tested 9 subjects (5F, 4M) ages 20 to 29 to determine the effect of promethazine on the vestibulo-ocular motor system of humans.

Methods: On three separate days, seven days apart, in random order, each subject was given no drug, promethazine 25 mg (1 ml) IM and saline 1 ml IM (placebo). Promethazine and placebo were administered in a double blind manner. Testing was performed one hour after injection. Video-oculography was used to record eye movements during OKN at 60 d/s, OKAN, VOR steps at 60 d/s (per and post rotation) and Pursuit at 0.1 and 0.2 Hz with a 30

deg peak-to-peak amplitude. Paired t-tests were performed between the promethazine and placebo groups.
Results: Pursuit showed no statistical significance difference between the two groups. The initial slow phase velocity of nystagmus during OKN was less for all subjects after taking promethazine (26.4 d/s) than after taking placebo (31.1 d/s) ($p=0.035$). For OKAN statistics were performed on six subjects. Five of six subjects had at least one beat of OKAN after taking placebo though the sixth subject had none. After taking promethazine three of the five subjects had no OKAN and the OKAN slow phase velocity was reduced for the other two subjects. The subject that had no OKAN after placebo also had none after promethazine. Promethazine as compared to placebo reduced the OKAN slow phase velocity ($p=0.028$). For VOR step gain there was no statistical significance found between the two groups. VOR step time constant (Tc) showed that promethazine induced a reduction of the VOR time constant from 16.4 s to 5.2 s ($p=0.013$).
Conclusion: In humans subjects the initial OKN slow phase velocity, initial OKAN slow phase velocity and the VOR time constant were all reduced by the use of promethazine. Promethazine did not have a statistically significant effect on VOR step gain or pursuit. These finding suggest that in humans promethazine may have an effect on velocity storage.
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O150
Vestibular Rehabilitation: Effects on Migraine Associated Dizziness
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Background: Migraine Associated Dizziness has been receiving increased attention over the last several years. There are a number of controversies surrounding the diagnosis and treatment of this disorder including the role of medicines and other therapeutic techniques. Vestibular rehabilitation has traditionally been utilized in groups of patients suffering from constant, stable dizziness. However, work in our lab reveals that, despite its intermittent nature, migraine associated dizziness may be effectively treated with vestibular rehabilitation.
Objectives: The purpose of this study was to investigate the effects of a vestibular rehabilitation program on a group of patients with the diagnosis of migraine associated dizziness (MAD).
Methods: Individuals with the diagnosis of migraine associated dizziness were treated with a customized vestibular rehabilitation program. The subjects' performance on the Dizziness Handicap Inventory (DHI), Activity Balance Confidence Scale (ABC), Dynamic Gait Index (DGI), and computerized Dynamic Posturography (CDP) pre-treatment were compared to their performance on the same set of tests post-treatment.
Results: After vestibular physical therapy all subjects showed significant improvement in DHI, ABC, DGI and CDP measures. The DHI improved from an average score of 46 pre-treatment to an average score of 18 after therapy. The pre-treatment ABC and DGI were 61 and 21, respectively and both measures improved to 86 and 24 post-treatment. The CDP improved from 61 before therapy to 74 after treatment. All of these changes were significant at ($p< 0.01$).
Conclusion: Migraine associated dizziness (MAD) is becoming an increasingly recognized vestibular disorder. This study demonstrates that patients with MAD benefit from physical therapy intervention. The results of this study are important in considering the approach to patients with this disorder.

O151
The Influence of Unilateral Canal Plugging or Gentamicin Treatment on VOR Recovery After Subsequent Unilateral Labyrinthectomy
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Background: Recovery of VOR gain and symmetry following labyrinthectomy has been extensively studied. Some clinicians have observed that symptoms of vestibular loss following surgical vestibular lesions are less severe in patients with previous vestibular dysfunction. In addition, recovery is more complete following lesions that do not impact the resting rate of vestibular afferents (such as semicircular canal plugging) than those that do (such as unilateral labyrinthectomy). It is not known, however, how previous lesions of the vestibular labyrinth, by methods that preserve afferent firing (such as semicircular canal plugging), influence recovery from subsequent ablation. This issue is of increased importance as patients are treated with intratympanic gentamicin, which, at some doses, attenuates vestibular function rather than completely ablating it.
Objectives: To document the recovery of VOR following unilateral labyrinthectomy in gerbils that have previously had ipsilateral semicircular canal plugging or single dose topical gentamicin treatment.
Methods: Gerbils were divided into three experimental groups: 1) unilateral labyrinthectomy as a primary lesion (n=7), 2) unilateral labyrinthectomy 21 days after a single ipsilateral dose of buffered gentamicin (27 mg/ml) is placed in the bulla for 15 minutes after a minifenestration of the vestibule (n=6), and 3) unilateral labyrinthectomy at least 10 weeks after unilateral plugging of all three semicircular canals with bone wax (n=9). In the gentamicin treated group, the semicircular canal ampullae were examined by light microscopy after they were removed. Bilateral controls of the canal plugging and gentamicin lesions were also

performed. Rotational VOR in the dark at frequencies of 0.2, 0.5, and 1.0 Hz at peak frequencies of 30, 60, and 90 deg/sec were also tested. Eye movements were recorded by videooculography. Data was collected prelesion and up to 10 weeks post-lesion.
Results: Previous lesion improved the VOR response to the contralesional side after unilateral labyrinthectomy. This effect was only present for the first 3 days after the lesion. Between the groups, there was no difference in the VOR responses to ipsilateral rotation.
Conclusion: Plasticity in the vestibular system after gentamicin treatment or canal plugging is preserved at subsequent ipsilateral labyrinthectomy but only for contralesional movements and only for 3 days after the lesion. These data suggest that, in this animal, dynamic VOR compensation is retarded by competing demands to balance static central vestibular activity after unilateral loss of primary afferent drive.

O152
Asymmetric Short-Term Adaptation of the Vertical Vestibulo-Ocular Reflex in Humans

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Background: Electrophysiological and anatomical studies have demonstrated asymmetries between upward and downward vertical ocular motor pathways.
Objectives: We investigated whether these asymmetries were reflected in the brain's capacity to rapidly adapt the vertical vestibulo-ocular reflex (VVOR) in humans.
Methods: During adaptation (duration: 30 minutes), healthy subjects (N = 8), positioned 90 º left-ear-down, fixed upon a small laser dot (diameter: 0.1 º) projected on a sphere (distance: 1.4 m), while being oscillated (0.2 Hz ± 20 deg) about the interaural earth-vertical axis in otherwise complete darkness. The laser dot either moved with the turntable (= head-fixed) or remained fixed relative to space (= space-fixed). During asymmetric visual VVOR cancellation, the dot was only head-fixed in one direction of pitch oscillation (pitch-up or pitch-down), but space-fixed in the other direction. During symmetric visual VVOR cancellation, however, the dot was head-fixed throughout the oscillation cycle. Before and after adaptation, the VVOR was assessed during oscillation in complete darkness.
Results: Before adaptation, average gains of pitch-up (0.75) and pitch-down (0.79) VVOR were not significantly different (paired t-test: $p > 0.05$). Relative gain reductions induced by asymmetric pitch-up (pitch-up VVOR: 32%; pitch-down VVOR: 21%) and pitch-down (pitch-up VVOR: 18%; pitch-down VVOR: 30%) visual VVOR cancellation were significantly ($p < 0.05$) larger in the direction of the cancelled VVOR. Symmetric visual VVOR cancellation led to a significantly ($p < 0.01$) larger relative gain reduction of the pitch-down VVOR (pitch-up VVOR: 33%; pitch-down VVOR: 41%). None of the asymmetric or symmetric adaptation paradigms led to significant changes of phase or offset.
Conclusion: We postulate separate, but interdependent mechanisms for pitch-up and pitch-down gain adaptation of the VVOR. During symmetric visual VVOR cancellation, the pitch-down adaptation is more effective. - Supported by Swiss National Science Foundation and Koetser Foundation for Brain Research.

O153
Vertical Skew as a Function of Gravity: A Possible Consequence of Otolith Asymmetry

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Background: During parabolic flight on a NASA KC-135 aircraft that provided alternating levels of reduced (~0 g) and enhanced (~1.8 g) g levels, subjects noted that a point target viewed binocularly in darkness seemed to split into two vertically separated targets. The perceived divergence seemed to depend on instantaneous g level. This perceptual observation suggested a vertical misalignment of the eyes (vertical skew), dependent on the magnitude of g level sensed by the otoliths.
Objectives: To measure vertical skew vs. g level as a function of target eccentricity, distance, size and effect of repeated g level alterations.
Methods: Video eye recordings of 10-140 sec were made of 6 subjects viewing foveal targets at different locations (center, 25° left/right, 15° up/down) and distances (12, 30 cm).
Results: The mean skew-differential=[(skew in 0 g)-(skew in 1.8 g)] across all trials is +1.18°±0.93° (significant in 48 of 53 trials (t-test, $p<0.001$)); the maximum is 3.7°. It does NOT depend on the position of targets (ANOVA; $p>0.4$); IS less for far vs. near targets (t-test; $p<0.1$); decreases with parabolic flight experience (time-constant 3.7 flights). There is a near-linear relationship between skew-differential and g level (significantly non-zero in 40/53 trials). Stereogram presentation to one subject yielded a skew-differential of 0.44°±0.56° for this larger stimuli size (significant in 11 of 12 trials (t-test; $p<0.001$)). A Maddox Rod test complemented recordings by demonstrating perceptual vertical skew under full-field stimuli. In one subject, during 0 g the line and dot were coincidental; during the transition from 0 to 1.8 g, the line moved towards the top of the dot, and during 2 g it appeared to alternate between the top and middle, representing attempted sensory fusion.
Conclusion: One effect of altered g levels is vertical skew resulting in diplopia. This may be the result of asymmetries between the utricles [5] and demonstrated with torsional asymmetries [3]. Otolith information can drive vertical alignment [4]; these authors implied that vertical skew may occur under varying g level. In otolith-ocular imbalance,

the ocular tilt reaction results in torsion and skew deviation [2]. Adding otolith asymmetry to an existing model [1] predicted the response. Such g-dependent skew could be detrimental to performance during dynamic phases of air or space flight.

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O154

Labyrinthine Lithiasis (BPPV & Variants)

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Background: Labyrinthine Lithiasis is a common condition in which abnormal heavy particles in a semicircular canal (SC) mechanoreceptor are distorting its hydromechanical function and causing it to become abnormally receptive to inertio-gravitational changes. These heavy particles may move freely in the SC endolymph, or attach to, or impinge upon, a cupula. Labyrinthine lithiasis is thought to arise most commonly from dislodgement of otoliths into the endolymph and thence migration into the SCs. The most effective non-surgical treatment methods are designed to "reposition" the particles out of the affected SC into the utricle where they no longer affect the SC dynamics and are thought to be eventually absorbed. Because these distortions in labyrinthine function are reflected in characteristic nystagmus profiles that may identify the location, character and direction of momentary movement of particles, nystagmus observation is crucial throughout diagnostic and treatment maneuvers. Thus, repositioning maneuvers should be "nystagmus-based", in response to any ongoing nystagmus. Technological advances to facilitate these measures will also be discussed.

Objectives: Moderators will give a brief introduction of the following subjects and introduce speakers: I. Incidence and Prevalence. II. Anatomy and Physiology, and Correlated Symptoms. III. Terminology: Recognizing Basic Profiles. IV. Basic Maneuvers: Semont and Epley Maneuvers for All Three Canals. V. Technological Advances. VI. Advanced Maneuvers. VII. Diagnosis and Treatment of Atypical Forms

Methods: Each speaker will address one or more of the above topics in a 10 minute presentation. The moderators will then invite comments from panel members and the audience.

Results: This panel presentation is designed to illustrate the state-of-the-art diagnosis and non-surgical management options for a wide range of clinical presentations, some of which are not widely recognized. Quantitative outcome methods for evidence-based medicine will be presented.

Conclusion: Labyrinthine lithiasis is the most common cause of vertigo. Prompt diagnosis and management results in immediate resolution of symptoms in most cases and significantly reduces or avoids comorbidity.

O155

Otolith-Driven Heading Perception in Humans

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Background: Human navigation is a coordinated sensorimotor process that integrates multiple sensory as well as cognitive inputs. Determining one's direction of translation (heading) is a critical element of that task. It has long been known that humans can use visual motion information (optic flow) to make precise estimates of their self-motion, with heading uncertainty from visual information as low as 1 degree.

Objectives: Although the vestibular system in general and the otoliths in particular have long been known to provide information about one's self-motion to the oculomotor system, our goal is to determine to what extent this information is also made available to perception.

Methods: In darkness, with the head restrained via a bite bar, while listening to a white-noise auditory mask and being subjected to a proprioceptive wind mask, human observers were exposed to an impulsive, damped sinusoidal oscillation on NASA's Vestibular Research Facility 30ft linear sled. This sled uses air bearings to produce nearly vibration-free (< 0.2mG rms) linear accelerations (ranging from 8 mG to 220 mG in this study). Prior to each trial, the chair was pulled along the translation axis to a predetermined extension from the rest position with the peak linear acceleration determined by the extension amplitude. A computer-controlled electromagnet provided a repeatable stimulus profile and allowed the observer to trigger the launch. At the end of each trial, observers indicated their forced-choice heading judgment with a button press. Stimulus heading was reset between trials by covertly reorienting the chair. We kept observers unaware of their new static orientation by using a random walk of threshold-level

yaw rotations. We validated this method empirically by showing that it resulted in random performance in a static orientation estimation task.
Results: We have found that humans can precisely estimate their heading, even when deprived of visual and auditory cues. Human heading uncertainty, under these conditions, is a well-behaved decreasing function of acceleration amplitude, with reliable direction judgments possible even for peak accelerations as low as 10mG and with an asymptotic uncertainty of approximately 1 degree for accelerations above 100mG. Furthermore, vestibular heading uncertainty appears lowest for motion along the naso-occipital axis and several fold higher for motion trajectories approaching the inter-aural axis.
Conclusion: The finding of low-threshold, high-precision psychophysical performance in our vestibular heading estimation task, systematically related to both acceleration amplitude and direction, is strong evidence that the otoliths provide an important input to human heading perception, one that can be as precise as that from vision.

O156
Visual Self-Motion Perception (Vection) in Humans: Results from PET and fMRI

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Background: Unlike vestibular stimuli, which lead to the sensation of motion or tilt of the body, visual motion stimuli can be interpreted as either self-motion or surround-motion. The sensation of vection can also be induced in a stationary observer by large-field visual motion stimulation. In an earlier human PET study, we found that visually induced vection in roll activated a medial parieto-occipital brain area (PO) bilaterally, while the posterior insula region (i.e., the human homologue of the parieto-insular vestibular cortex of the monkey, PIVC) was simultaneously deactivated.
Objectives: To investigate the areas involved in visual perception of self-motion in detail, we conducted two PET studies (A, B).
Methods: (A) The first study compared directly the differential effects of large-field visual motion stimulation that induced either circularvection (CV) or forward linearvection (LV) in the same subjects. The main question was whether the areas responding to vection are identical or separate for CV and LV. The rCBF PET image sets were obtained in 11 healthy volunteers using the H215O-bolus technique and compared to each other and to those of a stationary pattern ($p < 0.001$). (B) The second FDG-PET study in 15 right-handed subjects compared the glucose metabolism during visual motion stimulation either by random dot movements or CV; these data were correlated to perceptual parameters, e.g., intensity of vection and duration of vection after stimulus stop ($p < 0.001$).
Results: (A) CV and LV led to bilateral activations of visual areas including PO, motion sensitive areas MT/V5, and ventral occipital cortical areas, as well as superior parietal sites. Activations around the calcarine sulcus were more significant during LV, whereas temporo-parietal areas had higher activity levels during CV. Differential activation of PO or MT/V5 was not found. Both stimuli simultaneously induced deactivations of retroinsular regions, which were more pronounced during LV. (B) During CV compared to random dot movements without CV, increases of glucose metabolism were found in the precuneus (BA 7), PO, anterior cingulum (BA 24) bilaterally and in the vermis. The intensity of vection was correlated to medial and upper parts of the inferior parietal lobule (BA 40) adjacent to the precuneus (BA 7) as well as lower parts of BA 40 of the right hemisphere. The duration of vection was correlated to the hippocampus/uncinate fascicle and the medial temporal gyrus bilaterally, right more than left.
Conclusion: The data confirm the earlier concept of an inhibitory interaction between the visual and vestibular systems. Our PET studies showed consistent results for rCBF increases/decreases and glucose metabolism increases/decreases. The rCBF decreases seem to be caused by a reduction of neuronal metabolic activity, an interesting finding since the meaning of such decreases at neuronal level is still under discussion.

O157
Visual and Vestibular Contributions to 3D Heading Selectivity in Area MST

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Background: Perception of self-motion is a multi-modal process involving integration of visual and non-visual (vestibular, proprioceptive) cues. Area MST has been implicated in self-motion perception, as neurons in this area are sensitive to global patterns of optic flow that mimic those experienced during self-motion. More recently, neurons in MST have also been shown to be selective for the direction of translation in darkness, suggesting that they may integrate visual and vestibular signals to compute the direction of heading. Previous studies, however, limited translational movements to the horizontal plane and responses were analyzed during periods of constant-velocity motion, a condition that is suboptimal for the vestibular system.
Objectives: The goal of the present experiments was to characterize the contributions of visual and vestibular signals to heading selectivity in 3D using a virtual reality system, which can accurately simulate any 3D trajectory through a virtual visual space.
Methods: Neurons in MST in rhesus monkeys were tested with translational motion defined by: 1) optic flow alone; 2) vestibular stimulation alone (real motion without optic

flow); 3) congruent and synchronous combinations of optic flow and real motion. In all three cases, which were randomly interleaved, stimuli were smooth motion trajectories (with a Gaussian velocity profile) directed along one of 26 directions (45 deg apart in azimuth and elevation) emanating from the center of a sphere.
Results: Among 99 neurons recorded from one hemisphere in one monkey, 96 neurons (97%) exhibited significant heading selectivity based on optic flow alone, and nearly half of these units (47 neurons) show significant tuning for heading defined by vestibular stimulation alone. Surprisingly, however, the preferred heading in response to vestibular stimulation was typically 90-180 deg away from the preferred heading defined by optic flow. As a result, heading selectivity in response to combined visual/vestibular stimulation was typically weaker than that obtained using optic flow alone.
Conclusion: Although MST is involved in the analysis of optic flow, our findings are not consistent with the idea that MST neurons integrate visual and vestibular signals to provide more robust estimates of the direction of heading.

O158

Do the Eyes Move the Body?

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Background: It is a basic and common experience that vision improves postural stability. It is, however, not known what serves as the cue for visual stabilization of posture. Postural sway causes the image of the visual scene to move on the retina in the direction opposite to that of head sway. It is, therefore, generally assumed that retinal slip is utilized as feedback to compensate for body sway. However, use of the net retinal slip as a critical cue has a major limitation. Namely when a subject fixates a stationary target, there is almost no retinal slip. This is due to the vestibulo-ocular reflex (VOR) and smooth pursuit, which maintain gaze in space and keep it constantly on target. Thus, during fixation, eye movements rather than retinal slip best reflect head motion in space.
Objectives: To determine whether visual stabilization of postural balance depends on retinal slip or on extraocular signals, namely ocular motor input provided by efferent or re-afferent (proprioceptive) signals.
Methods: Two series of experiments were performed. In the first, postural sway was measured in patients with acute vestibular neuritis with and without visual suppression of spontaneous nystagmus. In the second experiment, postural sway was measured and retinal error (slip) was calculated in healthy subjects standing on a foam-rubber padded platform and with and without smooth pursuit during fixation.
Results: Compared with the condition of complete darkness, fixation of a bright head-fixed LED by the patients caused a significant suppression of the spontaneous nystagmus and a decrease of sway velocity. There was a significant correlation between body sway and intensity of nystagmus ($r = 0.64$, $p < 0.05$). In both experiments the best postural stability was measured when subjects fixated a space-fixed target. Smooth pursuit significantly increased postural sway during unstable stance, even in the presence of a stable background and with minimal retinal slip.
Conclusion: Both series of experiments suggest that visual stabilization of postural control depends on extraocular signals (efference copy and/or re-afferent signals) rather than retinal slip. Ocular motor signals are useful for postural control, because when fixating a target, retinal slip is close to zero due to the combined capacity of the VOR and smooth pursuit. Fixation drives the eyes to move in their orbits in a direction opposite to that of head motion with the same velocity and amplitude. Thus, to use visual information to compensate for head and body sway during fixation, information on eye velocity or position appears to be the most reliable cue.

O159

Human Surge Linear Vestibulo-Ocular Reflex (LVOR) During Horizontally Eccentric Target Fixation: Value as Lateralizing Otolith Test?

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Background: Visual fixation during anteroposterior head translation (surge) requires an otolith-mediated LVOR depending both on target direction and distance, and that differs between the two eyes [1,2,3]. The direction of the LVOR depends both on surge direction and lateral direction of a horizontally eccentric target. Unilateral vestibular deafferentation (UVD) markedly impairs the monkey LVOR for ipsilateral but not contralateral horizontally eccentric targets for at least 3 mos [1].
Objectives: We administered transient surge to normal and UVD subjects viewing horizontally eccentric targets to determine if LVOR asymmetry might lateralize otolith deficits.
Methods: Transients of 0.5 G peak whole body surge acceleration were delivered by a pneumatic servo on which were seated 6 subjects (53±5 yrs, mean±SE) with UVD due to acoustic neuroma excision, and 8 age-matched normal controls (54±6 yrs). Lesion duration averaged 2.5±1.2 yrs, ranging from 2 wks - 9 yrs. Eye rotation was sampled at 1,200 Hz using binocular magnetic search coils. Head acceleration was measured by a bite bar accelerometer. Immediately before surge in darkness, subjects viewed a luminous target 50 cm anterior to the interocular midpoint, centered or displaced 10 deg right or left. The target was extinguished 30-60 ms before onset of 20 randomly-directed forward and aft surges for each target location.
Results: Data were analyzed for the right eye of controls, and for the eye contralateral to UVD to avoid exposure keratopathy. Repeated responses were averaged, and LVOR gain determined between 250-300 ms after surge onset as percent of ideal velocity, which differs for each

eye. Since there were no systematic differences, gains for fore and aft surges were averaged. Gain of subjects with UVD for the contralesional eccentric target (0.59±0.08) did not differ significantly from normal (0.52±0.04), but gain for the ipsilesional eccentric target was significantly reduced (0.35±0.02) compared with normal (0.48±0.03, $P<0.05$). Normal subjects had a mean gain asymmetry for left and right targets of 0.11±0.02, while mean asymmetry in subjects with UVD was increased to 0.35±0.06 ($P<0.01$). Four of 6 subjects with UVD had gain asymmetry outside normal 95% confidence limits for at least one surge direction, while only one of 8 controls did. Asymmetry did not correlate with UVD duration.

Conclusion: Chronic human UVD, on average, significantly impairs the surge LVOR for horizontally eccentric targets placed ipsilesionally as compared with contralesionally. This asymmetric effect is smaller than reported in monkey, and varies among human subjects. Since normal subjects also exhibit appreciable surge LVOR asymmetry with horizontally eccentric targets, this asymmetry is probably not sufficiently robust to be used for clinical diagnosis or lateralization of UVD. Grant support: USPHS DC005224 & RPB.

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O160

A Videooculocephalographic (VOCG) Device Dedicated to the Halmagyi's Head Impulse Test: Description and First Results

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Background: The Head Impulse test, as described by Halmagyi and Curthoys in 1988, allows in a few seconds to suspect a unilateral or bilateral deficit of the lateral semicircular canal. Moreover, thanks to suitable positions of the head, the principle of this test can be applied to the vertical semicircular canals, thus making it possible to test one by one each of the six semicircular canals.

Objectives: So that this test is interpretable, we intend to give to the expert the capability to measure at least two significant conditions:

- the velocity of the movement applied to the head. That velocity should be higher than 200°/sec, in order to cancel any influence of optokinetic stimulation on the vestibulo-ocular reflex, and so be sure that the VOR is not a VVOR—the synchronism between the movements of the eye and of the head, as well as the gain of the VOR (eye/head velocities ratio).

Methods: Magnusson already showed that, in a population of vestibular neuroma, the use of a mask of videonystagmoscopy, by enlarging the eye image, increases the sensitivity of the observation. But that does not solve the problem of the test quantification. We present here a videooculocephalography device (VOCG), specifically adapted to the recording and the measurement of the head /eye movements during the Halmagyi test.

Results: We will show, thanks to recordings of normal and pathological subjects, that such objective eye/head measurements simplify the conclusions of the test, and improve the sensitivity.

Conclusion: Thanks to the possibility to quantify the Halmagyi's head Impulse test, the importance of that test in the field of vestibular examination become much more obvious.

O161

Torsional Eye Movement Evoked by Vertical Translation: The Influence of Physically and Visually Defined Gravity, and of Eccentric Gaze

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Background: Previous reports have suggested that linear acceleration and gravity can combine to evoke an apparent tilt of the head during translation [1,2]. This "tilt" might be responsible for some unexplained and apparently non-compensatory eye movements observed during translation.

Objectives: Our objective was to find a component of eye movement linked to the combination of translational acceleration and physical gravity, its internal representation, or both. We also looked for a gaze-dependent modulation of the orientation of the eyes' velocity axis as predicted by Listing's Law.

Methods: Subjects laid on an airbed either supine or on one side, in the light or dark. They were moved ±10cm along their vertical body axis sinusoidally at 0.3-0.7 Hz while maintaining fixation on an earth-fixed point either on the midline, or displaced to the left or right. Translation was always orthogonal to physical gravity. Visually defined gravity was manipulated by performing the experiments in a room built on its side with the direction of the "floor" orthogonal to both physical gravity and the movement. When subjects lay supine, the sum of their acceleration with physical gravity swung around their pitch axis, and the sum with visual gravity swung in roll. The phase of the latter depended on the direction of the "floor". When subjects lay on their sides, the sum with physical gravity swung in roll, and visual gravity swung in pitch. The phase of the former depended on which side was down. We looked for compensatory eye movements linked to these swings. 3D binocular eye movements were recorded using videooculography (Chronos).

Results: The compensatory translational vestibulo-ocular reflex (tVOR) evoked consisted predominantly of vertical eye movement but with a torsional component such that downward eye motion was accompanied by counterclockwise torsion in both eyes. The torsional component was only slightly affected by manipulations of the direction of physically or visually defined gravity, but was strongly modulated by horizontal displacement of gaze, resulting in a tilt of the velocity axis by half the angle of lateral gaze, as required by Listing's Law.

Conclusion: The torsional component evoked during translational movement does not appear to be driven by either a swing of physical gravity or its internal representation. Neither can it be in anticipation of such a swing [2] since vertical translation is not normally orthogonal to gravity. The modulation of the angular velocity axis by gaze position shows that the vertical tVOR, like smooth pursuit and the horizontal tVOR [3], obeys Listing's Law.

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O162

Clinical Application of Galvanic Nystagmus by Video-Oculography Analysis

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Background: Galvanic test has been studied as a test of equilibrium function. However, it has been less applied clinically than other tests. This is partly because analysis of records by ENG is difficult due to mixture of electric stimuli into records. To overcome this problem for the clinical application of galvanic test, we performed recording and analysis of galvanic nystagmus by video-oculography.
Objectives: The subjects were 14 healthy volunteers and 5 patients with Meniere's disease between attacks.
Methods: Electrodes were attached to the mastoid processes of the bilateral ears with the cathode on the stimulation side and the indifferent electrode on the other side. Stimulation was performed by direct currents (1, 2, 3, and 4 mA) for 30 seconds using an electric stimulator. Nystagmus was recorded by video-oculography, and the frequency of nystagmus and the average slow phase velocity were analyzed.
Results: In all healthy subjects, nystagmus was provoked toward the cathode direction. The nystagmus-triggering threshold was 1 to 2mA in healthy subjects. The frequency of nystagmus and the average slow phase velocity linearly increased with the electric current. The average slow phase velocity and the frequency of nystagmus were slightly lower in the patients than in the healthy subjects. The frequency of nystagmus in the patients was similar to that in the healthy subjects, but the average slow phase velocity was slightly lower in the patients that in the healthy subjects.
Conclusion: The results in the healthy subjects suggested that the electric current at the cathode increased firing activity in the vestibular afferent pathway, which provoked nystagmus in the cathode direction. With an increase in the electric current, the firing frequency of the vestibular nerve may linearly increase. The average slow phase velocity and the frequency of nystagmus on the affected side in the patients with Meniere's disease were lower than those in the healthy subjects. Since the pathology of Meniere's disease is endolymphatic hydrops, the differences in values between the patients with Meniere's disease and the healthy subjects were considered to be differences in the response to electric stimulation of this area. The lower average slow phase velocity after stimulation of the normal side in the patients with Meniere's disease than that in the healthy subjects may be the influences of responses on the non-stimulation side due to the attachment of electrodes to the bilateral ears. Galvanic test may be useful for assessment not only for vestibular neuropathy but also for damage in the vestibular end organ.

O163

Differential Diagnosis of Unilateral Otolith Function

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Background: Unilateral centrifugation (UC) involves the positioning of one ear on the axis of a rotating chair, thus introducing an effective tilt of the gravitoinertial force (GIF) acting on the eccentric ear. This paradigm provides a unilateral peripheral stimulus, predominantly to the utricle. Since its introduction by Wetzig et al, (1990) it has been variously demonstrated that this GIF tilt stimulus elicits a measurable change in torsional eye position and in the subjective visual vertical (SVV).
Objectives: In this contribution, clinical SVV and caloric test results are presented and classified. Data from over 200 patients presenting with a variety of vestibular disorders are included.
Methods: In addition to routine vestibular testing including in most cases calorics, the SVV was measured in the upright position, during full body tilts (15 , 30 and 60), during on-center rotation and during UC (effective tilt 11).
Results: In contrast to testing with full body tilt, the UC tests reveal clear asymmetries between labyrinths, which together with the case histories, provide strong indication of unilateral otolith dysfunction. In total, the results show that differentiation between groups consistent with unilateral dysfunction of otolith, SCC or both can be made on the basis of unilateral SVV and caloric testing.
Conclusion: Analysis of the SVV and caloric findings permits a classification of patients into various groups that can be associated with unilateral loss of SCC and/or otolith function.

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O164

Utricular versus the Horizontal Semicircular Canal Function in Healthy Subjects and Vertigo Patients - A Comparison

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Background: The recently developed unilateral centrifugation test (Clarke et al 1998, Wuyts et al 2004) enables the unilateral investigation of human utricles. The combination of these results with the standard caloric test provides the clinician and scientists with a more detailed overview of the vestibular function.
Objectives: To determine the relationship between utricular and horizontal canal function in the same patients with vertigo. This might increase the insight in the interaction between the different vestibular end-organs.
Methods: We tested the utricular function and the horizontal semicircular canal function, side by side, in 53 subjects, of whom 35 vertigo patients and 18 healthy subjects. The utricular function was unilaterally tested by means of the unilateral centrifugation test that provides two parameters of interest: the utricular sensitivity (i.e. the slope of the linear regression between the ocular counter rolling and the gravito-inertial acceleration tilt of the head center) and the utricular preponderance (i.e. the intercept of this linear regression). The bithermal (44 C, 30 C) caloric test was performed to evaluate the horizontal semicircular canal function. The responsiveness of the horizontal semicircular canals (i.e. the sum of the maximum slow-component velocity of each of the four irrigations) and the canal preponderance were assessed. By assessing these functions in the same subjects, a better knowledge can be obtained of the inter-relationship of utricle and semi-circular canals in both healthy subjects as in patients with specific vestibular lesions.
Results: The correlation between the responsiveness of the horizontal semicircular canals and the utricular sensitivity is significant for the right eye ($r2 = 0.20$, $p = .001$) as well as for the left eye ($r2 = 0.31$, $p < .001$). The correlation between the canal preponderance and the utricular preponderance is significant for the right eye ($r2 = 0.10$, $p = .024$) as well as for the left eye ($r2 = 0.08$, $p = .036$).
Conclusion: Weak but significant correlations are found between the responsiveness of the horizontal semicircular canals and the utricular sensitivity, and between the canal and the utricular preponderance. Several causes underlie the relative poor correlation, i.e. the canal and utricular functions are certainly not identically affected in the different diseases and the intra individual variation adds to this poor correlation. This indicates also that in the diseases that were investigated rather the organs were affected than the nerve, since both the horizontal canal and the utricle innervate the superior branch of the vestibulocochlear nerve. The extrapolation of the findings of the caloric test to the entire labyrinth proves to be quite inaccurate.
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O165

Vestibular-Evoked Postural Responses to Bone Conducted Sound

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Background: The vestibular apparatus in man can be activated by low frequency mastoid vibration, resulting in myogenic potentials (VEMPs) in the anterior neck muscles [1,2] and ocular torsion in the presence of unilateral dysfunction [3]. Whole-body responses to mastoid vibration have not been described thus far.
Objectives: To measure vestibulo-postural whole-body responses to mastoid vibration.
Methods: Seven normal subjects were studied standing with feet together and deprived of vision. Unilateral, bone conducted tone-bursts of 20V peak-to-peak intensity at 250, 500 and1500 Hz of 2s duration were delivered via a B71 clinical bone vibrator attached to one mastoid process. Responses to 20 stimuli were averaged for all frequencies tested. Ground reaction force data in the AP and lateral planes were collected for a 10 second period using a force platform; three dimensional body motion was recorded using a CODA mpx 30 system
Results: Following bone conducted sound, lateral displacement of the body, away from the stimulus, was recorded in subjects facing forwards (9.7mm mean displacement at C7 2s after stimulus onset). Displacement in opposite directions was observed upon stimulation of the left and right sides. In the AP plane, the displacement was variable between subjects, although as strong as the lateral effect in some. Ground reaction force responses consisted of “on” and “off” components that commenced at around 200ms and peaked at around 500 ms. The direction of these forces was in keeping with the observed lateral sway. Stimulation of the left and right mastoids produced oppositely directed ($p<0.05$) lateral “on” responses of 0.22 N and 0.32 N (measured over 300 ms) to the right and left respectively. AP forces, also consisting of “on” and “off” components, were measured over the same interval with mean forward directed “on” response values of 0.13 N and 0.16 N respectively. These were not affected by side of stimulation ($p>0.05$). For lateral and AP measures, ‘off’ responses were observed at similar latency to ‘on’ but in the opposite direction. With the head rotated by 90◦, stimulation evoked a consistent AP displacement away from the stimulus.
Conclusion: Bone conducted sound evokes a sway response with distinct lateral components that change direc-

tion with stimulus side. Based on animal work these are likely to represent otolith activation. The lateral components may be produced by utricular activation and the AP components by saccular activation.

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O166

Vestibular Impairment in Children with Sensorineural Hearing Loss

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Background: Complete evaluation of vestibular function has been performed on children referred for hearing loss or equilibrium problems in our department for over 15 years. This is part of the first evaluation for all hearing loss patients and cochlear implants candidates. The prevalence of vestibular impairments in children suffering from hearing loss is not well established (particularly in young children), because vestibular testing is often considered not feasible at these age and is often incomplete.

Objectives: The purpose of this study is to determine the prevalence of vestibular impairments in children referred for sensorineural hearing loss (SNHL), and determine if SNHL is a predictor of vestibular impairment. This would help to diagnose the pathological mechanism of inner ear damage. Furthermore vestibular functional evaluation could guide the choice of side for the cochlear implant and thus not impairing any existing vestibular function (the risk of vestibular deficit post-implant was evaluated as 5.5% ref.1).

Methods: The test battery for vestibular evaluation includes: clinical oto-neurological and vestibular examination, canal testing (caloric test, pendular stimulation, earth vertical axis rotations with 40°/s² acceleration), otolith testing (off vertical axis rotation at 60°/s with 13°tilt, vestibular evoked myogenic potentials, subjective vertical and horizontal measurements). VOR is recorded with electro-oculography. Of the 139 patients selected for this study, 69 were girls and 70 boys, with a mean age of 6 years 3 months ± 4 years 2 months. The severity of SNHL (based on the mean threshold for the best ear at 0.5, 1 and 2 kHz) was distributed as follow: 30% profound SNHL ($\geq$90 dB) of which 21(15%) were candidates for a cochlear implant; 6% were mild SNHL ($\leq$40dB) and in 64% thresholds were ranged from 40 dB to 90 dB.

Results: There was not always correlation between the severity of the SNHL and the severity of vestibular dysfunction. 43% of the children with unilateral or bilateral SNHL showed normal responses to all vestibular testing. Bilateral SNHL patients had bilateral vestibular impairment in 44.2% of cases. For unilateral SNHL vestibular responses were normal for 54.3%, and abnormal in 45.7%. For the latter, the vestibular impairment was ipsilateral to the hearing loss in 30.5% and on the opposite side in 15.2% (in these cases the vestibular dysfunction was only unilateral in 8.7% and bilateral in 6.5%). Equilibrium problems were present only in 27.3% of the uni or bilateral SNHL (vertigo, dizziness or disequilibrium). Reports of delay of walking and axial hypotonia were observed in 18% of the profound SNHL and all of these patients had a severe bilateral vestibular deficit.

Conclusion: Our results show that there is not always a comparable impairment in the cochlear and the vestibular part of the inner ear when a SNHL is diagnosed. Furthermore, a unilateral SNHL can be associated with a vestibular dysfunction in the other ear in 15.2% of patients. This suggests that the pathological process responsible of the SNHL could involve both inner ears. We conclude that complete vestibular testing should be performed for all SNH patients in order to evaluate more precisely the severity of the inner ear disease, the prognosis of the SNHL and inform the decision for appropriate treatment. In cochlear implant patients, the choice of the side to implant should take into account the quality and laterality of retained vestibular function.

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O167

The Use of Vestibular Reafference in the Control of Voluntary Movement

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Background: Vestibular information contributes to many functions involving the detection and quantification of self-motion. Galvanic vestibular stimulation (GVS) provides a tool for probing these different functions. In the present experiments we have used GVS to investigate the role of the vestibular system in the feedback control of voluntary movement.

Objectives: We hypothesize that during the execution of a goal-directed voluntary movement involving head motion in space, on-line motor adjustments are made based on reafferent signals from the vestibular system [1]. Thus a specific voluntary movement will be associated with a particular pattern of vestibular input as the head moves. Deviations from the expected afferent input indicate that the movement is not progressing according to the motor plan. Accordingly, we predict that on-line adjustments of a vol-

untary movement will occur when movement-related vestibular input is distorted by GVS.
Methods: An important component of the GVS signal appears to represent the vector sum of afferent firing from all six semicircular canals [2]. With binaural, bipolar GVS this results in a rotation vector approximately in the roll plane of the head. We therefore trained healthy subjects to perform discrete trunk tilts of 10deg in the frontal plane while seated on a stool. Vision was occluded during the movement but visual feedback of final head tilt was given at the end of each movement. After training, GVS was applied during movement for one in four trials selected at random. GVS was locked to the head movement by driving the stimulator with a current profile proportional to the head angular velocity. In half the GVS trials the current polarity was reversed. During the experimental session, subjects continued to receive visual feedback at the end of each movement for the control trials only.
Results: Subjects successfully learnt to execute the trunk tilt movement with a duration of around 1 to 1.5s and with a bell-shaped angular velocity profile. The velocity profile and tilt amplitude were altered in those trials in which GVS was delivered. At 1s after movement onset, tilt amplitude was 31.4% greater than control ($p<0.05$) when the polarity of GVS acted to reduce the movement-related semicircular canal afferent input. This effect reversed ($p<0.05$) with reversal of GVS polarity leading to 8.4% less tilt than control. The adjustment to voluntary movement occurred around 400ms after movement onset.
Conclusion: The results support the hypothesis that vestibular reafference is used for on-line control of voluntary movement involving head motion in space.
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O168

Galvanic-Induced Body Sway in Vestibular Schwannoma-Patients

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Background: Galvanic Induced Bodysway (GBS) remains mostly unaffected in patients with caloric hyporeflexia lacking signs of retro-labyrinthine disorders. This suggests that only retrolabyrinthine excitation accounts for response to galvanic stimuli. Neurectomy and a disturbed vestibular nerve function in VS-patients could allow differentiation between the vestibular nerve and more central located parts of the vestibular system as sites for retro-labyrinthine galvanic excitation.
Objectives: Identification of possible contribution of the central vestibular system to GBS
Methods: Prospective experimental study conducted in a tertiary referral center. 23 subjects with vestibular Schwannoma (identified by GD-enhanced MRI) were tested before and after extirpation of tumor with concomitant vestibular neurectomy and compared to responses obtained in 47 healthy subjects. Monaural stimulation was applied to the subjects via retro-auricular placed electrodes and on the neck at the C7 vertebra. Left and right sides were stimulated alternately 3x for 40s (cosinus 0.5-Hz, 2 mA). GBS was measured with a force platform and fed into the computer for data-storage and signal analysis. GBS gains at 0.5 Hz were calculated by spectral analysis and averaged per test (n=3). All VS-patients first underwent a caloric and examination and tone audiometry. Next, galvanic stimulation was performed in patients and healthy subjects.
Results: Caloric excitability and hearing of the affected side were significant lower then at the unaffected side (resp. UW 46.9 % (SD=30.2) and side difference 40 dB (SD=27)). No significant differences were observed between left an right GBS in healthy subjects and in VS patients before surgery. Only after surgical intervention a significant difference of GBS-gain on the affected side relative to the GBS in healthy subjects and to the unaffected side was observed. Post-operatively, GBS-gain of the unaffected side in VS-patients was not significant different from GBS gain in the healthy controls. In two patients with small tumors, GBS was nil after surgery.
Conclusion: This study showed no significant differences comparing the GBS-gain of VS-patients versus healthy subjects. This suggests that the galvanic stimulus can bypass the disturbed nerve to excite more centrally located vestibular structures directly. This hypothesis was further supported by the observation that after surgery (including neurectomy of SVN and IVN) still a GBS exists. In two patients with small tumors, GBS was nil after surgery, which suggests that not in all patients stimulation of the central vestibular system takes place. The significant difference ($p<0.001$) of the mean total GBS-gain (affected side) in all VS-patients after surgery versus healthy controls indicates that stimulation of the nerve significantly contributes to the GBS. To summarize we suggest that the GBS arises from stimulation of the vestibular nerve but also from excitation of more centrally located vestibular structures (vestibular nuclei, cortical areas).

O169

Enhancing the Use of Clinical Romberg Testing

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Background: Romberg testing is ordinarily performed with hips and knees near the limits of maximal extension. We have noticed that patients during clinical assessment will often voluntarily make this task less difficult by performing it in a crouched position, similar to a skier preparing to navigate over rough terrain. Tandem Romberg testing is difficult and at first glance, crouching seems to lower the center of gravity a small amount. However, this stance

flexes the hip, the knee and the ankle and we feel this increases information available at these joints that could potentially be used to stabilize the body in the presence of a diminished support surface (tandem stance). It also allows both flexion and extension movements at hip and knee, as well as hip abduction, and all of these changes allow for increased control.
Tandem Romberg is a task that has not been quantified clinically, and extension movements at hip and knee as well as hip abduction giving more control.
Tandem Romberg is a task that has not been previously quantified clinically. It serves as a gross measurement of standing balance. Swaystar is a belt mounted device that measures sway amplitude and velocity in the pitch and roll planes, thus making it possible to quantify sway during clinical assessment.
Objectives: We aimed to quantify the difference in sway during standard tandem Romberg assessment and during "crouched Romberg" testing, to verify our clinical suspicions that this is a beneficial strategy for maintaining balance.
Methods: We evaluated the performance of 20 subjects with no history of orthopaedic, neurological or vestibular complaints. We recorded sway amplitude and sway velocity in pitch and roll planes during tandem Romberg testing and also during "crouched Romberg" testing, using the flexion strategy. To make this task more challenging and unique we also performed it on a bank of 10 degrees. Amount of sway was also compared to sway standing on one foot, which is a much easier task.
Results: A significant difference in stability (reduction in sway amplitude) was shown by our subjects when they adopted the flexion strategy ("crouched Romberg") while performing Romberg testing.
Conclusion: Almost everybody referred to our dizziness clinic has vestibular disease, and few if any of them can tandem Romberg with eyes closed, which decreases the value of this technique. Some assessors use a task such as standing on one leg as a balance assessment tool, but we feel that it does not accurately assess standing balance, as it allows for flexion of the limb, and also allows a patient to use a counterbalance mechanism using the contralateral limb. We feel that it is not as accurate as tandem Romberg testing, but we saw the need to make Romberg testing easier, allowing us to assess the patient with a vestibular deficit. Our findings of better performance in the flexed Romberg may translate into a balance maintenance technique for patients with subtle deficits at times when their balance is unexpectedly compromised (e.g. on a ladder in a wind, or on a slippery roof).

O170
Influence of Gait Speed on Tandem Walking

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Background: Tandem walking testing is used clinically to assess balance in the office setting but is difficult to quantify. Swaystar is a belt mounted device which we use to quantify sway amplitude and velocity during walking and, using this device, we have shown that there is increased sway during tandem walking brought on by the ingestion of small doses of alcohol. During this study, we observed that at least one of our subjects showed decreased sway under the influence of alcohol, and they did so by electing to perform the required task at an increased rate of speed. This apparently paradoxical observation is consistent with some of our patients who sometimes report anecdotally that they are more secure when walking faster or when skiing down the steeper slopes at the local mountain. It has also been reported by Geurts that stability increases with increased speed, and an astute chance observation by Brandt, whose dog serendipitously suffered an acute vestibulopathy, showed him that his dog was not able to walk in a straight line, but was able to run straight.
Objectives: Based on our initial experiment and the anecdotal observations of ourselves and others, we postulated that healthy young subjects would be able to decrease sway by increasing the rate of walking speed, thus developing a different strategy. Furthermore, we hypothesized that we could disrupt the performance of these subjects and increase their sway by interfering with their normal cadence while performing tandem walking. This could be accomplished by having subjects walk at an unnaturally slow speed, or in time with an assessor-set metronome (another unnatural cadence).
Methods: Twenty young healthy subjects were asked to perform tandem walking while wearing Swaystar, which measures sway amplitude and sway velocity in the pitch and roll planes. Tasks included tandem walking with five different protocols, with order of performance randomized from subject to subject.
Results: In a group of healthy subjects, performance during tandem walking (measured by sway amplitude in the pitch and roll planes) deteriorated as the task speed slowed, and also deteriorated as preferred cadence was disrupted. In addition, there is a gradation of difficulty across the speeds.
Conclusion: The increasingly poor performance we saw (evidenced by an increase in sway in the pitch and roll planes) is related to decrease in speed at which the subject is required to perform tandem walking. We postulate that any significant variation of the slope of this relationship from the normal is indicative of pathology. Most people have a reasonably effective strategy for balance maintenance. The concept of compensating for a vestibular lesion entails an attempt to re-create the normal patterns of walking, and a patient with active or uncompensated disease will see a precipitous decline far beyond normal, in their ability to perform tandem walking under conditions where the normal cadence is disrupted, or where they are forced to perform the task at an unnaturally slow speed.

O171
Genetic Causes of Episodic Vertigo and Imbalance

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Background: Several neurotologic disorders are known to occur in families, yet studies of familial vestibular disorders have lagged behind those of sensorineural hearing loss, likely because of relatively few careful studies and difficulty in ascertaining vestibular dysfunction. Recent advances in episodic ataxia type 2 and familial hemiplegic migraine types 1 and 2 may enhance our understanding of the genetic mechanisms of the more common episodic vertigo and ataxia syndromes, particularly those associated with migraine.
Objectives: to identify genetic causes of episodic vertigo and imbalance by documenting patients with familial vestibular disorders, mapping disease loci, and identifying disease-causing mutations in the responsible genes.
Methods: We have clinically characterized all patients presenting to our neurotology clinic with complaints of recurrent episodic vertigo and imbalance. We try to stratify patients into subgroups to minimize clinical and genetic heterogeneity. We extracted DNA from peripheral blood samples of consenting subjects and their relatives. We screened for mutations in the two FHM genes in the index patients of families with hemiplegic migraine, basilar migraine, migraine without aura, or migraine with aura. In families with more than 3 affected individuals with recurrent vertigo or vestibulopathy, we performed genome scan and carried out linkage analysis.
Results: In all the patients whom we screened for mutations in the two FHM genes, we found only one mutation in one patient with hemiplegic migraine and episodic ataxia with progressive features. Migraine appeared to be highly prevalent in families with benign recurrent vertigo, characterized as recurrent vertigo without interictal neurological, vestibular, or otologic deficits. More than two-thirds of relatives of index patients with recurrent vertigo met the diagnostic criteria for migraine.
Conclusion: The two FHM genes are not associated with more common migraine syndromes and are not the most common hemiplegic migraine genes. Familial benign recurrent vertigo seems to be a migraine syndrome, probably inherited in an autosomal dominant fashion with decreased penetrance in men.
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O172
Pathophysiology of Migraine-Associated Dizziness

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Background: The pathophysiological basis for migraine-associated dizziness is unknown but may relate to both central and peripheral vestibular abnormalities.
Objectives: To explore several potential abnormalities in migraine-associated dizziness, we assessed vestibulo-ocular function, vestibulo-spinal function, visual-postural responses, spatial orientation, and the attention-balance interference in patients with migraine-associated dizziness.
Methods: Experimental subjects included headache-free controls (C), subjects who met the International Headache Society (IHS) criteria for migraine but who had no symptoms suggestive of a vestibular system abnormality (M-V), and subjects who met both IHS criteria for migraine and the Neuhauser et al.[1] criteria for migraine-associated vestibulopathy (M+V). Subjects with recognized neurotologic syndromes such as Meniere's disease or BPPV were excluded from all groups. For each experimental paradigm, five subjects from each group were tested. Vestibulo-ocular measures included responses to both semicircular canal and otolithic stimulation. Vestibulo-spinal function was measured with Equitest ™. Visual-postural responses were assessed using full-field optic flow in an immersive environment. Spatial orientation was assessed with the rod and frame and the rod and disk tests. The attention-balance link was assessed by combining rotational vestibular stimulation with a reaction time task.
Results: Abnormalities in M+V subjects included: decreased semicircular canal-ocular reflex gain, increased modulation during constant velocity off-vertical axis rotation, increased sway on platform posturography in a pattern consistent with a vestibular system abnormality, increased sway response to optic flow in an immersive virtual environment, slowed reaction time while testing interference between attentional processes and the VOR, and excessive visual dependence on subjective visual vertical testing.
Conclusion: Taken together, these results suggest that patients with migraine-associated dizziness manifest abnormalities in vestibular function and are more visually dependent than persons with migraine without vertigo or headache-free controls. The basis for these group differences is uncertain but may relate to changes in central nervous system structures that are common to the phenomenon of migraine and to central vestibular processing. Possibly, serotonergic mechanisms in the central vestibular system account for some of the pathophysiological changes in migraine-related dizziness.
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O173

Epidemiology and Clinical Aspects of Migraine-Associated Dizziness

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Background: About 16% of the adult population is affected by migraine at some time in their lives, and nearly 30% by dizziness or vertigo. The association of vertigo and migraine is complex, comprising vertigo that is causally related to migraine (migrainous vertigo, MV), vertigo syndromes that are not caused by migraine but show a statistical association with migraine such as BPPV or Menière's disease, and concurrence of these two common complaints by chance alone.
Methods: We have proposed the following diagnostic criteria for MV, which emphasize specificity: 1. Recurrent episodic vestibular symptoms of at least moderate severity. 2. Current or previous history of migraine according to the criteria of the International Headache Society. 3. At least one migrainous symptom during at least two vertiginous attacks: migrainous headache, photophobia, phonophobia, visual or other auras. 4. Other causes ruled out by appropriate investigations
Results: According to these criteria, we diagnosed MV in 7% of 200 unselected dizziness clinic patients and in 9% of 200 unselected migraine clinic patients. In a two-stage population-based study (n=4869 adults) with screening telephone interviews followed by expert telephone interviews, we found a lifetime prevalence of MV in the general adult population of 0.98% (95% CI 0.7 - 1.37). The clinical spectrum comprises spontaneous spinning vertigo, positional vertigo and a seasick-type sensation that is aggravated by head movement and complex visual environments. Duration of attacks varies from seconds to days; a common presentation is dizziness for several hours or days with superimposed vertiginous spells. Several large case series have documented that headache is missing during some or all of the attacks in at least 50% of patients. Auditory symptoms may accompany MV and include tinnitus (25-60%), hearing loss (30-50%) and aural fullness (30-55%). In contrast to Meniere's disease, hearing loss is usually not severe and non-progressive. Investigating 20 patients with acute MV, we found a central type of nystagmus in 10 patients: two had central spontaneous nystagmus, five had positional nystagmus and three had a combination of the two. Three patients had acute peripheral unilateral hypofunction while seven patients had only minor abnormalities and could not be classified with certainty. Interictally, mild to moderate central or peripheral vestibular findings are common.
Conclusion: The treatment of migrainous vertigo has not been studied by large controlled trials. Case reports suggest that acute attacks may be ameliorated by vestibular suppressants and triptans while effective prophylaxis may be achieved by migraine prophylactic drugs such as beta blockers, pizotifen, flunarizine or amitriptyline.

O174

Vertigo and Migraine in Children

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Background: The prevalence of vertigo in children is not precisely known because this symptom is often not clearly expressed by young children and is hence misdiagnosed. Thus children with vertigo are successively referred to several specialists and, in many cases, unnecessary CT scans or NMRs are performed. Vertigo migraine equivalent (VME) is the most frequent origin of vertigo in children (25 to 30%) and is often confused with benign paroxysmal idiopathic vertigo (BPV; 20 to 25%). The third most frequent cause of vertigo in children is cranial traumatism (10%) and the fourth oculomotor disorders (10%).
Objectives: This study of a large population of children attempts to better define the incidence of migraine equivalent in the diagnoses of vertigo in children and review the therapeutic outcomes available.
Methods: The study was done on a group of 987 children referred for dizziness and vertigo. In 30% of these patients VME was diagnosed when vertigo was associated or alternating with headache and there were no other abnormalities found in the oto-neurological and vestibular examinations. The complete vestibular battery of tests commonly included canal testing (caloric test, pendular stimulation, earth vertical axis rotation with 40°/s² acceleration) and otolith testing (off vertical axis rotation 60°/s² and 13° tilt, vestibular evoked myogenic potentials, subjective vertical and horizontal measurements). Hearing thresholds were measured with tonal and vocal audiometry and impedance testing.
Results: Most often the onset of VME occurs in children around 10 years of age, but only rarely in infants (less than 1 y.o.). Episodes of vertigo can be intense (rotatory sensation or dizziness) with autonomic syndromes (nausea, vomiting, sweating, pallor), and photophobia. It lasts from more that 15 minutes to several hours. Recurrence is variable and can be incapacitating. These patients had completely normal results in the neurological examination and normal responses to the audiological and vestibular tests. We found that more than 20% of these migraine-suffering children showed ophthalmological disorders (refraction abnormalities /or vergence dysfunction). In these cases VME was often triggered by visual fatigue (after long computer screen exposure or reading, during or after school). Correct diagnosis and adapted treatment of these ophthalmological problems greatly decrease the intensity and frequency of VME and avoid the need for extensive medication. AINS associated with analgesics is the first treatment suggested for the management of VME crisis; more specific anti-migraine medication can secondarily be chosen as a func-

tion of age. We did not found any correlation between the occurrence of VME and of BPV when the latter diagnosis was strictly limited to Basser's description. BPV was diagnosed (in 24 % of the cases) only if children were 2 to 4 years old, when vertigo or ataxia lasted less than 10 minutes, was not triggered by position, not associated with nausea, vomiting, pain or behavioral modification before and after the crisis and no abnormalities were found at the otological-neurological and vestibular examinations. BPV requires neither treatment nor brain imaging because it resolves spontaneously. Another group of patients was identified with symptoms suggesting episodic ataxia type II (12 patients observed in 7 years). These children were from an early age (as early as 4 months!) suffering from very intense recurrent episodes of headache, vertigo, ataxia, vomiting with a remarkable regularity (every month or two months). Complete examination and testing was normal as well as CT scans and NMR. Acetazolamide is actually the only treatment for these patients but new drugs with fewer side effects on a long term are in study. Posterior fossa brain tumor is a rare diagnosis (less than 1% in our population); it was associated with instability more than vertigo and always with neurological signs.
Conclusion: Vertigo as migraine equivalent represents 1/3 of children's vertigo. This should be distinguished from VPB, and requires a complete otological, neurological, vestibular and ophthalmological examination (including refraction and vergence measurements) before any other complementary tests. Brain imaging will be considered necessary at first only when neurological signs are found.

O175

Next Steps in Space Neurovestibular Research: Preparing for Missions to the Moon and Mars

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One year after the loss of the Space Shuttle Columbia, US President Bush committed NASA to human and robotic exploration of the solar system, including a return to the Moon by 2020 in preparation for human exploration of Mars. Russian and European goals are also evolving. US research on the International Space Station has been refocused on the development of specific countermeasures against the biomedical risks of space flight. The neurovestibular/sensory-motor community will face unprecedented challenges in protecting the health, safety, and performance of the crews aboard these missions. An international panel of seven vestibular scientists and clinicians will discuss these challenges, and plans to meet them, followed by a thirty minute general discussion with attendees.

O176

Neuro-Vestibular and Sensory-Motor Challenges Associated with NASA Mission Architectures for Moon and Mars

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Data from six-month low Earth orbit space flight missions suggest that that substantial neuro-vestibular/sensory-motor adaptation will take place during six-month transit missions to and from Mars. Could intermittent or continuous artificial gravity be used to offset these effects? To what degree would the effects of adaptation to this rotational cure affect its potential benefits? Also, little information exists regarding the gravity thresholds for maintaining functional performance of complex sensory-motor tasks such as balance control and locomotion. Will sensory-motor coordination systems adapt to 30-90 days of 1/6 g on the lunar surface or 18 months of 3/8 g on the Martian surface? Would some form of gravity replacement therapy be required on the surface? And, will transitions between 0 g and 1/6 g or 1/3 g present as great a challenge to the vestibular system as transitions between 0 g and 1 g? Concerted research and development efforts will be required to obtain the answers.

O177

Neurovestibular Risks of Spaceflight

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NASA and NSBRI scientists are continuing to evaluate the biomedical risks of spaceflight in terms of their probability and severity, based on both research and operational experience. In the neurovestibular domain, risks include in-flight disorientation and space sickness, sopite syndrome and "space stupids", vestibular Coriolis effects due to artificial gravity, landing vertigo, and post landing ataxia. On hypogravic missions lasting several years, we must also remain vigilant for the possibility of irreversible neurovestibular changes. NASA operational and clinical evidence relating to these risks will be reviewed.

O178

NASA/NSBRI Countermeasure Research

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NASA and the National Space Biomedical Research Institute have been working to better define the neurovestibular risks of space flight, and develop potential countermeasures. The latter include techniques for evaluating the relative role of visual, gravitational, and idiotropic effects on orientation, preflight visual orientation training, quantitative assessment of postflight locomotion, gaze and visual acuity deficits, exercise, techniques for inducing adaptive

generalization, and improving postural stability using a vibrotactile display.

O179
Recent Aspects of Neurovestibular Research in the ESA Microgravity Program
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Neurovestibular research constitutes one of the major branches in the life science programs of ESA and the national space agencies. For many years this has involved the investigation of basic vestibular and vestibulo-oculomotor functions in prolonged 0-g and after return. In recent years attention has been given to the influence of microgravity conditions on sensory-motor co-ordination and perception of three-dimensional space. This has bearing both on basic research and operational space medicine. Given the central role of the otolith organs in the mediation of gravitoinertial force, there have also been repeated examinations of otolith function in connection with the physiological implications of space travel. The refinement of otolith assessment techniques promises considerably more insight into the otolith function and the influence of altered gravity conditions. All of these approaches require adequate stimulus and measurement equipment. Fortunately, such equipment is now becoming available on the ISS, permitting new approaches to the often complex multisensory questions.

O180
Russian Countermeasure Research Strategies
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Research at the Institute of Biomedical Problems in Moscow includes studies of human sensory-motor and autonomic function and exercise during and after prolonged weightlessness in orbit and due to immobilization in ground laboratory simulations. Results will be discussed in the context of countermeasures for spaceflight.

O181
Short Radius Artificial Gravity Concepts and Countermeasure Development
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A short radius centrifuge inside a spacecraft could provide intermittent artificial gravity as a countermeasure against musculoskeletal, cardiovascular, and neurovestibular deconditioning. However, when a 2m radius centrifuge is rotated at 160-180 deg/sec; fast enough to produce in excess of 1-g at foot level, head movements about any axis not aligned with the centrifuge spin axis produce the well known vestibular Coriolis illusion and often causes motion sickness. Recent ground research shows the extent of context-specific dual adaptation that can be developed, allowing subjects to eventually make restricted head movements on and off the spinning centrifuge without discomfort.

O182
Postflight Neurological Assessment and Terrestrial Applications of Space Neurovestibular Research
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According to the NASA Longitudinal Study of Astronaut Health database vestibular symptoms experienced by most astronauts in the post-flight period include nausea, vomiting, vertigo while walking, vertigo while standing, and difficulty walking a straight line. Recovery from shuttle duration flights is faster (~4—8 days) than from longer duration (ISS ~weeks to months) exposure to microgravity. A NASA plan for longitudinal objective evaluation of vestibular function in astronaut crew members as part of a periodic Clinical Status Evaluation will be described and discussed in relation to possible development of predictive data.

O183
Anterior Canal Variant of Benign Paroxysmal Positional Vertigo
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Background: The anterior canal variant of benign paroxysmal positional vertigo (BPPV) is considered an uncommon finding, and it is characterized by a positional, down beating nystagmus (pDBN). This variant has been described in occasional reports estimating a frequency between 1-11% [1-3].The only recent study that clarify the clinical significance of pDBN in cerebellar disorders reported a series of 12 patients with possible anterior semicircular canalithiasis [4].
Objectives: We describe the clinical features and videooculographic (VOG) findings in patients with anterior semicircular canal benign paroxysmal positional vertigo (BPPV).
Methods: Study Design: A prospective case series. Setting: A outpatient clinic in a general hospital. Patients: Nine individuals with symptoms of BPPV and positional down beating nystagmus (pDBN) were included in the study. The diagnosis was based on a history of brief episodes of vertigo and the presence of pDBN confirmed in the VOG examination during Dix-Hallpike test or head-hanging maneuver. Intervention: Patients were treated by the particle repositioning maneuver (PRM) and the effectiveness was evaluated at 7, 30 y 180 days post-treatment. The treatment was repeated up to 4 times if pDBN was persistent. Main

Outcome Measures: number of patients without pDBN at 30 and 180 days.
Results: The pDBN was observed in the 21% of the individuals with BPPV. Six of the nine patients had arterial hypertension and 55% cases presented abnormalities on the caloric test. Horizontal spontaneous nystagmus was found in 2/9 individuals and a positive head-shaking nystagmus in 4/9 cases. Multiple positional nystagmus was observed in 5 of 9 individuals, suggesting the involvement of several canals. Five of nine (55%) did not presented vertigo or positional nystagmus at 30 days post-treatment. However, one of the patients maintained a persistent pDBN at 180 days, despite of the repeated maneuvers.
Conclusion: The pDBN can be found in 21% of cases of patients with BPPV without CNS abnormalities. These individuals are likely to show alterations in the vestibular caloric or head-shaking testing and they can have multicanal affectation in 55% cases.
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O184
Atypical Positional Nystagmus in Benign Paroxysmal Positional Vertigo: 3D Study of 40 Patients
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Background: Benign paroxysmal positional vertigo (BPPV) is characterized by vertigo during changes in gravitational head position (Dix and Hallpike 1952) due to activation of the semicircular canal receptors by misplaced otoconia either free floating or adherent to the cupula. It occurs most commonly in the posterior (Dix and Hallpike 1952) or horizontal canal (Baloh et al. 1993). However in some patients, the positional nystagmus does not conform to the typical patterns identifiable with either of these semicircular canals.
Objectives: To localize the semicircular canals involved in benign paroxysmal positional vertigo with atypical positional nystagmus by 3D vector analysis of the positional nystagmus.
Methods: Positional nystagmus from 40 BPPV patients provoked by the Dix-Hallpike or supine ear-down test with a two-axis manual rotator was measured with dual search coils. The eye rotation axes derived from 3D vector analysis of the positional nystagmus were compared with the published axes orthogonal to mean semicircular canal planes (Blanks et al. 1975) to determine the semicircular canals affected.
Results: We identified three profiles of atypical positional nystagmus consistent with involvement of bilateral posterior canals, superior canal, and combined posterior-horizontal canals from the same or opposite ear. In bilateral posterior canal BPPV, Dix-Hallpike provocation of either ear generated an eye rotation axis, which aligned with the on-direction of the activated posterior canal i.e. downward with torsional slow-phase directed away from the dependent ear. Eye rotation axis from superior canal positional nystagmus during Dix-Hallpike provocation aligned with the on-direction of the activated superior canal consisting of upward torsional slow-phase directed away from the affected ear. Eye rotation axis from combined posterior-horizontal canal BPPV aligned part-way between the on-directions of posterior and horizontal canals consisting of downward and large horizontal-torsional slow-phase directed away from the dependent ear. In contrast to horizontal cupulolithiasis, in which provocation of the affected semicircular canal produces an inhibitory response, positional nystagmus evoked by the Dix-Hallpike test from posterior or superior cupulolithiasis are excitatory responses.
Conclusion: We showed that BPPV could affect the posterior, horizontal or superior canal individually or concurrently with other semicircular canals from the same or opposite ear.
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O185
Horizontal Semicircular Canal Benign Positional Vertigo
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Background: Geotropic HSC-BPV (horizontal semicircular canal benign positional vertigo) was initially described by McClure in 1985,characterized by nystagmus provoked by supine bilateral head turns and beating toward the undermost ear. It produces short latency nystagmus with prolonged duration and poor fatigability. Geotropic HSC-BPV is believed to be caused by freely moving debris or particles in the long arm of the horizontal semicircular canal

that stimulate utriculopetal endolymph flow during supine head turn to the affected side and utriculofugal flow when the head is turned away from the affected side. The ageotropic variant, thought to be rarer, was not reported until ten years later when Baloh (1995) and later Casani (1997) recognized it. Ageotropic HSC-BPV is characterized by short latency prolonged nystagmus beating away from the undermost ear in bilateral supine head turns. Ageotropic HSC-BPV may be due to debris that adheres to the cupula of the horizontal canal, rendering it gravity sensitive during supine head turns. HSC-BPV is rare, affecting only about 2% of patients with benign positional vertigo.

Objectives: Describe the author's experience with the diagnosis and management of a case series of 20 consecutive patients with HSC-BPV, including diagnostic vestibular test sensitivity and findings, and response to repositioning.

Methods: Review of 20 consecutive patients with idiopathic HSC-BPV (10 with geotropic and 10 with ageotropic nystagmus) presenting to a tertiary balance center. Diagnosis was confirmed using recorded infrared video nystagmography, and sixteen patients had full vestibular testing. Patients were treated with one or more repositioning maneuvers including the 270-360 degrees Lempert roll, Casani-Gufoni, and Vanucchi-Asprella techniques.

Results: 1) Dix-Hallpike position testing is relatively insensitive to HSC-BPV 2) Vestibular test findings include isolated reduced cold caloric responses in geotropic HSC-BPV and significant caloric and VOR abnormalities in ageotropic HSC-BPV 3)Vertigo resolved in all 10 patients with geotropic HSC-BPV but in only 5/10 patients with ageotropic HSC-BPV.

Conclusion: The accuracy of HSC-BPV diagnosis is improved by adding supine head turns to traditional Dix-Hallpike position testing. Outcomes in geotropic HSC-BPV were excellent; however ageotropic HSC-BPV is a chronic condition in 50% of patients, and is associated with significant vestibular test abnormalities. The implications are discussed relevant to theories of otolith-horizontal canal interaction.

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O186

Horizontal Canal Benign Positional Vertigo

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Background: Although Schuknecht predicted the existence of horizontal canal benign positional vertigo (BPV) in 1969, it was not clinically described until 1985 by McClure. The mechanism can be canalithiasis or cupulolithiasis. Epley was the first to describe the sudden "conversion" of posterior canal BPV to the horizontal canal variant, and to suggest a repositioning treatment for it, which has been refined by others.

Objectives: Between 1995 and 2004 the author has treated 400 patients with BPV. There were 48 (12%) with the horizontal canal variant, whose detailed records were reviewed to extract: age, sex, onset, preceding cause, mechanism (conversion, canalithiasis, cupulolithiasis), treatment and outcome.

Methods: A "barbecue" repositioning rotation of 360 degrees was done at least twice. When the direction of nystagmus implied cupulolithiasis a reverse direction repositioning was done if the standard direction did not improve or aggravated the vertigo. Followup was at between two and five weeks to confirm cessation of vertigo, and later by telephone for the final correlation of results.

Results: The age range was 29 - 87 years (median 59 years). In 17 there was canal conversion (the most intense vertigo) with immediate response to appropriate repositioning and no recurrences. The largest group had canalithiasis (N = 25) with 8 recurrences. The smallest group had cupulolithiasis (N = 8). Two patients had cupulolithiasis and canalithiasis at different times.

Table:

Followup Without Recurrence		
Conversions (N = 17)	Canalithiasis (N = 25)	Cupulolithaisis (N = 8)
2 mo – 8 yr (median 5.5 yr)	2 mo – 8 yr (median 4 yr)	2.5 yr – 7 yr (median 4 yr)

Conclusion: The horizontal canal form of BPV explains nearly all the variations from "typical" BPV. Correct identification of the symptomatic ear and correct repositioning results in immediate cessation of vertigo in most cases.

O187

Treatment of the Apogeotropic Variant of Horizontal Canalithiasis

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Background: Gufoni et al [1] proposed a maneuver to shift the canaliths from the anterior to the posterior arm of the horizontal canal obtaining a change of the apogeotropic variant of the benign paroxysmal positional vertigo in that geotropic and accelerating the successful recovery of the symptomatology.

Objectives: The aim of the present study was to evaluate the effectiveness of this new maneuver in the treatment of the apogeotropic variant of the horizontal canal.

Methods: 20 patients suffering from apogeotropic horizontal canalithiasis were studied. The whole series was evalu-

ated between 2001 and 2003.All of the patients were treated with the Gufoni maneuver [1]. It consisted of the following steps: 1.the patient sits on the side of the treatment table with the head straight ahead 2.the patient is very quickly moved into a side-lying position on the affected side and remains in this position one minute after the end of the apogeotropic nystagmus 3.the head of the patient is very quickly turned 45° upward and kept in this position for two minutes 4.the patient slowly returns to the sitting position.

Results: In eleven patients (55%) the diagnostic repeated maneuvers with a head turn laterally in supine position resulted sufficient to transform the apogeotropic canalithiasis into the geotropic one. In the other nine cases (45%), the persistence of the apogeotropic variant induced us to perform the Gufoni maneuver. All the patient had the change in the geotropic variant and thus they were treated with the specific repositioning maneuver. All patients had been successfully cured.

Conclusion: Our results confirm the effectiveness of the Gufoni maneuver. If the initial treatment is ineffective the maneuver can be repeated as after as need because of its low invasiveness and the usual absence of side effects.

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O188

Vertical Nystagmus Revealed in BPPV Patients

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Background: Vertical nystagmus has previously been considered exclusively to be an indication of a central disorder or disturbance. However, we observed a number of patients exhibiting vertical nystagmus who complained of vertigo that was positional in nature.

Objectives: Benign paroxismal positional vertigo (BPPV) patients who were revealed vertical nystagmus were analyzed.

Methods: An omni-axial chair and IR videography were used to study these patients. Nystagmus was recorded digitally and analyzed by the Public Domain NIH Image Program and macros developed by Yamaguchi University.

Results: Several factors leading us to determine that the vertical nystagmus in these cases had peripheral origins were: 1. Although the nystagmus was predominantly vertical, it contained a rotatory component, sometimes transient. 2. The nystagmus responded to changes in the gravity vector. 3. Not only did these patients not have any positive central findings, but many were in their youth. 4. The nystagmus improved with use of a 360-degree rotation of a posterior or anterior canal in the earth-vertical plane, or other repositioning procedures.

Conclusion: We propose that vertical nystagmus may, at times, be caused by complicated labyrinthine lithiasis (such as multiple semicircular canal involvement or heavy cupulae) and may be treatable.

O189

Effectiveness of Nurse-Delivered Vestibular Rehabilitation for Dizziness in Primary Care: Randomized Controlled Trial

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Background: Dizziness is a very common symptom, and in many countries, including the UK, up to 90% of patients are managed in primary care. Treatment typically consists of reassurance, and anti-vertiginous and anti-emetic drugs for symptomatic relief. However, several reviews of the management of dizziness have concluded that no medication in current use has well-established curative or prophylactic value or is suitable for long-term palliative use, and have called for evaluation of an exercise-based form of treatment known as vestibular rehabilitation. Vestibular rehabilitation for dizziness is a simple treatment potentially suitable for primary care delivery, but its effectiveness has not yet been evaluated.

Objectives: To carry out a single blind randomized controlled trial to evaluate the effectiveness of nurse-delivered vestibular rehabilitation in primary care for patients with chronic dizziness.

Methods: 170 adult patients with chronic dizziness were recruited from 20 general practices in Southern England and randomized to vestibular rehabilitation (n = 83) or usual medical care (n = 87). Treatment consisted of one 30-40 minute appointment with a nurse based in primary care who taught the patient rehabilitation exercises to be carried out daily by the patient at home, supported by a treatment booklet. Primary outcome measures were assessment at baseline, three months and six months of self-reported spontaneous and provoked symptoms of dizziness, dizziness-related quality of life, and objective measurement of postural stability with eyes open and eyes closed.

Results: Improvement in the vestibular rehabilitation group was significantly greater than in the usual medical care group on all primary outcome measures at three months, and was maintained at six months. 56 (68%) of treated patients reported clinically significant improvement, compared with 33 (38%) controls (odds ratio = 3.39, 95% confidence interval 1.80 to 6.38). Treatment effects were strongest for symptoms and handicap directly related to balance system dysfunction (provoked and spontaneous

vestibular symptoms and dizziness-related handicap) and were weak or non-significant for secondary measures of general physical and psychological well-being (anxiety, depression, physical functioning).
Conclusion: A single brief session of vestibular rehabilitation delivered by nurses in general practice was effective in improving symptoms, postural stability and dizziness-related handicap in patients with chronic dizziness. Our study demonstrates that nurses in primary care are able to carry out vestibular rehabilitation effectively after just one half-day of training, using a booklet that supports both nurse and patient in understanding and appropriately tailoring the therapy. Our findings also indicate that, despite the difficulty of diagnosis, general practitioners are able to identify patients who can safely benefit from rehabilitation in primary care.

O190
Factors Influencing Adherence to Vestibular Rehabilitation

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Background: Since vestibular rehabilitation involves self-management of treatment, the success of the treatment crucially depends on the patients' adherence, but there has been no previous research determining the factors relating to adherence to this therapy.
Objectives: To determine the factors influencing adherence to vestibular rehabilitation.
Methods: Two studies were carried out, using qualitative and quantitative methods. Both studies involved employing a structured interview format to assess participants' beliefs regarding the advantages and disadvantages of taking part in the therapy, their perceptions of whether others think they should take part in the therapy, and beliefs relating to their perception of the control they have over carrying out the exercises. Study 1: 43 participants were asked to describe their key beliefs before and after taking part in vestibular rehabilitation. Study 2: 120 participants were asked to rate agreement with key beliefs using a 7-point bipolar (-3 to +3) scale. Participants' beliefs were assessed before randomization and at 3-month follow-up, with 64 participants having completed treatment and 56 controls. Adherence was also assessed at 3 months in the treatment group.
Results: Study 1: Content analysis revealed that the main perceived advantage of vestibular rehabilitation was reduction in symptoms of dizziness, but over half of the participants were concerned that rehabilitation might instead make their symptoms worse. Factors that they believed would help them to adhere to rehabilitation were 'support and encouragement', 'routine' and 'self motivation', and barriers to rehabilitation were 'physical illnesses', and 'daily schedule'. Study 2: GLM and test-retest reliability calculations both indicated much greater change in the beliefs of those who had taken part in the treatment than in the control group, with beliefs being less positive post-therapy. For the treatment group, multiple regression analyses confirmed an association between reported adherence and attitudes before and after treatment, with a stronger association with post-therapy beliefs.
Conclusion: These results indicate that attitudes to a treatment that has not previously been experienced may change considerably following experience of the treatment, and so pre-treatment attitudes may not be powerful predictors of adherence. Patients need to be reassured that the treatment will not make their symptoms intolerable, and need support during the early stages of rehabilitation when symptoms may initially worsen, and assistance with making rehabilitation a routine part of their daily schedule.

O191
Postural Deficiencies Treatment in Patients with Peripheral Vestibulopathy

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Background: Postural abnormalities are an important issue in patients with chronic disequilibrium of peripheral vestibular origin and are implicated in the level of handicap that these patients refer. As such they must be approached specifically during rehabilitation.
Objectives: To present the results after proper treatment of postural abnormalities in patients with chronic dysequilibrium. The procedure is based on the specific manipulations of limits of stability and sensory system selection during visual feedback exercises.
Methods: 37 patients seen because of persistent disequilibrium.
Questionnaire and tests-The DHI questionnaire was translated and adapted to the Spanish language following the method of cross-translation. The DHI was answered before beginning the therapy (DHIpre) and 2-3 months after ending that (DHIpost). Computerized dynamic posturography, was carried out with the SOT battery. In terms of general performance, a composite score (CS) can be given as an overall estimate of postural stability. The LOS test presents an ellipse of eight targets arrayed around a centre target at a distance determined by the patient's height. Patients were asked to shift the centre of gravity, displayed on-screen by a cursor, toward the cued target while keeping their feet in place on the force plate. This assessment quantifies several movement characteristics associated with the patient's ability to voluntarily sway to various locations in space and briefly maintain stability at those positions. Exercise protocols-Each patient attended two 1½-hour sessions per week for 5 weeks. Several exercises were performed but the following parameters were modified: 1) end-point excursion, 2) type of exercise and 3) type and degree of movement of the supporting surface and/or the visual environment. The purpose of these combinations was to make the patient to work the most dysfunctional sense in the most unique pos-

sibility by referencing the support surface and/or the visual environment to his sway not being useful during that particular exercise.
Results: There was an important reduction in the mean value for the DHI score after treatment: from 52±21 to 34±25. According to the definitions given for follow-up assessment 3 patients were considered to be "worse", 11 showed "no change" and, 23 were "better". The reduction of the value for the total score of the DHI is significant only for the group of patients that are considered to be better. There was an increase in the SOT composite score for each of the groups. Differences were significant ($p<0.001$) for the patients in the group of patients being "better". In the LOS test for each of the variables only the difference between the value obtained before treatment and after treatment is significant for the patients in the "better" group.
Conclusion: We were able to document a reduction in the handicap after postural improvement in patients treated for chronic disequilibrium. The recovery lasted more than two months.

O192
Retinal Image Stabilization (RIS) During Caloric Nystagmus Reduces Vertigo
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Background: During caloric stimulation the brain receives erroneous information of predominantly yaw head rotation. But instead of stabilizing the image on the retina, nystagmus produced by the vestibulo-ocular reflex (VOR) destabilizes the retinal image. The sensory mismatch theory [1]states that this leads to a central mismatch of sensory information, causing vertigo, discomfort and nausea.
Objectives: We set out to proof our hypothesis that artificial stabilization of the retinal image during nystagmus would reduce the sensory mismatch and thus the subjective vertigo/nausea.
Methods: RIS was achieved by coupling a monitor signal to the horizontal eye position from a high resolution (250 Hz) video-oculography (VOG) signal. 12 healthy volunteers were tested with warm water (44 deg C) caloric irrigations of both ears in complete darkness and with RIS. Immediately after each trial, subjects were asked to estimate the amount of vertigo on a scale from 0 -10. In other experiments, one ear was rinsed with ice water for 30 s, while the viewing condition was changed every few seconds between darkness, RIS, and visual fixation of a light dot to achieve visual cancellation of nystagmus. Eye movements were recorded by a 2D VOG system.
Results: We found that RIS reduced vertigo in 11 of 12 subjects by about 50% compared to complete darkness, which supports the mismatch theory. During ice water testing, vertigo was significantly less under RIS than in total darkness or with visual VOR cancellation. The variability of the slow component velocity of nystagmus (SCV) was markedly increased. Smooth pursuit eye movements interacted with the SCV.
Conclusion: Our results confirm the theory of sensory mismatch. The technique of RIS may become a new therapeutical option to treat acute vertigo.
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O193
Effects of Electrotactile Head-Based Feedback on Subjects with Bilateral Vestibular Dysfunction
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Background: Rehabilitation of patients with bilateral vestibular deficit or complete loss (BVD) is extremely difficult (if at all possible). Intensive physical rehabilitation and compensation methods can help BVD subjects regain some ability to keep balance and posture control. However, numerous symptoms - like oscillopsia, inability to stand or walk on soft ground, uneven surface, or in low luminance conditions are outside of current therapeutic capability.
Objectives: The major objective of our study was to estimate feasibility and efficacy of an electro-tactile vestibular substitution system (EVS) in aiding recovery of posture control in BVD subjects during in sitting and standing.
Methods: Twelve healthy adult subjects (control) and thirteen BVD patients (males and females, 25 - 72 yrs.) were tested. The majority of BVD patients had lost vestibular function as a result of gentamycin or streptomycin ototoxicity. One patient had "mal de debarkment" syndrome and one had physical damage to both labyrinths (fistulas).
Results: We found two groups of EVS effects on BVD patients: immediate and residual. After short (15-40 minutes) training procedures all patients were capable of maintaining vertical posture with closed eyes, and after additional training (30-160 minutes) some were capable of standing with closed eyes on a soft base or in a sharpened Romberg stance. Residual effects were observed in all subjects after complete disconnection from EVS. The response can be subdivided into three groups. Short-term after-effect was observed in sitting subjects after 1-5 minutes of EVS exposure and lasts from 30 sec to 3 minutes, respectively. Long-term after-effect was observed in trained patients (3-5 training sessions) after 20 minutes standing with eyes closed and EVS, with stability lasting from 4 to 12 hours, as measured by standard posturographic techniques and spectral analysis. Additionally, during that period patients also experienced dramatic improvement in balance control during walking on uneven or soft surfaces, or even riding bicycle. Rehabilitation effects were observed in one patient after 20 – 40 training sessions and continued for at least 8 weeks after the last EVS exposure.
Conclusion: The application of EVS is a radically new and effective way to combine physical exercises and sensory

substitution (using electrotactile vestibular feedback), to improve, accelerate and amplify rehabilitation of BVD patients.

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O194

Evaluation of Rotatory Chair Velocity Step Test in Patients with Peripheral Vestibular Disorder

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Background: In the last decade there is significant advancement in diagnosis and management of dizzy patients yet studies on velocity step test are limited in literature.

Objectives: Standardize rotatory chair velocity step test in normal subjects. Study rotatory chair velocity step findings in subjects suffering from peripheral vestibular disorders. Monitor recovery of patients suffering from peripheral vestibular disorders after vestibular rehabilitation therapy through rotatory chair velocity step test.

Methods: Study group consisted of 20 patients suffering from peripheral vestibular disorders diagnosed by history, office tests, ENG and rotational chair test. All of them were asked to fill DHI questionnaire, 11 received customized vestibular rehab programs for 6 weeks and they were monitored by DHI and rotational chair (SHA and velocity step). The control group consisted of 20 subjects with normal vestibular function and velocity step test was done to all of them.

Results: Patients with unilateral peripheral vestibular disorders show directional asymmetries in response to velocity step stimuli towards the side of lesion in the form of low gain and reduced time constant. The response pattern of reduced gain and increased phase lead at low frequency in SHA test is observed frequently in patients with unilateral peripheral vestibular disorders. Rotatory chair velocity step test can be applied to monitor the recovery of patients suffering from peripheral vestibular disorders after vestibular rehabilitation therapy.

Conclusion: Response of decreased gain and increased phase lead is observed routinely in patients with peripheral vestibular lesion. Rotatory chair velocity step test is a useful tool to monitor the recovery of patients suffering from peripheral vestibular disorders after vestibular rehabilitation therapy.

P001

An Experimental Study on Correlation Between Cochlear Morphological Changes and Endolymphatic Sac Responses in Guinea Pigs Exposed to Blast Waves

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Objectives: The effects of blast wave exposure on the endolymphatic sac (ES) in guinea pigs were investigated, focusing on the correlation between cochlear morphological changes and ES responses.

Methods: The guinea pigs were exposed to blast waves from the biological shock tube with a peak pressure value of 182.2dB SPL for 10ms.The morphological changes of the ES and the organ of Corti of the animals were observed under the light microscope, scanning and transmission electron microscope before exposure and 0,8,24,and 72 hours and 7 days after exposure.

Results: There was no obvious change in hair cells of the organ of Corti, but the amount of freely floating cells increased, and precipitate was found in ES in the 0 hour group. One of the sacs was filled with numerous erythrocytes. In the groups of 24 hours to 7 days after exposure, the hair cells of the organ of Corti displayed damage in various degrees. ES contained some freely floating cells that were very similar to phagocytes in nature and precipitate assumed correlative changes.

Conclusion: At the early stage following exposure, blast wave exposure might activate respondent increase in the amount of freely floating cells with phagocytic activity in ES. At the later stage, ES plays a role in swallowing and clearing the cell debris, and degenerate products that are excreted into the endolymph and accumulated in the sac after damages to the organ of Corti.

P002

Single L-Type Calcium Currents in Chick Embryo Vestibular Type I and Type II Hair Cells

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Background: Several reports indicate that vestibular type I and type II hair cells express a Ca^{++} current which flows mainly through L-type channels. These data have been obtained mostly by using the whole-cell configuration of the patch-clamp technique. Only very recently the single-channel properties of hair cell Ca^{++} currents have been described, and for type II hair cells only.

Objectives: Present experiments were undertaken in order to fill this gap in the literature. By using the cell-attached patch-clamp technique in combination with the chick embryo crista slice preparation, we have recorded single-channel ionic currents from type I and type II hair cells in situ, at different developmental stages.

Methods: To increase the driving-force for inward currents through voltage-dependent Ca^{++} channels, and to block outward K^+ currents, the patch pipette solution contained $BaCl_2$ 70 mM, TEA-Cl 40 mM, 4-aminopyridine 5 mM, CsCl 1 mM, plus niflumic acid 50 μM to block chloride channels (plus HEPES 5 mM; pH adjusted to 7.40 with HCl). Bay K 8644 (5 μM) was added to the patch pipette solution to better resolve L-channel openings. The bath solution had a high content in K^+ (composition in mM: KCl 135, $MgCl_2$ 5, HEPES 15, L-glutamine 4, glucose 5; pH 7.4

with KOH) in order to set hair cells' resting membrane potential at 0 mV (which we checked in preliminary experiments by recording the membrane potential in current-clamp mode in ruptured whole-cell configuration).
Results: In cell-attached recordings, a single-channel inward Ba^{++} current was observed which activated around -60 mV and decreased in amplitude with depolarization up to 30 mV. The average amplitude at - 20 mV was 1.22 pA (± 0.21 SD; n = 13); the average slope conductance between - 40 mV and 0 mV was 24.2 pS (± 3.2 SD; n = 15). The majority of patches apparently contained only one active channel, and few patches two channels. In two experiments a few minutes of perfusion with bath solution added with nimodipine 10 μM produced a significant decrease of the open probability of the channel. Type I and type II hair cells were identified in the slice on the basis of their morphology. In few cells however it was possible to achieve the whole-cell configuration following cell-attached recording. $I_{K,L}$, the signature current of type I hair cells, was still recognizable. This allowed us to confirm the identity of type I vs. type II hair cells.
Conclusion: Present results suggest that chick embryo type I and type II semicircular canal hair cells express a similar Ca^{++} channel population. Biophysical and pharmacological properties indicate that inward Ca^{++} currents in both hair cell types are carried through L-type Ca^{++} channels.

P003
A Comparison of the Negatively Activating Potassium Conductances of Mammalian Cochlear and Vestibular Hair Cells
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Background: Cochlear (OHC) and type I vestibular (VHC) hair cells of mammals express negatively activating potassium (K^+) conductances, called $g_{K,n}$ and $g_{K,L}$ respectively, which are important in setting the hair cells' resting potentials and input conductances. It has been suggested that the channels underlying both conductances include KCNQ4 subunits from the KCNQ family of K^+ channels. However, published records of voltage-evoked currents in type I and outer hair cells also suggest kinetic and other differences, but differences in experimental protocols make it difficult to draw firm conclusions.
Objectives: Knowing whether $g_{K,n}$ and $g_{K,L}$ are related at the biophysical and molecular level is of value in thinking about the functions and evolution of negatively activating conductances in hair cells. Our aim in these experiments was to obtain data permitting direct comparisons of the biophysical properties of $g_{K,n}$ and $g_{K,L}$.
Methods: Whole-cell currents were recorded from outer hair cells isolated from the apical turns of rat cochleas on postnatal days (P) 14-17, several days after hearing onset. At this age, several measures of outer hair cell function have matured, including the cochlear microphonic (reflecting outer hair cell transduction) and the amplitude of electromotility. The outer hair cell currents are compared with results from type I hair cells isolated from the sensory epithelium of the rat utricle on P16-P24. At this age, type I hair cells in mice and rats have acquired $g_{K,L}$
Results: The average membrane capacitances of OHC and VHC were 16±0.4pF and 4±0.2pF respectively. $V_{1/2}$ and S-values of OHC and VHC were -91.2±1.06mV, -12.6±0.46mV and -80.4±1.90mV, -6.0±0.56mV respectively. Time constant (au_{fast}, au_{slow}) of $g_{K,n}$ is 10 fold faster than that of $g_{K,L}$ at holding potential of -80mV. On the other hand, VHC showed some applicable permeability of Cs^+, but OHC was completely blocked when K^+ ion was substituted by Cs^+ externally and internally.
Conclusion: Relative to $g_{K,L}$, $g_{K,n}$ has a significantly broader and more negative voltage range of activation and activates with less delay and faster principal time constants over the negative part of the activation range. Deactivation of $g_{K,n}$ has an unusual sigmoidal time course, while that of $g_{K,L}$ is fit by one or two exponentials. $g_{K,L}$, but not $g_{K,n}$, has appreciable permeability to Cs^+. Unlike $g_{K,L}$, $g_{K,n}$'s properties do not change ("wash out") during the replacement of cytoplasmic solution with pipette solution during ruptured-patch recordings.

P004
Membrane and Discharge Properties of Medial Vestibular Nucleus Neurons in Transgenic KCNE1 (-/-) Mice Lacking Functional Inner Ears
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Background: In the transgenic KCNE1 (-/-) mice, mutations of the KCNE1 potassium channel gene provoke a degeneration of hair cells of the inner ear (Vetter et al., 1996). These homozygote mice are deaf and show vestibular symptoms such as circling and head bobbing, whereas the heterozygote (KCNE1 ±) mice have no degeneration of hair cells of the inner ear and no abnormal behavioral symptoms. As in other rodents, medial vestibular nucleus (MVN) neurons of wild type mice subdivide into two populations (type A and type B neurons) with respect to intrinsic active and passive membrane properties (Dutia and Johnston, 1998).
Objectives: We have compared the proportion of type A and type B MVN neurons as well as the dynamic properties of these neurons in both transgenic homozygote and heterozygote mice.
Methods: Experiments were performed with the whole cell patch-clamp technique on brain slices of 15-21 day old mice. In all recorded MVN neurons, active and passive membrane properties were tested according to a protocol of intracellular current injections developed earlier for guinea pig MVN neurons (Beraneck et al., 2003).
Results: Preliminary results show that type A and type B MVN neurons present similar active and passive membrane

properties in homozygote and heterozygote mice and that in heterozygote mice, type A and type B MVN neurons subdivided in the same proportion (about 30 % vs. 70 %) than in wild type mice. However, the proportion of type A and type B MVN neurons in homozygote mice was reversed and similar to that observed in newborn mice (see Dutia and Johnston, 1998).

Conclusion: These results suggest that the action potential form and consequential biophysical properties of MVN neurons are significantly dependent on their afferent input from the inner ear.

(Transgenic mice were kindly supplied by Dr. J Barhanin, Institut de Pharmacologie du CNRS, Valbonne Sophia-Antipolis, France)

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P005

M Current in Vestibular Afferent Neurons from the Rat

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Background: Synaptic transmission between hair cells and afferent neurons in the vestibular system has been shown to be mediated by excitatory amino acids. However, little is known about modulatory mechanisms operating in this synapse. The peripheral circuit comprising efferent neurons, hair cells and afferent neurons has complex properties, and its activity implies the participation of various neurotransmitters (for an extensive review Guth et al., 1998).

Objectives: In this study we addressed the problem of determining the expression and the characteristics of the M current (I_{KM}) in the vestibular afferent neurons.

Methods: Recordings were performed in vestibular ganglia afferent neurons held in primary culture (18-24 hrs) isolated from Wistar rats (postnatal days 7-10). A total of 70 neurons were recorded using standard whole cell patch clamp techniques (C_m = 42 ± 2 pF, R_m = 219 ± 19 MOhms, V_m = –57 ± 1 mV).

Results: Linopirdine (0.1 to 100 μM) decreased the outward current up to 25% in 77% of the cells studied. The dose response curve showed an IC_{50} of approximate 4 μM. To further characterize the M current we studied the action of linopirdine and oxotremorine-M (oxo-M) on the current deactivation. For this, we applied pulses of 1200 ms to -60 mV from -a holding potential of -20 mV. We used this voltage clamp protocol because when the cell is hyperpolarized, an inward relaxation that corresponds to I_{KM} amplitude is produced (Conley, 1999; Adams et al., 1982; Robbins et al., 1992). In these conditions 10 μM linopirdine reduced the current deactivation 54 ±7 % in 6/10 cells. In the rest 4/10 cells, the reduction was of 19 ± 2 %. In current clamp, 10 μM linopirdine significantly increased the firing rate response to current pulses in 44 % of the cells. By its side oxo-M (10 μM) decreased the outward current 15 ± 2 % in 6/9 cells and only 5 ± 1% in the rest of the cells. The study of the current deactivation showed that 10 μM oxo-M decreased the M current 51 ± 5 % and this effect was blocked by 1 μM atropine (n = 3). Oxo-M and linopirdine current voltage sensitivity was very similar. In current clamp experiments oxo-M also increased the firing rate response of afferent neurons to current pulse stimulation (n = 3/10).

Conclusion: Our results suggest that cultured vestibular afferent neurons express I_{KM} that is very probably generated by KCNQ4 type potassium channels (Kharkovets et al., 2000) that are sensitive to linopirdine. The fact that some cells seems to be less sensitive both to linopirdine and oxo-M, may probably be due to the fact that afferent neurons innervating type II hair cells may not receive cholinergic efferent input in physiological conditions. Thus I_{KM} may be a sign current for afferent neurons innervating type I hair cells.

P006

Modulation by Extracellular pH of Voltage Activated Calcium Current of Type I Rat Vestibular Hair Cells

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Background: Changes in the extracellular pH have been shown to modify synaptic transmission affecting a variety of ligand- and voltage-gated ion channels, such as NMDA receptors and Ca^{2+} channels. In a recent study, we have shown that the electrical discharge rate of semicircular canal afferent neurons, and its response to excitatory amino acid receptor agonists is modulate by extracellular proton concentration (Vega et al., 2003).

Objectives: In light of the importance of Ca^{2+} channels in the synaptic transmission, in this study, we examined the effect of extracellular pH on the Ca^{2+} current in type I vestibular hair cells enzymatically dissociated from Long-Evans rats (P14-P17).

Methods: Semicircular canal crista ampullaris Ca^{2+} currents were recorded using whole-cell patch clamp technique with extracellular Ba^{2+} as a current carrier. Cs^{+}-TEA solutions were used to block K^{+} currents (Almanza et al., 2003). Modifications of the extracellular pH (8, 6.8, 6, 5 and 4) were done substituting the perfusion solution with a solution to which NaOH or HCl was added to adjust the pH to the various values.

Results: Extracellular alkalinization (pH 7.4 to 8) did not significantly modify the amplitude nor the gating properties of the Ca^{2+} current (n = 4). In contrast, extracellular acidification to 6.8, 6, 5 and 4 (n = 4, 4, 2 and 2, respectively)

produced a reversible pH-dependent reduction of the Ca^{2+} current. Acidification from 7.4 to 6.8 decreased the current by 32% but did not change the activation voltage; while acidification from 7.4 to 6 diminished the current by 51% and half-maximal activation voltage ($V_{1/2}$) was significantly shifted to more positive from -36 mV to -29 mV. Higher acidification up to pH 4 shifted the Ca^{2+} current $V_{1/2}$ up to -15 mV. Time constants were not significantly affected by changes in the extracellular pH. Normalized current amplitudes ($I/I_{7.4}$) fitted as a function of pH revealed an apparent pK_a of 6.

Conclusion: Even small shifts in the voltage dependence of Ca^{2+} channel activation or a reduction of the Ca^{2+} current may have a large impact on the cell voltage response and transmitter release. Our results show that the Ca^{2+} current expressed in type I vestibular hair cells exhibit a significant extracellular pH sensitivity. Synaptic space acidification may thus play a significant role in transmitter release modulation both in normal and in pathological conditions.

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P007

Effects of Azithromycin and Clarithromycin on Acetylcholine-Evoked K^+ Currents and Intracellular Ca^{2+} Concentrations in Guinea-Pig Outer Hair Cells

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Background: Azithromycin (AZ) and clarithromycin (CL) have received attention as a possible ototoxic agent. But the mechanism by which these macrolides cause ototoxicity is unknown. Recently, there is a report that the reduction of TEOAE responses due to AZ and CL could likely be attributable to the transient dysfunction of outer hair cells.

Objectives: The aim of the present study was to determine whether these macrolides could affect cholinergic receptors at the postsynaptic membrane in outer hair cells (OHCs). Therefore the authors studied the effects of AZ and CL on acetylcholine-evoked K^+ currents and intracellular Ca^{2+} concentrations in guinea pig OHCs.

Methods: OHCs were isolated from white guinea-pigs enzymatically and mechanically and observed using an inverted microscope. K^+ currents (IK) and resting membrane potentials were recorded with Axopatch 200B amplifier using conventional whole-cell patch clamp technique. The effects of AZ and CL (10 μM, 20 μM, 40 μM, 80 μM) on IK_{ACh} were observed. And the effects of AZ and CL on intracellular calcium concentrations were observed using a confocal microscope with fluo-3 fluorescence dye.

Results: The resting membrane potential was -40 ~ -70 (-55 ± 3) mV and potassium currents were recorded 2782 ± 546 pA in 20 mV increments from a holding potential of -70 mV. ACh increased whole K^+ currents of guinea pig OHCs: 3226 ± 349 pA. AZ and CL had antagonistic effects on the K^+ channel and reversibly suppressed the K^+ currents in a concentration-dependent manner; 24 % decrease in AZ 80 μM and 20 % decrease in CL 80 μM. ACh increased whole intracellular Ca^{2+} concentrations of guinea pig OHCs. Intracellular Ca^{2+} concentrations were suppressed by AZ, but not by CL.

Conclusion: This study demonstrates that exposure to AZ and CL causes reversible electrophysiological changes in OHCs, suggesting possible mechanism of AZ and CL in the development of sensorineural hearing loss on OHCs.

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P008

Depersonalization/Derealization Symptoms in Patients with Peripheral Vestibular Disease (Pilot Study)

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Background: Since 1950, Schilder held that "dizziness due to organic causes often provokes phenomena which are akin to the psychic phenomena of depersonalization of the body". However there are few data concerning an association between vertigo and feelings of unreality.

Objectives: To assess the frequency of depersonalization/derealization symptoms and their relation to vestibular function, in patients with vestibular disease.

Methods: Twelve patients with vestibular disease, 52±10 y.o. (7 women) and 12 sex and age matched healthy subjects, 53±11 y.o. (7 women) gave their informed consent to participate in the study. Healthy subjects were selected

from a larger group of 108 adults with no history of dizziness or common mental disorders (GHQ12 <3). I. All subjects completed 3 questionnaires: 1. general medical health questionnaire; 2. the 12 item General Health Questionnaire (GHQ12); 3. the 28 item depersonalization/derealization (D-D) questionnaire of Cox & Swinson (2002). II. Seven patients also had calorics (30° & 44°C) during which they reported their symptoms on the D-D questionnaire.

Results: I. Vestibular patients reported 2 to 28 symptoms on the D-D with a median score of 26 (P25-P75= 11.5-41.2). Apart from dizziness, the most frequent symptoms in this group were: difficulty concentrating (80%), sensation of walking on shifting ground (75%), thoughts seeming blurred (75%), feeling "spacy" (66%) and feeling as though in a dream (66%). Healthy subjects reported between none and 5 symptoms, (median score 1; P25-P750-3). The most frequent symptoms in this group were "deja vu" (33%), difficulty concentrating (33%) and difficulty understanding what others were saying (16%). These experiences were similar to those reported by the 108 healthy subjects. II. Before receiving calorics, patients reported that since their first attack of vertigo, they had experienced 2 to 23 of the D-D symptoms (median score 27). However, during calorics they reported significantly fewer symptoms (1 to 13; median score 5; Wilcoxon, $p<0.05$). The decrease in D-D score was related to both the number and the severity of the symptoms. Apart from dizziness, the most frequent symptoms during the caloric test were feeling "spacy" (57%) and time seeming to pass very slowly (57%).

Conclusion: There is a substantial increase in the occurrence of symptoms of depersonalization/derealization in patients with vestibular disease. Patients also reported significant D-D symptoms during caloric testing.

P009

Depersonalization/Derealization Symptoms and Self-Orientation With Respect to the Environment in Patients with Vestibular Disease (Pilot Study)

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Background: Derealization is defined by DSM-IV as "an alteration in the perception or experience of the external world so that it seems strange or unreal". It has been associated with a variety of neuropsychiatric conditions and spatial disorientation (break-off).

Objectives: To assess the relationship between depersonalization/derealization symptoms and ability to update orientation in the environment during passive rotations in the yaw plane in patients with vestibular disease.

Methods: We evaluated 12 healthy subjects (age 53±11 y.o.) and 12 patients (52 ±10 y.o.) with peripheral vestibular disease and abnormal caloric responses. Only 7 patients had active balance symptoms. All subjects completed a depersonalization/derealization questionnaire (Cox and Swinson 2002) followed by a test of orientational ability. For the test, subjects sat upright in a chair, blindfolded and with ears occluded. They were exposed to 10 manually driven whole body rotations of 45°, 90° or 135° (circa 40, 60 & 70 °/s, peak velocity) to the right or to the left, in an unpredictable sequence balanced for amplitude, direction, and order. Before the test, subjects were familiarized with the room, which was square and contained distinctive features positioned in the middle of each wall so that features and corners subtended 45° arcs. After each rotation subjects reported which wall or corner they were facing. Error was calculated by subtracting the reported rotation from the actual rotation.

Results: The average (±SD) score for the depersonalization/derealization questionnaire was 1±1 for healthy subjects and 28±21 for patients. Patients reporting recent balance symptoms had a score of 38±18 and patients without current symptoms had a score of 15±18. In the orientation test, the average error for the 10 rotations was 8±4° in healthy subjects and 27±28° for patients. Those patients with current symptoms averaged 42±30° while patients without recent symptoms averaged of 8±5°. Across all patients there was a significant correlation between the depersonalization/derealization score and the average error in the orientation test was $r = 0.86$ ($p< 0.02$). There was no relationship for healthy subjects.

Conclusion: Symptoms of depersonalization/derealization in vestibular patients are proportionally related to impairment of the ability to estimate orientation in the environment. Patients with active vestibular disease are most impaired whereas those with abnormal caloric responses without current vestibular symptoms can have similar performance to healthy subjects.

P010

Cognitive Demands Affects the Gain of the Torsional Optokinetic Response

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Background: Cognitive tasks such as mental arithmetic and fixation of imagined targets are known to affect vestibular nystagmus. Here we show that another cognitive task – a subject's control of the rotation of a single moving visual line in an otherwise darkened room – influences the gain of the torsional optokinetic response to that of a single moving visual line.

Objectives: To investigate the differential effect on ocular torsion when subjects actively controlled the rotation of the visual stimulus in contrast to when subjects passively viewed rotation of the same visual stimulus.

Methods: Six subjects participated in this study; none reported any history of visual, neurological or vestibular dysfunction aside from normal refractive errors. The visual

line consisted of 11 blue light-emitting diodes, mounted on a lightweight plastic rod placed centrally in the subject's line of sight; had a total length of 230 mm, and subtended an angle of 19.6 degrees at a distance of 68 cm from the subject. The visual line was programmed to rotate at a speed of 4.8°/s through an angle of 20 degrees in a clockwise or counter-clockwise direction. There were three test conditions: Active, Passive, and Effort Control. In the Active condition, subjects were instructed to rotate the visual line to horizontal by holding down the left or right button of a mouse. In the Passive condition subjects simply watched the central light-emitting diode of the visual line, as the line automatically rotated to horizontal. In the Effort Control condition subjects were instructed that the line would automatically rotate to horizontal as in the Passive condition, but they were nevertheless to hold down the corresponding mouse button as if rotating the line to horizontal. 3D eye positions were measured using the VidEyeO videooculographic system (Moore et al. 1991; MacDougall 2003). Torsional eye positions were desaccaded and lowess smoothed to remove artifacts from blinks, saccades or quick phases. The gain for each bar movement was defined to be the average gradient of four least squares linear regression lines fitted to torsion position versus the line orientation for each 5°of stimulus movement.

Results: The torsional gain was significantly greater in the Active than in the Passive condition for five out of the six subjects tested. It was also found that the torsional gain was similar for the Passive and Effort Control conditions. These results were consistent for both within- and between- subjects analyses.

Conclusion: The mean gain of torsion was significantly greater in the Active than during the Passive condition for five out of the six subjects tested. It was also found that the torsional gain was similar for the Passive and Effort Control conditions. These results were consistent for both within- and between- subjects analysis.

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P011

Oculogravic Illusion and Individual Differences: Role of Spatial Expertise

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Background: In the presence of the constant acceleration of earth's gravity, the otoliths and the other graviceptors provide information that allows the orientation of the head to the vertical to be sensed with reasonable accuracy. Perceptual errors arise when there is a sustained linear acceleration and the gravito-inertial forces (GIFs)are no longer aligned with the gravitational vertical. Large GIFs induce an illusory perception of body tilt in pitch accompanied by perceived upward movement of visual objects (oculogravic illusion). This illusion is related to a mechanical action on the otolithic and somaesthetic systems. Low accelerations also induce an oculogravic illusion. Contrary to high GIF changes, the limited variations of GIF exclude any tactile and kinesthetic origin, then, the illusion was due to the stimulation of the utricular maculae in upright position and to the saccular maculae in supine position [2]. However, there were large individual differences, which would be partially dependent on the subject's experience of GIFs variations.

Objectives: The aim of this study was to understand how the relation that the subject maintains with the spatial environment modifies the processing of sensory information and the perceptive construction resulting from it.

Methods: The subjects in upright or in supine position were instructed to set a luminous target to the eye level while they were in total darkness and undergoing low centrifugation (GIF<9.95ms-2). Two populations were tested: control subjects and acrobats (spatial experts).

Results: In the upright position, spatial experts showed a smaller sensibility to the oculogravic illusion ($p<.05$) whereas they were not subjected to illusion in the supine position ($p>.05$)compared to the control group.

Conclusion: Individual differences in sensitivity to the oculogravic illusion may be related to a better efficiency in the use of the vestibular information. The absence of oculogravic illusion for the spatial experts could result from a functional enhancement of the otolithic system that can distinguish a linear acceleration from a head tilt [1]. However, the appearance of the illusion for the stronger acceleration suggests that the individual differences may be related to a sensorial weighting with respect to subjects experience. The perceptive shift would be associated to a process of sensory integration that gives more weight to the otolithic information. Conversely, the absence of oculogravic illusion may be the result of a somaesthetic sensory dominance.

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P012

Long Term Effect on Vestibuloocular Reflex and Self Motion Perception Induced by Prolonged Asymmetric Vestibular Stimulation

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Background: It is well known that post-rotatory nystagmus (PRN) is induced immediately after prolonged constant velocity rotation. Post-rotatory nystagmus (PRN I) gradually decreases until its direction reverses (PRN II). These eye responses have been attributed to the acceleration change eliciting the velocity storage mechanism and to a subsequent process of adaptation that balances activity in the vestibular system. On this basis, one could hypothesize that these mechanisms operating in the oculomotor system could also affect the self motion perception.
Objectives: The present study was aimed at comparing oculomotor response and body movement perception during the development of the processes responsible for the enhancement and the attenuation of the responses. To this aim, we analyzed perception of the body movement and the vestibuloocular reflex (VOR) during repetitive cycles of asymmetric body oscillations provoking prolonged unidirectional labyrinthine activation.
Methods: Ten subjects placed on a rotating platform were asymmetrically oscillated in darkness to induce an illusory shift the body position in space. The asymmetric vestibular stimulation consisted of rotation on the horizontal plane resulting from a combination of sinusoidal half cycles with the same amplitude (± 40°), but different frequencies (0.5 Hz and 0.125 Hz). To evaluate the perception of movement the subjects were asked to remember a light spot presented only before the beginning of vestibular stimulation and to track it with a pointer. The eye position was recorded by EOG.
Results: The prevalent acceleration toward one side caused an erroneous enhancement of movement perception in this direction and a shift of the imaginary target position in the opposite direction that was about 45° at the end of a cycle of four oscillation. This shift increased progressively with the repetition of the cycles and reached values greater than 180° after 10 cycles. VOR, studied in a separate series of stimulation, showed asymmetric gain reflecting stimulus asymmetry. Slow phase cumulative eye position was shifted by about 35°. This shift, however, tended to be unchanged or reduced (6 out 10 subjects) with the repetition of the trials. Asymmetric vestibular stimulation causes a progressive increase of movement perception and of VOR in the direction of the fast component and reduction in the opposite direction. The disparity of movement perception increases throughout the trials, while that of VOR remained unvaried or reduced.
Conclusion: This suggests the presence of different internal vestibular processing for self motion perception and VOR. In fact, the process of perception does not show adaptation but only a progressive enhancement in the direction of the faster body movement. On the contrary, the VOR asymmetry appears to be counteracted by an internal balancing process.

P013
The Use of Non-Motion-Based Cues to Control the Direction of Smooth Pursuit Eye Movements
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Background: Human smooth pursuit eye movements are principally driven by visual feedback and cannot normally be initiated at will. However, when tracking a predictable periodic target, smooth eye movements reverse direction prior to target reversal, being driven by anticipation, not visual feedback.
Objectives: We investigated whether human subjects could volitionally control eye reversal using cues derived not from the motion stimulus itself, but from audio cues presented prior to target motion.
Methods: Target stimuli were discrete double ramps – constant speed (30o/s) rightwards followed by similar leftward movement returning the target to its origin. The reversal time ranged from 420-840ms in 60ms steps.
Four experimental conditions were examined. In the precued (PRE) condition double ramps of randomized reversal time were presented. Prior to ramp presentation audio precues were given with an interval indicating start and reversal time of the upcoming double ramp. Subjects fixated during precue presentation - no motion stimulus was presented. After two precues, target motion was presented and subjects were required to pursue the target, estimating reversal time.
Results: All six subjects could use the precues to voluntarily control timing of anticipatory eye reversal. Consequently, when occasional false precues gave an underestimate of target reversal time, reversal of eye velocity occurred before target reversal. Precued eye reversal times were comparable to those in the steady state response of a second, predictable (PRD) condition, in which double ramps with identical reversal time were given repeatedly without precues. However, the PRD steady state response was only attained after at least 2-3 presentations. In a third, reactive (RCT) condition, without precues, unexpected early target reversals occurred sporadically within a series having identical, predictable reversal time of 960ms. This led to eye reversals occurring >150ms after target reversal, much later than in the PRD and PRE conditions. Finally, reversal time was randomized, without precues, in the RND condition. Unlike RCT, this did not result in reactive responses to target reversal, but to initiation of eye deceleration prior to target reversal at a comparable time for all target reversal times. Analysis revealed that initiation of RND eye deceleration was indeed uncorrelated with the timing of the current stimulus, but significantly correlated with timing of the two previous stimuli, revealing a strong past-history effect.
Conclusion: These findings provide the first demonstration that timing of anticipatory smooth eye velocity reversals can be volitionally controlled using non-motion-based timing cues. They add to the emerging picture of human anticipatory ocular pursuit as a pre-programmed behaviour, the characteristics of which reflect a complex interaction of cognitive factors – automatic expectations derived from both past and present target behaviour are interwoven with

consciously acquired knowledge derived from predictive cues.

P014

Impaired Spatial Learning After Hypergravity Exposure in Rats

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Background: Most of astronauts experience spatial disorientation and space adaptation syndrome for several days after exposure to weightlessness, indicating that constant gravity, mainly sensed by otolith vestibular organs, would be utilized as a basis of sensory cue during spatial cognition.
Objectives: The purpose of the present study was to clarify the spatial learning ability after exposure to the different gravitational environment in rats.
Methods: Male Wistar strain rats were used. Rats were forced in 2G linear acceleration in a centrifuge device for two weeks and then received spatial learning task in a radial arm maze three times per day for ten days. Control rats were placed close to the centrifuge device but not exposed to hypergravity. Rats were trained to search the four baited arms. Spatial learning ability was evaluated by accuracy and re-entry rate, which is a rate of correct arm entries and a rate of entries to the arms that they had once visited, respectively. Locomotor activity of rats was represented by a total number of entries per minute. A number of baits that animals got per minute was also assessed.
Results: The accuracy to enter the correct arms was significantly inferior in 2G rats compared to that of control rats. Re-entry rate was also significantly higher in 2G rats. These differences disappeared at the later five days. Locomotor activity was higher in 2G rats and there was no difference in a number of baits per minute between 2G and control animals.
Conclusion: Spatial learning was impaired by hypergravity exposure, however, hyperkinetic activity and a possible increase of egocentric sensory cues through proprioceptive and motor efference copy signals subsidized it.

P015

Quality of Life in Benign Paroxysmal Positional Vertigo with a Vestibular Deficit Associated

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Background: The incidence and prevalence of positional vertigo is well established. But the incidence of an associated vestibular hypofunction and the differences in evolution are still not well determined.
Objectives: The aim of this study was to assess BPPV quality of life and the incidence of recurrence in two group of patients established depending on a vestibular hypofunction associated.
Methods: A prospective study including 70 new cases of BPPV was carried out. The diagnosis was based on the history of recurrent sudden crises of vertigo and a typical positional-induced nystagmus during the Dix Hallpike test. Caloric tests were performed in every patient. Handicap and severity of vertigo were determined with the Dizziness Characteristics and Impact on Quality of Life (UCLA-DQ) questionnaires . Two groups of patients were created depending of the vestibular hypofunction associated: 48 primary and 22 secondary VPPB. Weekly follow up until resolution and a six month follow up was performed in every patient
Results: The canalith repositioning procedure was immediately successful in 63 patients (90%) , with no significant differences between the two groups of patients. Recurrence of vertigo spells was higher in the vestibular hypofunction associated VPPB group ($p< 0.05$) within a six month follow-up period. UCLA-DQ showed higher punctuation in the secondary VPPB group, specially in items 4 and 5 ($p<0.05$)
Conclusion: In our group of patients, VPPB with an associated vestibular hypofunction showed worse prognosis, with a higher incidence of recurrence of the vertigo spells and a higher impact on quality of life.

P016

Estimating the Relative Weights of Vestibular, Optokinetic, and Podokinesthetic Cues from Self Turning Perception During Discordant Sensory Stimulation

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Background: During active turning in an environment without landmarks, perception of angular displacement (ψD) mainly draws on 3 sensory signals: vestibular (V), optokinetic (O), and podokinesthetic (P). In order to evoke a unitary perception, these signals must be combined in a process known as sensory fusion. How exactly fusion is performed is not known so far.
Objectives: We here proceed from the hypothesis that sensory fusion occurs by weighted averaging of V, O, and P, and we try to estimate the relative weights by which these modalities contribute to the average. To do so, we compare ψD during concordant (all cues signaling same amount of rotation) and discordant (one or two cues signaling larger or smaller rotation than the others) stimulation. Rationale: the heavier a cue is weighted, the more it will attract ψD when it differs from the other cues and, hence, the more ψD will differ from its value during concordant stimulation.
Methods: Subjects (Ss, N=15) actively or passively turned in space at v=15, 30 or 60°/s on a rotatable platform (PFM) surrounded by an optokinetic pattern (OPA). Ss were subjected to 5 different stimulus combinations: V+dO, V+dP, V+O+dP, V+dO+P, V+dO+dP, with d ={0.75, 1, 1.25}denoting a factor of discordance (d=1, concordant stimulation). For example, during V+O+0.75P Ss circled on PFM and viewed the stationary OPA while PFM rotated at

0.25·v in the same direction, reducing P by 25% with respect to V and O. Ss were to continuously estimate their angular displacement in space by pressing a signal button for each *perceived* increment of 90° and to retrospectively report whether they had noticed a sensory discordance (motion of PFM or OPA in space).

Results: The probability of detecting a discordance depended on stimulus combination and Ss (13%-88%). In all stimulus combinations, ψD varied roughly in proportion to d, becoming larger during rotations of O and/or P with the subject (d=1.25) and smaller during rotations against (d=0.75). On average, ψD could be modeled as a weighted average of P, V, and O with weights having a ratio of about 0.5:1:2. However, this model may be too simple because closer analysis revealed that discordant stimuli that went *undetected* had a larger effect on ψD than those detected. Specifically, when *detected*, P discordances had little effect on ψD as had O discordances of d=0.75 (OPA rotating with Ss); only O discordances of d=1.25 (OPA rotating against Ss) increased ψD even when detected. Yet, the ranking of the relative weights in the averaging model remains the same if only *undetected* stimuli are considered.

Conclusion: The effect of mutually discordant V, O and P stimulation upon angular displacement perception depends critically on whether the discordance is detected or not. Measuring the effect of undetected discordances allows the determination of sensor weights in a linear model. If discordance is detected, sensory information may not be averaged but be exploited for scenario detection, instead.

P017

Instability Improves Perception of Spatial Orientation

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Background: We do not remain immobile but tend to bob and weave, when aligning objects such as picture frames or shelves; observation at odds with the many psychophysical studies of spatial orientation which have deployed static, even restrained subjects. In this context Stoffregen and Riccio [1,2] propose that through the activity involved in balancing, the 'dynamics of balance', the protagonist gains important information about orientation. An important feature is that cues from dynamics of balance would be largely non-visual providing visual cues to orientation.

Objectives: To measure the effect of active balance on the visual vertical and rod and frame effect.

Methods: Subjects were challenged to set a visual line to earth vertical when seen in isolation and when set within a misleadingly tilted square frame [3,4]. Subjects were seated, standing normally or balancing on a narrow beam.

Results: Subjects performed both of these tasks 30% more accurately when balancing precariously on a narrow beam than when seated or in normal stance.

Conclusion: The findings suggests that information can be derived from the act of balancing [1,2] that may be combined in a Bayesian fashion [5,6] with visual and other orientational cues to create an information manifold which improves perception of spatial orientation and protects against misleading cues [7]. The study confirms quotidian observations that we do not remain static but tend to maneuver when making orientational judgments and are most aware of our orientation when about to fall.

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P018

Effect of Rotation Paradigm on the Visual Subjective Vertical at Large Body Tilts

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Background: Previous spatial-orientation studies have emphasized that luminous line settings to the vertical of roll-tilted subjects in darkness deviate in the direction of the long-body axis at large tilt angles (Aubert or A-effect), even though estimates of head tilt in space are nearly veridical. This apparent discrepancy has led to the suggestion [2] that a central egocentric bias signal (idiotropic vector) acts to pull the subjective visual vertical (SVV) to the subjects' zenith (M-model). In a recent study [1], we tested the SVV with a polarized luminous line and used roll rotations (velocity: 30 deg/sec) anywhere between 0 and 360 deg, starting from upright. As a result, the direction of rotation and of the final tilt angle, where testing took place, were uncoupled. Body-tilt estimates were obtained in a separate series of otherwise similar experiments. As in

classical studies, SVV responses for absolute tilts up to about 135 deg showed a gradually increasing Aubert effect that could not be attributed to errors in perceived body tilt but was nicely in line with the M-model. At larger absolute tilts, however, SVV errors abruptly reversed sign (E-effect), now showing a pattern correlated to errors in body-tilt estimates but incompatible with the M-model. These results suggest that, in the normal working range, the perception of external space and the perception of body posture are based on different processing of body-tilt signals. Beyond this range, both spatial-orientation tasks seem to rely mainly on a common tilt signal.

Objectives: The purpose of the present investigation was to clarify why the sudden reversal from A to E-effect was not seen in most earlier investigations of the SVV, including our own [3].

Methods: Therefore, the SVV experiments were repeated using a reduced 0-180 deg rotation range, as in classical studies. Subjects knew that they would never pass through the upside-down position.

Results: The response reversal was no longer seen with this new tilt paradigm, but responses at smaller tilts were not affected.

Conclusion: We conclude that prior knowledge about the maximum rotation angle has a clear effect on SVV responses. That this effect is limited to large tilts fits our earlier suggestion that SVV settings in this range seem more susceptible to cognitive factors.

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P019

Internally and Externally Mediated Triggers in the Acquisition of Visual Targets

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Background: From the clinical neuropsychological practice is known that patients with cerebral stroke in the dominant hemisphere have usually combined aphasia and apraxia. In assessing the performance of some clinical tasks for the purpose of clinical neurology use we probably neglect that some differences undetectable with routine clinical methods could normally exist in healthy subjects depending on the way of triggering of the task.

Objectives: The purpose of this study is to answer the question whether there is difference between internally (IT) and externally mediated triggers (ET) in the acquisition of visual targets that require both head and eye movement. That is, are there differences between the strategy associated with a verbal command of a test operator and that associated with a memorized written command when the target to be acquired is predictable (e.g. spatial location is known to the subject).

Methods: Ten persons were tested. The acquisition targets were permanently fixed to a screen at angular distances -20°, 30°, and 60° - in the horizontal plane. Eye movements were obtained with EOG. Head movements were detected with a triaxial rate sensor system mounted on a hardhat liner that could be fixed firmly to the head.

Results: The results indicate that unlike the eye velocity and acceleration there was difference in the head peak velocity and acceleration between the IT and ET test conditions. Those trials undertaken with an ET are significantly more delayed ($p<0.05$) than those using an IT. The head/eye command latency also indicates difference between IT and ET. That with ET is consistently longer ($p<0.05$), i.e., the command for the head movement precedes the command for the eye movement.

Conclusion: It is concluded that the difference in the motor pattern between ET and IT conditions is based on the difference in their psychophysiological structure. Obviously the 'recalled' mechanism modifies the eye-head coordination reflexes.

P020

Neural Processes Underlying Perception of Roll Tilt and Ocular Torsion Are Qualitatively Different

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Background: Interaural shear force, predominantly stimulating the utricle, is the primary inertial cue eliciting ocular torsion (OT), a reflexive eye movement that helps compensate for image rotation on the retina during roll tilt. However, perception of roll tilt has been found to be qualitatively different from OT responses, showing that the neural processes underlying perceptual and eye movement responses are different.

Objectives: We sought to determine the contribution of inertial cues to perceptual and eye movement responses by changing the orientation of the subject with respect to dynamic linear acceleration. We also sought to determine the contribution of static gravitational cues to determine whether the responses were dependent on the static orientation of the head relative to gravity. We hypothesized that the contribution of otolithic cues to roll tilt perception is qualitatively different from the contribution of identical otolithic cues to OT.

Methods: We measured OT binocularly while sinusoidally accelerating (0.5 G) six human subjects parallel to earth-

horizontal at four frequencies (0.01, 0.02, 0.05 and 1 Hz) in darkness. OT was calculated by mathematically integrating the torsional slow phase velocity, yielding torsional slow cumulative eye position. Simultaneous with eye recordings, subjective roll tilt was measured by use of a somatosensory bar. Three experimental conditions were investigated: (1) *Y-Upright* – acceleration along the inter-aural (*Y*) axis while upright; (2) *Y-Supine* – acceleration along the *Y*-axis while supine; (3) *Z-RED* – acceleration along the dorso-ventral (*Z*) axis with right ear down (RED).
Results: Subjective roll tilt and eye movement responses were qualitatively different. The amplitude of the subjective roll tilt responses decreased with increasing frequency for *Y-Upright* and *Z-RED* conditions, while no response was observed for the *Y-Supine* condition. The amplitude of OT responses (always conjugate) decreased and the phase lag increased with increasing frequency for the *Y-Upright* and *Y-Supine* conditions, and responses for the *Z-RED* condition were always significantly smaller than for the *Y-Upright* and *Y-Supine* conditions. The *Y-Upright* OT responses appear to include two components: one a response to inter-aural force (as in the *Y-Supine* condition), and a second in response to roll tilt of gravito-inertial force (as in the *Z-RED* condition).
Conclusion: Subjective roll tilt and OT responses were qualitatively different, showing that the neural processes underlying perceptual and eye movement responses are not identical, though some neural pathways could be shared. Subjective perception of roll tilt appears mostly influenced by roll tilt of the gravito-inertial force, centrally processed using multisensory fusion. In contrast, OT responses appear mostly influenced by a simple central low-pass filtering mechanism with a small component in response to roll tilt of the gravito-inertial force.

P021
Vestibular and Non-Vestibular Influences on the Autonomic Response to Linear Acceleration in Human Beings
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Background: Evidence supports that the vestibular system participates in reflex autonomic responses to postural changes. However, predictive control and habituation of responses to re-orientation stimuli, and their relationship to vestibular control of autonomic responses have not been addressed.
Objectives: To evaluate the influence of vestibular function and stimulus predictability on the cardio-respiratory response to transient forward linear acceleration of the whole body.
Methods: Thirteen healthy subjects, and six patients with bilateral loss of vestibular function participated in the study. For comparison with patients, an age/sex matched subgroup of 3 subjects was selected from the healthy group. Subjects sat upright and blindfolded, head and torso restrained, in a car seat mounted on a motorised bogie. They were exposed to linear acceleration of circa +0.26 G peak, which was developed in 100 ms and maintained for 160 ms. Acceleration stimuli were: I 'unpredictable', triggered by the experimenter either at the end of expiration or at the end of inspiration (trials with no acceleration were also included). II. 'predictable', triggered by the subjects pressing a button, although subjects knew that sometimes after pressing the button nothing would happen. During each acceleration trial, continuous recordings were taken of respiration, electrocardiogram and trunk acceleration.
Results: I. When the experimenter triggered the acceleration, in all subjects and patients, the RR interval decreased within the 1st to 2nd beat after acceleration onset. In healthy subjects, this decrease was maintained or more evident during the 3rd to 5th heart beat after onset. Patients did not have a prolonged response. In both, healthy subjects and patients, cardiac responses were similar when acceleration was triggered at the end of inspiration or at the end of expiration. II When acceleration was triggered by the subjects, healthy subjects had a decrease of RR interval, which was attenuated in comparison with the response to unpredictable acceleration. However, in patients with vestibular loss, there were no cardiac responses to predictable stimuli. During all acceleration trials, all subjects consistently had a rapid inspiration reaction.
Conclusion: A vestibular signal is required to sustain cardiac responses during motion and to mediate predictive control of autonomic responses to motion.

P022
Circularvection in Patients with Dizziness
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Background: Patients with reduced or no vestibular function tend to have a greater reliance on visual and proprioceptive cues. Indeed, the documentation of a group of patients that were diagnosed as suffering visually induced symptoms of vertigo (visual vertigo) has been an important step in the recognition of this complex process. In a society in which subjects are frequently exposed to complex visual stimuli both at work, during social relationships and leisure activities, this question must be properly addressed when the history of any patient with dizziness is obtained.
Objectives: To analyze the relation between the relevance that visual stimuli have on deterioration of patients with dizziness and the test of time to circularvection.
Methods: 200 patients with dizziness to which the importance of the visual stimulation to evoke, generate or aggravates disequilibrium was specifically questioned. Three different time to circularvection were tested.
Results: 18% of the patients gave an affirmative answer to the existence of clinical deterioration in their equilibrium

when complex visual stimuli was provided. 82% answered that visual stimulation had not any relevance in their symptoms. Mean CVtimes were t2 5.3 s, t3 6s and residual 5.41 s in the former group. However in the latter group times were respectively 6.45 s, 6.91 s and 6.22 s. Differences were significant only for the CVt3.
Conclusion: The test of CVtime can discriminate both populations of patients. Future work is directed to acknowledge other differences that could be of help in understanding this complex phenomenon.

P023

Firing Behavior of Vestibular Sensitive Cells in the Ventral Posterior Thalamus of the Squirrel Monkey During Passive Rotation and Translation in the Horizontal Plane

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Background: Vestibular signals arising from the vestibular nuclei reach cortical processing centers via the thalamus. The ventral posterior thalamus (VP) is a major target of vestibular inputs from the vestibular nuclei. In this study we examined the firing behavior of cells in this region of the thalamus that were sensitive to vestibular stimuli.
Objectives: The objectives of the study were to examine convergence of otolith, semicircular canal, and proprioceptive signals on single neurons in this region of the thalamus.
Methods: Systematic extracellular recordings from ventral posterior thalamus were obtained in two alert squirrel monkeys. The monkeys were seated on a perch in a harness that allowed their trunk to be restrained from moving. Vestibular stimuli were produced with a linear track that was mounted on an angular turntable, which in turn was mounted on a tilt platform. Passive head on trunk movements were produced with motor mounted on the ceiling. Somatosensory receptive fields were mapped. Neck proprioceptive responses were studied by passive rotation of the head with respect to the trunk. Microelectrode punctures were made in region of the thalamus that extended from the medial border of the lateral geniculate nucleus to the medial aspect of the ventral posterior medial nucleus, and extended rostro-caudally from the medial geniculate body to the rostral end of the ventral posterior lateral nucleus.
Results: The firing behavior of 1171 neurons in the VP was studied during passive whole body rotation (WBR) and whole body translation (WBT) in the horizontal plane. Approximately 14% of the cells in this region (163/1171) were sensitive to WBR and/or WBT in the light. In many cases (31 cells) the modulation was attributable to stimulation of somatosensory receptive fields by relative motion of the monkey with respect to the harness restraint system. 35 cells were not sensitive to WBR and WBT in the dark. The remaining 97 cells (8% of the total sample) were sensitive to vestibular stimuli in the absence of visual and somatosensory stimulation. Those neurons were located in clusters primarily on the borders of the VP nuclei -- either immediately dorsal to VP or between VP and the medial geniculate nucleus. In the latter region cells could be activated following electrical stimulation of the vestibular nerve. None of the cells were sensitive to eye movements. Canal-otolith convergence was observed in very few of these cells. A few cells (14/97) were strongly sensitive to passive neck rotation and were poorly modulated during passive head-on-trunk rotation, but most vestibular sensitive cells were relatively insensitive to passive neck rotation.
Conclusion: The firing behavior of most vestibular sensitive neurons in the ventral posterior thalamus is primarily a sensory estimate of either the angular or linear motion of the head rather than an estimate of body or self-motion in space.
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P024

Estimation of a Linear Path Length when Blindfolded in a Wheelchair

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Background: Many studies deal about the capacity to detect the distance walked when vision is excluded (Rieser et al., 1990; Mittelstaedt and Glasauer, 1991; Marlinsky, 1999). This ability is allotted to the vestibular and proprioceptive systems. But few authors (Mittelstaedt & Mittelstaedt, 2001) worked on these processes when during motion in wheelchair.
Objectives: We want here to study whether subjects are able to correctly estimate a linear path length without vision, when lower limbs' motor information is not available. And we want to show that the practice of sports activities in every day life supports and optimizes the utilization of proprioceptive information.
Methods: Four groups took part to the experiment (male and female athletes and non-athletes). Subjects had to reach a target (10m ahead) that they have seen before being blindfolded. Subjects used two kinds of locomotion: actively propelling oneself in a wheelchair and passive motion in a wheelchair (i.e. being pushed). They carried out the tasks at three different velocities: normal, slow and fast.
Results: In Active wheelchair, the performances of the athlete groups (male and female) are better than those of the non-athlete groups. For athlete groups, we observed a decrease of the traveled distance with increase of the velocity, so that the best performance was obtained at slow velocity (9.51 ± 0.12 m, mean ±SD) and the worst fast velocity (8.75 ± 0.32 m). We observed the opposite effect for the non-athlete groups (slow: 8.12 ± 0.72 m; fast: 8.50 ± 0.84 m). In Passive wheelchair the performances of both groups

were the same. We observed an increase of the traveled distance with increase of the velocity, so that the worst performance was obtained at slow velocity (7.86 ± 0.76 m) and the best at fast velocity (10.03 ± 0.47 m). For athletes, the distance estimate was more accurate in the active wheelchair condition than in the passive wheelchair condition. Whereas for non-athletes, performances in active and passive wheelchair were similar.

Conclusion: When the subjects use new proprioceptive information that they do not have the practice to treat, the performance is definitely worse (in comparison with walking). The practice of a regular physical activity allows an easier adaptation when using new proprioceptive information. But without these information, the vestibular system can compensate the missing information.

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P025

Visual and Non Visual Information in Perception of Passive Linear Displacement

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Background: According to path integration (Mittelstaedt and Mittelstaedt, 1982), a subject knows continuously his position with respect to the starting point: this sort of navigation, which doesn't need any external reference is based on idiothetic signals generated during the displacement such as inertia, proprioception, efference copy and optic flow. Studies with humans (Mittelstaedt and Glasauer 1991, Berthoz et al. 1995, Israel et al. 1997, Mittelstaedt and Mittelstaedt 2001) have asserted the ability for subjects to estimate traveled path.

Objectives: We here examine perception of passive linear displacement through its self-controlled reproduction, with and without vision.

Methods: Participants were passively transported on a mobile robot and then had to drive it with a joystick to reproduce the distance in two conditions, light and darkness (blindfolded). The stimulus distances (from 2m to 8m) were traveled at constant velocity. The joystick used for response controlled linear speed. Stimulus and response conditions were first identical and then alternated.

Results: The results show first a great accuracy when stimulus and response conditions were identical. Second, for any stimulus, the distance gain (response/stimulus) was lower when response was in darkness. Stimuli in darkness also tended to induce a higher distance gain whatever the response condition was. Third we found same results for gain duration with also a great correlation between duration and distance gain. Mean velocity gain tended to decrease with darkness response condition and correlation between mean velocity and distance gain was significant.

Conclusion: This experiment suggests a tendency to overestimate displacement in darkness compared to vision, which was already noticed (Nico 2002). Nevertheless the correlation between distance, duration and mean velocity gains raises questions about which of distance or its dynamic components are estimated during motion.

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P026

Visual and Vestibular Contributions to the Perceived Direction of "Up"

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Background: The perceived direction of up results from an integration of visual and non-visual information, including the direction of gravity (sensed primarily through the otolith system), the orientation of the body, and visual cues. Measuring the direction of up has been attempted in various ways, including assessing the presumed direction of

illumination [1,2] or setting the orientation of a rod [3]. Such methods involve assumptions about the connection between what they actually measure and the implied direction of perceptual up that are difficult to test directly.

Objectives: Here we use a new method to assess the perceived up direction. The method involves simple character recognition and is minimally dependent on assumptions about physical laws. We use this probe to assess how cues are combined in generating perceptual up and the consequences of manipulating and removing them. Results are compared with assessments made using other methods.

Methods: To probe the direction of up we used a simple letter recognition task. The only visible difference between 'p' and 'd' is the orientation of the character. Subjects were shown the character in one of 18 orientations and indicated whether they recognized it as a 'p' or a 'd'. The perceived direction of up was then assessed as the orientation half way between the transition points between these interpretations. Visual cues were varied by viewing the character superimposed on a highly polarized visual background presented on a computer screen viewed through a shroud so that nothing else was visible. The background orientation was varied randomly in 15 steps of 22.5 deg. The body cue was dissociated from gravity by repeating the experiment with observers upright, supine or on their side.

Results: Both the orientation of the visual background and the orientation of the subject had a significant effect on the orientation of the transition zones between the p and d interpretations of the character. The corresponding "up" directions could be predicted from a simple weighted vector sum of the directions of gravity, the body and the orientation of the visual environment. On average the body was weighted about twice as much as either gravity or visual cues.

Conclusion: Assessment of up using the new p/d probe confirmed previous measures of perceived up direction using shape-from-shading [2] thus validating both methods. Visual, body and gravity cues combine almost linearly to indicate the perceived direction of up. Several different methods of assessing perceived up can be regarded as broadly equivalent.

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P027

Long Time Intervals Production Under Passive and Active Self-Motion

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Background: Semjen et al. (1998) found that under microgravity, as the otoliths are perturbed because of the lack of gravity, the inter response temporal intervals were increasingly undershot and the timing became more variable, suggesting that the vestibular system could influence time perception. In a tapping-each-second task performed in darkness, with and without self-motion, it has been found (Israël et al., in press) that time perception is probably influenced by self-acceleration polarity, which corresponds to the way the vestibular organs detect acceleration. Macar et al. (1994) found that time duration is perceived differently during passive and active modalities.

Objectives: We examined the influence of self-motion on the estimation of time intervals of 8 or 15 s, close to the perception threshold latency of self-motion variation, and with two conditions of temporal estimation during motion: button push during passive transport (passive) and control of self-transport with a joystick (active), in order to investigate the role of "activity".

Methods: In these preliminary results, only the passive condition was executed. Blindfolded healthy volunteers seated on a mobile robot had to press a button at the beginning and the end of the temporal interval. After one trial without motion, rotations and translations with 3 constant velocities were applied, followed by a last trial without motion.

Results: We found that during motion, the intervals produced were longer than without motion. We did not find differences between angular and linear displacements, and neither between the levels of constant velocity.

Conclusion: It is concluded that during passive transport, the production of long temporal intervals is perturbed as the intervals are overestimated. During the active condition of temporal estimation will the subjective duration shorten as the amount of attention devoted to the temporal task decreases? When the task was to produce taps each second, the functioning of the internal timing module only underwent changes for the trials with varying velocities (Israël et al., in press). Therefore we will submit here also the subjects to varying velocities profiles in order to compare the results

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P028

Role of Moving Air Stream for Creating Perception of Self-Motion

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Background: Moving visual surround and sound field can provoke illusion for self-motion. Birds for their orientation in space during flight use the sense of touch of air streams. A question arises: Could an air-flow moving around a stationary subject influence self-motion perception caused by moving visual surround.
Objectives: The purpose of the study is to investigate how an air-flow stimulus moving slowly around the body influences through the sense of touch the visually evoked vection and the decay of that vection in darkness.
Methods: Seventeen persons were exposed to optokinetic stimulus (OKS) 60º/s sitting stationary in the center of a rotating spherical device. After 45 s of experience of visual vection the light was switched off. The vection was indicated by pointer and reported verbally. This was repeated with switched on air blower, attached to the sphere wall and directed to the subjects' face. The air-blower was moving in light and in darkness with the same velocity.
Results: The air-stream increased consistently the strength of visually evoked vection. The duration of vection, when the light was off, lasted significantly longer -average twice longer. In one subject it did not decay and lasted to the end of air-stream rotation in darkness.
Conclusion: A rotating air current, through the sense of touch, facilitates the visually evoked self-motion illusion in humans and prolongs its aftereffect. This experiment shows that the sense of touch even alone could create vection.

P029

Eye Movement Control by Primate Cerebellar Hemispheric Lobule VII/VIII

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Background: Cerebellum has critical roles in control of both voluntary and reflex eye movements. Cerebellectomy including the three nuclei completely abolishes smooth pursuit. Several distinct areas of the cerebellum are supposed to be involved in the smooth pursuit control. Vermal lobule VII/VIII and lobulus petrosus of paraflocculus have been reported to be related to smooth pursuit control by lesion studies. Recent anatomical studies reveal that cerebellar hemispheric lobule VII/VIII receives inputs from frontal eye field via medial and lateral pontine nuclei, and projects to ventral portions of cerebellar interposed and lateral nuclei.
Objectives: To evaluate the role of hemispheric lobule VII/VIII in oculomotor control.
Methods: Experiments were carried out in three well-trained Macaca Fuscata. Eye movements were measured with the scleral search coil system. We examined dynamics characteristics and adaptations of post-saccadic smooth pursuit using a moving target in step-ramp mode. Effects of lesions of cerebellar hemispheric lobule VII/VIII were evaluated.
Results: After unilateral ablation, velocities of smooth pursuit were depressed, especially at relatively fast velocities, when the target moved ipsilaterally to the lesioned side. Latencies of smooth pursuit were also delayed. Adaptation of the smooth pursuit velocities ipsiversive to the lesioned side was appreciably depressed. Amplitudes of small catch-up saccades seen during pursuit movements were hypometric and their latencies were delayed.
Conclusion: Cerebellar hemispheric lobule VII/VIII plays an important role in smooth pursuit and saccade control.

P030

Predictive Saccades with Different Instructions and Self-Paced Saccades in Control Subjects

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Background: The effect of the specific instructions to the subject on predictive saccade behavior has only rarely been taken into account (Polidora et al. 1957), and the lack of uniformity of instructions may contribute to the considerable variability in the results from studies of predictive tracking.
Objectives: Our aim of the study was to re-investigate the effect of instructions on predictive saccade latencies and arrival times (difference between target appearance and time the eye arrived at the target position). We also wanted to evaluate, how the time between oppositely-directed saccades (saccadic intervals (SIs)) of self-paced saccades correlated with their best predictive inter-stimulus intervals (ISIs).
Methods: We analyzed saccade latencies in a predictive (square-wave) tracking paradigm in 10 normal subjects comparing 3 amplitudes (10, 20, 40º) and 5 inter-stimulus intervals (ISIs; 400, 500, 625, 1000 and 2000 ms). We analyzed the correlation of the different ISIs with the mean saccadic intervals (SIs) of self-paced saccades. Subjects were instructed to "follow the lights" (passive, reflexive instruction) or "move your eyes in time with the lights" (active, volitional instruction).
Results: Instructions had a clear effect on responses. Effects were greatest with 1000 and 2000ms ISIs and the largest target displacement. With the active instruction there were more predictive (–200ms < latency < 100ms) and anticipatory (latency < -200ms) saccades and with the passive instruction more reflexive saccades (latency > +100ms). Subjects could even take into account the duration of the impending saccade so that eyes would arrive close to the appearance of target independent of the amplitude of the required saccade. We compared mean SIs of self-paced repetitive eye movements of individual subjects with their best predictive ISIs found for the two instructions. For passive instruction there was a correlation of 0.68

($p = 0.04$) between self-paced SIs and the best predictive ISIs, while for active instruction the correlation was 0.92 ($p<0.001$).

Conclusion: Predictive saccade behavior depends upon instructions, and this finding must be taken into account in studies of eye movements in control subjects and patients. Each individual appears to have an optimal rhythm for predictive saccades that is reflected in their self-paced behavior.

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P031

Ultra-Short Perceptual Vestibular Time Constants and Its Association with Vestibular Navigatory Performance in the Congenitally Blind

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Background: Congenitally blind subjects are dependent upon non-visual mechanisms for navigating in everyday life. Sighted humans accurately utilize vestibular signals for navigating in the dark but the presence of such ability in the congenitally blind is unknown. Vestibular navigation may also be influenced by a brainstem mechanism called the 'velocity storage' integrator that prolongs the duration of the peripheral vestibular signal.

Objectives: We studied vestibular navigation, quantified perceptual vestibular velocity storage time constants and assessed lifetime physical activity, in congenitally blind and sighted subjects.

Methods: Vestibular navigation was assessed by having subjects (6 blind vs. 12 sighted) steer a motorised Baranyi chair in response to imposed angular displacements for two tasks, 'Go Back to Start' (GBS), a path reproduction task and 'Complete the Circle' (CTC) a path completion task. Vestibular velocity storage was measured by subjects (5 blind vs. 31 sighted) turning a tachometer wheel to indicate instantaneous angular velocity perception following velocity steps of 90deg/s. Lifetime physical activity scores were obtained by questionnaire.

Results: For GBS both sighted and blind subjects were accurate (stimulus vs. response displacement: r2 range for individuals 0.61 – 0.94) with no difference between both groups' performance ($P>0.05$ for slopes and r2 of grouped regressions). Multi-regression analysis indicated that sighted and congenitally blind humans encode head angular velocity and acceleration. In contrast, for CTC, blind subjects performed worse than sighted subjects ($P < 0.05$ for comparison of regression slopes and r2). The average velocity storage time constant of the congenitally blind was significantly shorter than in normal controls (5.34s vs. 16s; $P<0.001$). Two congenitally blind subjects had ultra-short time constants (2.39s and 3.30s) that were associated with superior angular path completion performance. These two subjects participated throughout childhood and adulthood in spatial activities involving body movements and scored highly on our lifetime physical activity scale compared to other blind subjects.

Conclusion: Our results suggests that the amount of physical activity requiring whole-body movement may influence the development of ultra-short time constants and enhanced navigation in blind subjects. The navigational experiments show that humans maintain representations of derivatives of the raw velocity vestibular input, which can be accessed for spatial navigation in both sighted and blind humans. Whilst congenital blindness does not interfere with simple path reproduction navigation, it is associated with impaired path completion task performance. Early and prolonged physical spatial activities in childhood and adulthood may be of value in improving vestibular navigation in the congenitally blind.

P032

Properties of Vestibulospinal Neurons Receiving Inputs from Anterior Semicircular Canal in Cats

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Background: The vestibulospinal reflex is important for the control of proper body posture and movement. In previous work from our group, we selectively stimulated the otolith nerves and described features of the utricular and saccular nerve-activated vestibulospinal neurons using electrophysiological techniques (SATO et al. 1996,1997). Although some aspects of semicircular canal-activated vestibulospinal neurons, in particular the strong connections between the canals and neck motoneurons, have been documented previously little is known about the spinal projection levels of canal-activated vestibular neurons.

Objectives: The present study was designed to clarify the projection level and the pathway of the anterior semicircular canal (AC) nerve-activated vestibulospinal neuron. We also investigated whether there were any differences between the neurons that projected solely to the cord and those that additionally sent ascending collateral branches to the oculomotor nucleus.

Methods: Experiments were performed on seven adult cats. The AC nerve was selectively stimulated. Vestibulospinal neurons were activated antidromically with four stimulating electrodes, inserted bilaterally into the lateral vestibulospinal tracts (LVST) and medial vestibulospinal tracts (MVST) at the C1/C2 junction. Stimulating electrodes were also positioned in the C3, T1, and L3 segments and in the oculomotor nuclei.

Results: AC nerve-activated vestibulospinal neurons were mainly located in the ventral portion of the medial and lateral vestibular nuclei. Almost all the vestibulo-oculospinal neurons and vestibulo-spinal neurons had axons that

descended through the MVST. Almost all those neurons were activated antidromically only from the cervical segment. Only one neuron was activated from the L3 segment of the i-LVST.
Conclusion: 1. The majority of vestibulospinal neurons with axons descending through the MVST were antidromically activated from the oculomotor nucleus.
2. It is likely that the majority of AC nerve-activated vestibulospinal neurons terminate in the cervical cord and have strong connections with neck motoneurons.

P033
A Model Based Approach to Latency Detection in Oculomotor Responses
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Background: Latency is the amount of time between the application of a stimulus and the onset of the response that the system produces to that stimulus. When such measurement is performed on experimental and intrinsically noisy signals it is typically computed using techniques based on an adaptive thresholds, related to the standard deviation of the signal on a time window [1,2]. The information provided by such measurement, though, takes into account at least three distinct factors: transmission time, processing time and system dynamics. Considering linear systems (order >= 2) the longer is the dominant time constant of the system the longer will be the progressive build up of the response. Thus the onset of these responses will easily be masked by noise in the recordings.
Objectives: Our goal here is to show the limitations of approaches based on adaptive thresholds to the problem of latency determination and to suggest a new, model-based technique, for attempting to determine the real latency (pure delay) of a biological motor system.
Methods: We built different dynamical systems of increasing order with Matlab to represent the system being studied, and delayed the input (a step of amplitude 5) to such block by a pure delay of τ seconds. The simulations were performed at 5 KHz sampling frequency. 250Hz band limited white noise was added to the output of the process block to represent the various sources of biological and instrumental noise. The resulting signal to noise ratio (SNR) averaged 220. We identified the delay and the time constants of the model through a genetic algorithm, based on elitism and tournament selection. Then we built a second order model having time constants comparable to those of the plant and tested the technique against step and steep ramp commands of amplitude 5 (minimum 100 deg/s).
Results: We compared the latencies estimated by the three standard deviations technique (A), those provided by the three standard deviations technique with backtracking (B) and those resulting from our approach (C), by simulating a model having time constants comparable to those of the ocular motor plant, and thus behaving as a first order system. The GA approach outperformed the other techniques against higher order (>=2) models (errors at least 6 times smaller). When tested against the dynamics of the ocular motor plant the performance of (B) was comparable to that of the GA when the input was an ideal step (23% vs. 12%) but quickly degraded as the steepness of the input decreased (61% vs. 31% with 100 deg/s).
Conclusion: Using noise-corrupted, model-generated data of known latency, we showed that the use of a model-based approach to the problem of latency detection provides much closer estimates of the true latency values than the common threshold-based techniques. A further advantage of our approach is that of being insensitive to the amplitude of the response.
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P034
Coordinate Transformations and Sensory Integration in the Detection of Head Orientation and Inertial Motion
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Background: Estimation of head orientation and inertial motion are fundamental tasks of the vestibular system. However, the underlying neural processing is complicated by the fact that otolith afferents encode inertial and gravitational accelerations equivalently. Recent behavioral studies have shown that the brain resolves this sensory ambiguity using both otolith and semicircular canal signals [1,2]. These experimental results are consistent with theoretical proposals that the brain solves a vector differential equation that relies on a canal-derived estimate of angular head velocity to calculate the rate of change of gravitational acceleration in a head-fixed reference frame [3]. However, so far, the required computations have not been directly related to the types of neural responses expected from a network that effectively implements them.
Objectives: The goals of this investigation were to: 1) propose a physiologically relevant network implementation of the theoretical relationships necessary to distinguish tilts and translations; 2) examine the key attributes of this network and its implications for identifying and characterizing the response properties of the neurons involved in inertial motion detection.
Methods: A model network of vestibular-only neurons was developed that embeds two key features required to perform the computations for inertial motion detection. These include: 1) neural integration and 2) nonlinear otolith-canal interactions. The predicted responses of this model during rotations and translations in different head orientations were simulated using the MATLAB simulation toolbox SIMULINK (Mathworks, Inc.).
Results: The proposed model reproduces recent behavioral observations including a translational vestibulo-ocular re-

flex driven by the semicircular canals [2] and predicts average neural populations that encode internal estimates of dynamic translational and gravitational accelerations. In addition, the model accounts for several previously unexplained characteristics of neural responses including complex patterns of otolith-canal convergence and the presence of integrated otolith signals [4]. The most fundamental prediction is a required coordinate transformation of canal signals from a head-fixed to a spatial reference frame. As a result, cell responses may reflect canal signal contributions that cannot be easily detected or distinguished from otolith signals.

Conclusion: The proposed framework makes an essential first link between the computations for inertial motion detection and predicted neural response properties. New experimental paradigms and alternative data interpretations that account both for an implied coordinate transformation and the integrative properties of the system will be required to elucidate the contributions of sensory vestibular signals to estimating spatial orientation and motion.

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P035

Three-Dimensional Reconstruction and of the Human Semicircular Canal and Measurement of Each Membranous Canal Plane Defined by Reid's Stereotaxic Coordinates

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Background: The plane-equation to estimate the human semicircular canals was determined by Blanks et al from the dissected bony labyrinth of human skull. However, the same study on the membranous semicircular canals has not been reported. In this study, each plane of the membranous semicircular canal to the Reid stereotaxic plane was measured from serial histological sections of the human temporal bone.

Objectives: We reconstructed three semicircular canals of seven temporal bones of Japanese adults by computer-aided 3-dimensional analysis. The angles between each pairs of both osseous and membranous canal planes were measured.

Methods: Each temporal bone was fixed by formalin, decalcified and embedded in celloidin. Three reference holes were put into a hardened celloidin block of each case. These reference holes were adjusted to be parallel each other. The celloidin block on a microtome was placed in the position of reference holes perpendicular to its cutting surface. The specimen was cut horizontally at 20 micron. Each cutting surface was photographed with a camera, the axis of which was parallel to the reference holes. The film of the picture was inserted into a slide scanner and data of the images were stored in a personal computer. Data of both osseous and membranous canals were transformed with computerizing digitizer. Three-dimensional reconstruction of semicircular canal was made with 3-D CAD from Every 10th section. The center of each cross section of the canal was calculated by using 3-D CAD. Plane-equation to estimate the canal plane defined 3-D CAD coordinates was obtained by the least square method. 20-40 centers of the cross sections were used for calculation in each canal, but the points at the ampullary regions were excluded.

Results: Angles between each pair of both ipsilateral osseous and membranous canals were calculated. In the bony labyrinth angles between the horizontal-anterior, anterior-posterior, and horizontal-posterior canal plane were 90.51±2.98(mean and the standard deviation), 91.70±1.85, and 94.52±3.32 degrees, respectively. The same angles measured from the membranous labyrinth were 90.05±4.74, 91.03±2.93, and 91.92±5.22 degrees, respectively.

Conclusion: Our data showed that angles between each pair of canal planes were much more closed to 90 degrees than Blanks' data calculated from the human bony labyrinth. This difference might occur by slight rotation of the membranous anterior canal at the region between the ampula and common crus inside the bony labyrinth.

P036

Static and Dynamic Membrane Properties of Prepositus Hypoglossi Neurons in Guinea Pigs

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Background: During the vestibulo-ocular reflex, a head velocity signal is sent from the semicircular canals to the medial vestibular nucleus (MVN) neurons, which forward this velocity signal to the abducens motoneurons. To get a functional reflex, a head position signal must be added at the level of the motoneurons. This position signal is obtained by integrating the velocity signal transmitted by the MVN neurons. In mammals, this integration takes place in the prepositus hypoglossi nucleus (PHN), which has strong reciprocal synaptic connections with the MVN (for review, see [1-2]).

Objectives: To search for the cellular substrates of integration, we measured the membrane properties and response dynamics of PHN neurons (PHNn) and compared them to those of MVN neurons (MVNn).

Methods: The stimuli previously used to characterize MVNn, namely steps, ramps and sine waves of current, were applied into PHNn recorded intracellularly on brainstem slices of adult guinea pigs [3].

Results: Our quantitative data confirm that PHNn can be classified in three types of cells according to their membrane properties. Two of them are similar to the type A and B neurons described in the MVN. Type A PHNn are characterized by their strong A-like rectification and deep AHP, while type B PHNn display no or a small A-like rectification and a double AHP. However, the average strength of

the A-like rectification is lower for PHNn than for MVNn, while the double AHP of type B PHNn is stronger than that of type B MVNn. Altogether, there is a general shift of the membrane properties of A and B PHNn towards "B-like" properties compared to MVN neurons. The dynamic responses of type B PHNn are similar to type B MVNn, whereas type A PHNn display more phasic and non linear responses than their MVN counterpart. The third type of cells is classified as type D PHNn. They display strong A-like rectification and a single deep AHP similar to type A neurons, but could be distinguished from A neurons by the spontaneous subthreshold oscillations of their membrane potential, a lower and more irregular resting discharge, and the ability to discharge in clusters of action potentials during steady-state depolarization. Interestingly, their dynamic response properties are the most phasic of the neurons in this nucleus.

Conclusion: Thus, compared to MVNn, the PHNn are characterized by their higher sensitivity to current and display the most phasic as well as the most non-linear response dynamics. In particular, the tonic type A neurons having regular resting discharge were much less numerous than in the MVN. This suggests that the type D neurons, which are specific to the PHN, might play an important role in vestibulo-oculomotor integration; and that the very phasic and non-linear properties of PHNn are important requirements for this function.

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P037

Perceived Surrounding Space Determines Posture, Eye Movement, and Sensation Under 1G and Microgravity

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Background: Findings of Coriolis experiments under 1G suggest that perceived surrounding space controls uniformly posture, gaze, and sensation. To assess the inference, responses to Coriolis stimulation under microgravity must be compared with responses under 1G.

Objectives: In order to elucidate a general rule of sensory-motor coordination, we compared posture, eye movement and sensation between 1G and microgravity situations.

Methods: Coriolis stimulation was done with 5 normal subjects on the ground (1G) and on board an aircraft (microgravity during parabolic flight). Subjects were asked to tilt their head forward during clockwise rotation at a speed of 100 deg/s under both conditions. Body sway was recorded with a 3D linear accelerometer, and eye movements with an infrared CCD video camera. Every subject boarded twice and underwent 11 to 16 parabolic maneuvers every flight.

Results: Coriolis stimulation at 1G caused body sway, nystagmus, and a movement sensation in accordance with inertial inputs. Neither body sway, excepting a minute sway due to the Coriolis force, nor a movement sensation occurred during microgravity, but nystagmus was clearly recorded although its duration was shortened.

Conclusion: Posture, eye movement, and sensation at 1G are uniformly controlled with reference to spatial coordinates that represent an outer world in the brain. Since normal spatial coordinates do not work in microgravity because there is no Z-axis, posture regulation and sensation that depend on them collapse. The discrepancy in responses between posture and eye movement may be caused by different dependencies on gravito-inertial situations.

P038

Semicircular Canal Modeling

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Background: The semicircular canal is working as a second order system. The understanding of this mathematical notion is difficult for physicians.

Objectives: Aiming at understanding how the semi circular canal (SCC) works, we will propose three successive improved models: the first one (1) has a stiff cupula and a stiff canal, the second (2) has an elastic cupula and a stiff canal; the last (3) has both an elastic cupula and an elastic canal.

Methods: (1) hydostatic model: no fluid displacement occurs. Suppose we cut the SCC through the cupula and unroll the SCC so that it becomes a straight tube. Then we place it vertically. The pressure at the bottom of the hemicupula is: $P = \rho g l$ according to Pascal law (P= pressure (P) ρ is the volumetric weight (kg/m3) g is the gravitational acceleration (m/s²) and l the length (m) of the unrolled SCC). If it is placed horizontally, no pressure occurs over the cupula. (2) model is an improved (1) with an elastic cupula. A pressure through the cupula produces its deformation, admitting a volume δV of endolymph ($\Delta P = K\Delta V$. (3) model is an improved (2) with an elastic cupula and an SCC. In this case the inflating pressure of the SCC becomes a regulating factor of the SCC.

Results: In (1) when its shape is restored, an angular acceleration θ produces a transcupular pressure equals to $P = \rho 2\pi R^2\theta$ (R is the diameter of the SCC and θ the angular acceleration).

In (2) the endolymph (endo) movement leads to the second order equation $A\, d^2y(t)/dt^2 + B\, dy(t)/dt + Cy(t) = x(t)$ where: A is the mass of endo ($A = 2\pi a^2 l\rho$) (a is the radius of the canal section), $d^2y(t)/dt$=endo acceleration, B=rubbing forces coefficient, $dy(t)/dt$=endo velocity, C=is dependant of the elasticity factor K of the cupula, y(t)=endo displacement, x(t)=input

in the SCC i.e. the motor force $f(t) = \Delta P(t)\ 2\pi a^2$. In (3) if endolymph pressure is increasing, the stiffness of the cupula is increasing too (because the elastic factor K is decreasing) and conversely if the inflating pressure decreases the stiffness of the cupula decreases. The variation (i.e. decrease) of the elastic factor K is responsible of parallel variation (i.e. decrease) of fluid displacement ΔV. Consequently endolymph movement equation is modified.

Conclusion: The forces inside the SCC are explained by the hydrostatic model (1): $P = \rho 2\pi R^2\theta$. The dynamic (2) model explains the equation of the SCC by its morphology: size, volume and weight. The self-regulated model (3) explains how the SCC is working in normal and pathologic conditions.

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P039

Discharge of Brainstem Burst Neurons During Combined Eye and Head Gaze Shifts in the Canal-Plugged Monkey

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Background: The vestibular contribution to head-unrestrained gaze shifts where both the head and eyes move is not fully understood. Any correlation between gaze movement and the neural activity upstream of the motoneurons is potentially affected by a vestibular signal generated by head movement.

Objectives: To assess the influence of vestibular signals on the saccadic command we have recorded from burst neurons in the brainstem after canal plugging.

Methods: We recorded burst activity in 41 brainstem burst neurons in two monkeys following bilateral canal plugging. All neurons were recorded during combined eye and head gaze shifts and during head restrained saccades.

Results: Canal plugging, which eliminated the passive VOR, caused initially dysmetric gaze shifts, which again became normetric after a few months. Eye counterrotations also gradually developed to stabilize gaze. Following canal plugging, burst neurons no longer discharged to the end of the gaze movement, but rather discharged only to the end of the eye saccade. Burst end was best aligned on eye end, and burst end always preceded eye end during both head-restrained and unrestrained gaze shifts. In control monkeys, burst end occurred at or slightly after eye end.

In control animals, the number of spikes in a burst was linearly related to gaze but not eye amplitude. In canal-plugged animals, the number of spikes in a burst was linearly related to both eye and gaze amplitude. In control animals, the burst discharge during head-unrestrained gaze shifts had two frequency peaks correlated with two peaks in eye velocity. After plugging, eye velocity did not have a second peak but instead exhibited a gradual extended deceleration. This asymmetric velocity profile with a single peak was nicely reflected in post-plugged neural discharge patterns.

Conclusion: These results indicate that elimination of vestibular contributions to gaze shifts alter eye movement characteristics and the associated discharge patterns of brainstem burst neurons. Since the alteration of velocity profiles caused by plugging is reflected in the firing rate profile of burst neurons, some vestibular signals must exert influence at or upstream of the burst neurons. However, the altered timing of burst end with eye end after plugging is consistent with a second influence of vestibular signals downstream of the burst neurons. Such signals would alter the relationship between the eye movement commanded by the burst neurons and the movement that actually is produced.

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P040

Abnormal Dynamics of Head Impulse Responses in Cerebellar Disease

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Background: The vestibulo-ocular reflex (VOR) must compensate for head velocity over a wide range of frequencies, accelerations, and velocities. Previous studies of patients and animals with cerebellar lesions have found varying effects on the rotational VOR. The reflex is preserved, although response gains may be high or low, and the ability to adaptively modify the gain is lost. However, in general, these studies examined responses to low frequency head motion and did not evaluate conjugacy. In our studies of head impulse responses in cerebellar patients, we have observed a similar variability of VOR gain. Here we ask whether the gain depends on the velocity of the stimulus and whether there is an effect on VOR conjugacy.

Objectives: To determine VOR disconjugacies and the head-velocity dependence of VOR gain during yaw impulses in patients with cerebellar disease.

Methods: Four patients and three normal subjects were studied. Manual head impulses of different velocities and accelerations were applied in near darkness, while the subject viewed an LED target in the center of the ocular motor range. The magnetic field search coil system was used to record eye and head positions, from which rotation vectors and angular velocities were calculated. For each impulse, the VOR gain (ratio of horizontal eye velocity to yaw head velocity) was determined for both eyes at 70 ms from the onset of head rotation (defined by a head velocity threshold of 5°/s).

Results: For each subject, the VOR gain was calculated as the median gain for all impulses for which the head velocity at 70 ms ranged between 120 and 180°/s. Gains varied more widely in patients, especially in the adducting eye, for which three patients had gains greater than unity (Table). For both groups, the gain was greater in the adducting eye

($p<0.00001$, paired t-test on all impulses). This disconjugacy was slightly greater in patients: the ratio of the gain in the adducting eye to that in the abducting eye was 1.14±0.09 and in normals 1.06±0.05. Finally, we used linear regression to determine the relationship of gain to head velocity over the full range. Combining both groups, the slope was greater in the adducting eye ($p < 0.0001$). However, patients had even larger slopes than normals.

Table:

	Control Subjects	Patients
Gain in Abducting Eye	0.90 ± 0.03	0.95 ± 0.05
Gain in Adducting Eye	0.98 ± 0.23	1.12 ± 0.25
Slope in Abducting Eye	-0.10 ± 0.57	0.93 ± 1.60
Slope in Adducting Eye	0.56 ± 0.61	2.25 ± 1.60

Gain at 70 ms and regression slope (gain vs. head vel) (mean ± s.d.

Conclusion: VOR disconjugacies and stimulus-dependent nonlinearities are exaggerated in cerebellar patients. This suggests either that the normal cerebellum compensates for nonlinearities inherent in brainstem VOR pathways, or that disease of the cerebellum introduces new nonlinearities. The consequence is that the VOR is less able to maintain gaze stability and binocular coordination over the wide range of normal head movements.

P041

Investigation of the Effect of Peripheral Vestibular Stimulation upon the Smooth Pursuit System

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Background: When moving through the environment and also tracking a moving target, labyrinthine inputs drive the vestibulo-ocular reflex (VOR) to stabilize gaze, and retinal inputs evoke pursuit movements that change gaze to track moving targets. How these seemingly conflicting signals interact depends upon many factors including whether head motion is active or passive, and whether target motion is predictable.

Objectives: To study pursuit-vestibular interaction by superimposing pursuit tracking on the VOR slow phase elicited by sinusoidal passive body rotation.

Methods: 7 healthy subjects were oscillated in a chair (yaw axis) using two different peak chair speeds (3 and 6°/s) in darkness. They were instructed to fix upon the location of a small light on the wall that flashed for 20 ms every 2 s. At peak chair velocity a pursuit stimulus was superimposed on the VOR slow phase. The target was a small laser dot applied in a step-ramp fashion at 5, 10 or 20°/s. The target speed and direction were randomized and were applied in the same or the opposite direction as the VOR slow phase. For comparison the same pursuit stimuli were presented with the head still. Eye movements were recorded with a scleral annulus. The initial open-loop 100 ms of pursuit tracking were analyzed looking at gaze (eye in space) acceleration.

Results: Acceleration over the first 100 ms of tracking depended upon the relative direction of the target and the VOR slow phase eye movement. E.g., at 20°/s target speed and 6°/s chair speed, eye acceleration was 120°/s/s for same directed eye movements and 100°/s/s for oppositely directed eye movements. Conversely, this effect was not apparent for the earlier epochs of smooth tracking. E.g., in the 25-50ms epoch for the same target and chair speeds, eye acceleration of tracking was ~150°/s/s for both directions. Pursuit latencies tended to be lower for the faster target stimuli but showed no consistent pattern as to whether the head was still or moving.

Conclusion: These preliminary results suggest that for the initial 100 ms of smooth pursuit tracking there is a direction dependent interaction between the smooth pursuit and the VOR slow phase responses. On the other hand such an interaction was not observed for the earlier epochs of smooth tracking. These findings are in accord with previous studies of pursuit, which suggest that the earlier and the later components of the open-loop response are under separate control mechanisms. Whether or not these interactions are specific to VOR elicited slow phases, or are a more general pursuit response to ongoing eye movements from any source, remains to be shown.

P042

Vestibular-Neck Interaction in the Primate Cerebellum

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Background: The vestibular labyrinth is located inside the head, and the head may move relative to trunk and limbs. Consequently, vestibulospinal reflexes, which recruit trunk and limb muscles to stabilize the body in response to physical stimuli acting on the labyrinthine sense organs, must take trunk-re-head orientation into account. The neuronal mechanisms involved in this fundamental task are largely unknown.

Objectives: To study the effect of changes in trunk-re-head position on the vestibular responses of fastigial nucleus neurons in primates and develop conceptual models of the underlying neuronal mechanisms.

Methods: Single unit recordings from fastigial nuclei neurons of two rhesus monkeys subjected to vestibular stimulation at different trunk-re-head orientations.

Results: Most vestibular-responsive FN neurons exhibit expedient changes in their spatial tuning, which (partially) compensate for the imposed changes in trunk-re-head orientation. The observed effects can be conceived as reflecting a (partial) coordinate transformation from head-centered sensory signals arising in primary vestibular affer-

ents to trunk- or body centered motor responses in the vestibulospinal effector muscles.
Conclusion: We propose that this neuronal behavior could be based on multiplicative interaction between spatially diverse vestibular input signals and neck proprioception, resembling "gain-field"-mechanisms that have been described for coordinate transformations in the visuomotor system.

P043

An Investigation of the Relative Stability of Reactive and Predictive Oculomotor Tracking

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Background: Previously (Shelhamer M and Joiner, 2003) we demonstrated a phase transition between reactive and predictive eye tracking of alternating targets. At the slowest pacing, subjects made a reactive eye movement after the target moved. As the pacing frequency increased, there was an abrupt transition to a predictive response: eye movements preceded the target jump. When pacing decreased in frequency, a phase transition again occurred, but this transition point was different. This hysteresis suggests that the tracking system has two stable behavioral modes.
Objectives: Our experiments were designed to determine the relative stability of reaction and prediction in the saccadic system. By analyzing a subject's response to the abruptly changed target pacing, we could quantify how much the system preferred to be in one state over the other.
Methods: The eye movements of four subjects were recorded while they performed four saccade tasks. Subjects were seated in a stationary chair inside a dark room, and the head was fixed with a chin rest. The targets were two alternating LEDs at + 15 on either side of the vertical midline. Subjects were requested to make saccades between these two targets. Each task was similar in design and duration (approximately 6 minutes). The targets alternated at different frequencies (ranging from 0.2 to 1.0 Hz) for a variable amount of time (8 to 10 cycles). For example, the targets would initially alternate at 0.6 Hz for 8 cycles and then abruptly change to 0.2 Hz for 10 cycles. This pattern was repeated throughout each set.
Results: We found that all four of our subjects could easily make a transition between pacing frequencies, if the old and new frequencies promoted identical behaviors (reactive or predictive). For example, all subjects could switch from tracking the targets at 0.2 Hz to 0.3 Hz, since both of these frequencies produce reactive behavior. However, when the transition was from a frequency that promoted prediction (1.0 Hz) to one that promoted reaction (0.2 Hz), all subjects continued to make saccades at the higher frequency for 2 to 3 saccades after the transition. The reverse was not true: subjects could easily make a transition from the reactive mode to the predictive mode.
Conclusion: Our results suggest that the saccadic system prefers to generate predictive saccades over reactive saccades, once it is in the predictive mode. This difference in affinity for the two behaviors may be responsible for the hysteresis seen in our earlier phase-transition experiments. If reactive and predictive saccades are found to be distinct stable states of the saccadic system, then present models of oculomotor control (Schmid and Ron, 1986) may need to be revised in order to incorporate the preference for one behavior over another.
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P044

Nose-Up and Nose-Down Sinusoidal Off-Vertical Axis Rotation as a Clinical Otolith Function Test

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Background: The vestibular system consists of semicircular canals and otolith organs. To evaluate the semicircular-ocular reflex (ScOR), caloric and rotational tests are routinely used. However, there is no practical test of the otolith-ocular reflex (OOR) in clinical use. The development of an evaluation tool for OOR is potentially important, because disorder of the otolith organs may be responsible for the complaints of some undiagnosed vertigo patients.
Objectives: In the present study, we investigated the contributions of the semicircular canal versus otolith organ signals to the vestibule-ocular reflex (VOR) by providing canal-only (earth vertical axis rotation: EVAR) and canal plus otolith 30-degrees nose-up and nose-down conditions (off-vertical axis rotation: OVAR).
Methods: The subject population consisted of 12 healthy adults, ranging in age from 28 to 40 years (mean, 29.5). In the OVAR session, we tilted the chair to 30 degrees both in nose-down and nose-up conditions. Stimuli were carried out sinusoidally at frequencies of 0.2 Hz, 0.4 Hz, and 0.8 Hz and a maximum angular velocity of 60 deg/sec both in the EVAR and OVAR. Horizontal eye movement was recorded and processed using infrared video oculography (SensoMotoric Instrument, GmbH, Berlin, Germany). The VOR gain differences between EVAR and nose-down, and EVAR and nose-up OVAR were statistically analyzed by 1-way ANOVA.
Results: There was no difference in the VOR gain between EVAR, and both nose-down and nose-up OVAR at 0.2 Hz. There was also no difference in the VOR gain between EVAR, and both nose-down and nose-up OVAR at 0.4 Hz. However, the VOR gain in nose-down OVAR at 0.8 Hz was significantly lower than that in EVAR ($p<0.01$). More-

over, the gain in nose-up OVAR at 0.8 Hz showed a lower tendency than that in EVAR (p=0.08).
Conclusion: During sinusoidal OVAR, when the head rotates counterclockwise from the nose-up position, the ScOR acts on ocular rotation to the right. However, the gravitational force stimulates the otolith organs simultaneously. Thus, the OOR should rotate the eyes to the left. There may be conflict between the ScOR and OOR responses in nose-up OVAR. Consequently, the VOR gain becomes low in this position. Contrary, in nose-down OVAR, when the head rotates counter-clockwise from the nose-down position, the ScOR acts on ocular rotation to the right. Consequently, eye movements derived from the ScOR and OOR go in same direction. Therefore, VOR gain in nose-down OVAR should be higher than that in EVAR, theoretically. However, in the present study, the VOR gain at 0.8 Hz in nose-down OVAR was significantly lower than that in EVAR. Therefore, it is postulated that VOR gain reduction in nose-down OVAR at 0.8 Hz contributes to the static otolith signal change, responding to the change in gravity from 1.0 g to 0.5 g, instead of dynamic otolith signal input.

P045
Quantitative Study of Head Thrust Test Using Infrared Video-Oculography

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Background: Head thrust test (HTT) has been introduced by Halmagyi et al. as clinical bedside testing for the purpose of examining the ipsilateral severe dysfunction of the lateral semicircular canal. Although its clinical significance has been well known, there has been few studies describing its quantitative evaluation.
Objectives: The aim of the present study was to verify the advantage of detecting the semicircular canal dysfunction with HTT using infrared video oculography(I-VOG) and to determine whether I-VOG could provide quantitative information of HTT and to evaluate the result of HTT of subjects with not only the peripheral vestibular dysfunction, but with central disorder.
Methods: 63 patients who had visited our clinic with a complaint of disequilibrium from April, 2002 to August, 2003 were included in this study. 47 patients were found to have unilateral vestibular disorder and 16 patients were diagnosed as central nerve disorder. We performed HTT with I-VOG and caloric test by electronystagmography. Catch-up saccade(CUS) was analyzed in two ways: the first one was to observe the CUS with naked eye on the output monitor of the I-VOG, and the second one was to determine the presence of CUS by the recorded waveform of HTT. Then we compared the above result with that of the caloric testing. The degree of CUS was also evaluated in comparison with that of the caloric testing.
Results: Subjects with severe unilateral vestibular dysfunction showed insufficient amplitude of vestibule-ocular reflex, followed by CUS. CUS was detected in 5 of 47 subjects by observing the eye movement on the monitor, whereas it was demonstrated in 8 of 47 subjects by observing the recorded waveform. CUS could not be found until the impairment of the caloric response would become severe. There was no significant correlation between the degree of caloric weakness and the amplitude of CUS. (p=0.734) Subjects with central disorder showed distinctive ataxic eye movement.
Conclusion: Naked eye observation on the output monitor could not always detect CUS, even in patients with highly impaired lateral semicircular canal function. Whereas, recorded waveform could slightly improved detecting ability of CUS. However, the quantitative analysis of CUS did not correlate with the degree of the lateral semicircular canal dysfunction. In addition, recorded waveform of HTT was available for distinguishing subjects with central disorder from subjects with peripheral vestibular dysfunction.
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P046
Bone Conducted Sounds Preferentially Activate Guinea Pig Utricular and Saccular Irregular Primary Afferents

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Background: Clinical tests of otolithic function by air conducted sounds are based on physiological evidence of the preference by saccular afferent neurons for such stimuli. Here we explored the effect of bone conducted sounds on primary afferents from all vestibular sensory regions.
Objectives: To measure the response of guinea pig primary vestibular afferents to bone conducted sounds in order to determine whether there is a preferential activation of otolithic afferents as opposed to canal afferents to such stimuli.
Methods: Single primary afferents were recorded extracellularly in anesthetized guinea pigs. Neurons were identified by location in the superior or inferior division of the vestibular nerve and classed as regular (CV < 0.1) or irregular (CV > 0.1)on the basis of their spontaneous firing. Each neuron was successively tested by: angular acceleration in yaw, pitch and roll and maintained position in pitch and roll to identify which semicircular canal or otolithic sensory region the neuron originated from. Each neuron was then tested by bone conducted stimuli - either clicks or continuous pure tones, delivered by a B-71 clinical bone conduc-

tion transducer cemented to the guinea pig's skull. All sound stimulus intensities were referred to the threshold for ABR response to clicks. The criterion for a neuron being classed as activated was a reliable, detectable increase in firing rate in response to the sound.

Results: Both regular and irregular canal neurons were insensitive to bone conducted sounds and very few responded: only 3 out of 118 semicircular canal neurons tested responded to bone conducted stimuli at the maximum levels our B-71 stimulator could deliver. Regular otolithic afferents likewise had an poor response; only 4 out of 75 tested responded to bone conducted sounds. However irregular otolithic afferents from both saccular and utricular maculae showed a clear response to bone conducted sounds, of 37 irregular otolith neurons tested 32 were activated, some at very low intensities (only about 30dB above ABR threshold).

Conclusion: There is a clear preference for irregular otolith afferents to be activated by bone conducted sounds at low stimulus levels. This result appears to be in conflict with the result of Young et al 1977 in the squirrel monkey but they were able to deliver much more intense stimuli than here and their criterion for activation was phase locking rather than the detectable increase in firing we used. A human skull stimulated by a B-71 vibrator will only receive a relatively small stimulus, and at such low levels our results suggest it is likely that such a stimulus to a human subject or patient will preferentially activate otolith irregular afferents probably originating from the striola.

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P047

3D Vestibulo-Ocular Reflex Evoked by Click-Trains in Superior Canal Dehiscence

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Background: Superior canal dehiscence (SCD) usually causes sound and pressure induced vestibular symptoms such as vertigo, imbalance and oscillopsia (Minor et al. 1998). In many symptomatic patients, it is often difficult to elicit any nystagmus responses to sound and pressure. Our recent work (Halmagyi et al. 2003a,b) has shown small vertical eye movements in response to single clicks.

Objectives: To determine if click-trains are a more reliable method of diagnosing SCD than either single clicks or pure tones.

Methods: 3D eye movements were recorded in 6 symptomatic SCD patients (SCD confirmed by CT imaging) in response to sound stimuli and the results were compared to 10 normal subjects. The sound stimuli were 1) monoaural 100microsec clicks at 5/s; 2) a train of 3 or 5 clicks spaced 1ms apart at 2trains/s; 3) pure-tones at 500Hz or 2kHz. To determine the response threshold of the SCD patients, 50 single clicks and 20 click-trains were tested in all patients with decreasing loudness from 110dB to 70dB in 10dB steps.

Results: All 6 SCD patients had 3D vestibulo-ocular reflex responses to single clicks and click-trains. Monoaural single click and click-train stimulation always generated upward slow-phase eye velocity and torsional slow-phase directed away from the stimulated ear. Horizontal slow-phase eye velocity was small and variable. As the number of clicks in the train increased to 3 and 5 clicks, the responses increased in amplitude. The peak eye velocity response for 5-click-trains at 110dB was: torsion ~25deg/s; vertical ~20deg/s; horizontal ~5deg/s. This was about five times the response magnitude from a single click. Normal subjects had similar responses, but only one tenth of the amplitude. The thresholds in SCD patients to single clicks and 5-click-trains were 20-30dB below normal. Four of the six SCD patients did not respond to pure tones.

Conclusion: Our study shows that click-train stimuli could be a more reliable method of diagnosing SCD than single clicks or pure tones. As the responses to 5-click-trains were sufficiently large, averaging was not necessary in order to measure the response.

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P048

Vibratory and Head Shaking Nystagmus in Peripheral Vestibular Lesioned Patients

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Background: It is known since 1973 that vibration applied on the mastoid can induce nystagmus (VN) under certain conditions. The nystagmus appears immediately, it is unfatigueable and disappears immediately at the end of the stimulus. Another test to show a one-side peripheral vestibular deficit is the Head Shaking Test (HST).

Objectives: To determine the clinical interest of the HST and VN, and to show the correlation—if there is—with the caloric test.

Methods: During the examination, the patient sits, and the eye movements are registered using videonystagmography (VNG). 100 Hz vibration stimulus is applied simultaneously on each mastoid for 10 sec. In unilateral vestibular deficit patients, a horizontal nystagmus is elicited which is always directed (not depending on the side of the stimulation) towards the healthy side. The registration and calculation of the NIV is done by a computer. During HST, the examiner shakes the patient's head in the horizontal plane for 20 seconds at 1 Hz frequency. In healthy patients no nystagmus is seen, but by peripheral vestibular hypo- or areflexic patients, a two phases answer is registered: the first phase is short and directs toward the healthy side, while the second phase is long and directs toward the pathological side. The recordings were done with VNG during 80 seconds.
Results: We had 35 areflexic patients (JI>80).VN: T-test for frequency (pathologic vs. intact) and for the velocity showed (pathologic vs. intact) no significant (p=0.95 and 0.66) difference between the two sides. HST: T-test for frequency (primary vs. secondary phase) and for the velocity showed no significant (p=0.49 and 0.51) difference. We had 35 hyporeflexic patients (20 < Jonkees Index < 80). VN:T-test for frequency (pathologic vs. intact) and for the velocity showed no significant (p=0.46 and 0.68) difference beetwen the two sides. HST:T-test for frequency (primary vs. secondary phase) showed no significant difference (p=0.95), while for the velocity showed significant (p<0,05) difference. After comparing the hypo- and areflexic patients with T-tests, we found a strongly significant difference in the velocities and the frequencies of the induced nystagmus. Our results support, that there is no significant side difference, but there is a strong difference between the hyporeflexic and areflexic patients. Finally in our study, we examined 27 normoreflexic patients (Jonkees Index < 20). In 13 patients, there was no elicitable response for the vibratory test, while the others (14 patients) presented positive response. For the HST in 13 cases, there was no response, by 5 only a primary phase could be observed, in 8 patients both a primary and secondary phase and in 1 patient only a secondary phase was elicited. These data show therefore an absence of correlation beetween the caloric and vibratory-HST tests.
Conclusion: In the clinical field, this test is useful, because it is easy to do and gives trustful information about the reflexivity of the horizontal canal peripheral vestibular apparatus. The vibratory nystagmus doesn't compensate with time, which can have also a medico-legal interest.

P049
VEMP and SVV in Benign Paroxysmal Positional Vertigo
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Background: According to current hypothesis Benign Paroxysmal Positional Vertigo originates after otoconia from a degenerating utricular macula float freely in a semicircular canal. Therefore it is of interest to assess the function of both maculae (utricle and saccule) in patients with this frequent disorder
Objectives: To test the function of utricular and saccular maculae in patients with BPPV.
Methods: 10 patients with BPPV
VEMP. Patients were examined in the recumbent position on a couch with their trunks at 25-30º from the horizontal plane, whilst lifting their heads against gravity. Surface EMGs were recorded using conventional adhesive electrodes applied in both stenocleidomastoid muscles (SCM). The active electrode was placed over the junction of the upper and middle third of the SCM, and the reference electrode over the medial ends of the clavicles. An earth electrode was applied to the sternum. Unrectified and rectified EMG signals were recorded and stored using an Oxford Profile EMG apparatus (Oxford instruments. Surrey, UK). The stimuli were clicks (of 0.1 ms duration) applied monoaurally through headphones (TDH49, Telephonic corporation, Huntington, NY, USA). Five hundred responses, in time spans of 100 ms, were averaged at each intensity of the stimulus (100, 90,80, 70, dB NHL). Latency and peak amplitude of N13 P13 waves ipsilateral to the stimulated ear were measured. Reflex thresholds were determined using 10dB decrements in click intensity.
SVV. The patients were given the instruction to place a light bar in the most accurate vertical position. The degrees of deviation to one or the other side were computed after 4 trials.
Results: There were different combinations of results in both tests nut were not normal in all the patients.
Conclusion: The functional assessment of other receptors in the posterior labyrinth opens a new method to more extensive evaluation of patients with dizziness. In the case of BPPV it can be of relevance to establish a hypothesis of the origin of the supposedly free floating otoconia. It can also explain some particularly unpleasant evolution as disequilibrium after repositioning maneuver.

P050
Value of Different Horizontal Vestibulo-Ocular Reflex Parameters in Detection of Peripheral Vestibular Lesion
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Background: Caloric and rotatory testing are traditionally used to assess the horizontal vestibulo-ocular reflex (h-VOR) function. In previous studies [1,2], we evaluated the dynamic h-VOR properties after impulsive testing in patients with acute unilateral labyrinthine diseases. We assess herein the value of caloric and rotational results in the identification of a vestibular pathology.

Objectives: To evaluate the value of certain h-VOR parameters in detecting peripheral vestibular dysfunction.
Methods: We compared the vestibular function of 89 patients presenting with acute onset of vertigo with spontaneous nystagmus (with or without associated hearing loss), to that of 22 normal subjects. All patients were examined during the acute stage of the symptoms (within one week after onset) and had normal neurological evaluation. According to history and clinical presentation, patients were classified in four main diagnosis: vestibular neuritis: 42, viral labyrinthitis: 22, Meniere: 15, miscellaneous (mainly traumatic vertigo): 10. The VOR function was evaluated by conventional caloric and impulsive testing. A simplified model of vestibular function was used to analyze the vestibulo-ocular response to rotational stimulation. The following parameters of the h-VOR response were considered: caloric asymmetry (canal paresis), time constant (tau), coefficient of sensitivity (k), gain (k/tau), bias (due to spontaneous nystagmus), and asymmetry between the two directions of rotation (tau1-tau2/tau1+tau2 x100, where tau1 was obtained toward the healthy side and tau2 on rotation toward the affected side). Statistical comparisons were performed using the likelihood ratio test.
Results: In an univariate analysis, caloric asymmetry (p=0.001), asymmetry between the two rotational directions (p=0.009), gain (p=0.004) and coefficient of sensitivity (p=0.005) were highly significant parameters for detecting vestibular lesion. Multivariate analysis demonstrated a better detection of vestibular dysfunction by combining parameters. In particular, using both caloric and rotational asymmetries increased the power of detection with 86.4% sensitivity, 90.9% specificity and 88% correct classification.
Conclusion: Numerous h-VOR parameters can be used, alone or in combination, to detect vestibular lesion in patients presenting with acute peripheral vertigo. Taking both caloric and rotational results into consideration is particularly useful. We attempt to evaluate whether some of these parameters or combination thereof can help in characterization of certain vestibular diseases or labyrinthine dysfunctions.
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P051

Sound-Evoked Neurogenic Responses with Short Latency of the Vestibular Origin

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Background: In ABR recording a large negative deflection with a latency of 3 msec (N3) could be recorded in patients with peripheral profound deafness (Kato et al., 1998). Ochi et al. (2001) suggested that N3 might be of vestibular origin. They recorded N3 only in patients with peripheral profound deafness. If we can record N3 potentials in subjects with normal hearing, recording N3 potential will be a new clinical test of the vestibular system.
Objectives: To record neurogenic potentials (N3) of the vestibular origin in healthy volunteers and patients with preserved hearing.
Methods: Twelve healthy volunteers (10 men and 2 women, age 23 to 37 years) and patients with vestibulocochlear disorders and preserved hearing were enrolled into this study.
For recording responses, surface electrodes were placed on the bilateral mastoids and the vertex. An electrode on the nasion was served as the ground. Recording was performed using an auditory evoked potential recording system (Neuropack sigma, Nihon Kohden Co. Ltd., Tokyo, Japan) with a mini mixer (MN04, Fostex) and a stereo amplifier (NS901, Maruei Electric Co. Ltd., Tokyo, Japan) (Takegoshi et al. 2003). Signals were amplified and band-pass filtered (100 – 3000 Hz). One thousand Hz short tone bursts (1kH STB, rise/fall time = 0.5 msec, plateau time = 1 msec) were presented to either ear through a headphone (Type DR-531, Elga Acous. Co. Ltd., Tokyo, Japan) with or without white noise (WN) to the ipsilateral to the stimulated ear. The stimulation rate was 10 Hz, and the analysis time was 10 msec. The responses to 500 stimuli were averaged twice.
Results: When 1 kH STB (95 dBnHL) were presented with 100 dBSPL WN (ipsilateral to the stimulated ear), a negative peak with 3 to 4 msec latency was observed in 23 of the 24 ears (95.8%) with reproducibility. Without WN, a negative peak with 3 to 4 msec latency was observed in 17 of the 24 ears (70.8%). The threshold of a negative peak with 3 to 4 msec latency was 89.7 dBnHL on the average. In some patients, a negative peak with 3 to 4 msec latency was absent. Then their VEMP was also absent on the affected side.
Conclusion: Using techniques of white noise exposure to the stimulated ear, we recorded a negative peak with 3 to 4 msec latency in healthy subjects and vestibulo-cochlear disorders patients with preserved hearing. This negative peak is likely to be of vestibular origin.
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P052

The Influence of Unilateral versus Bilateral Clicks on the Vestibular Evoked Myogenic Potentials

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Background: Vestibular evoked myogenic potentials (VEMPs) are a new physiologic test to examine the integrity of the sacculo-collic reflex. Any lesion in this pathway may display with abnormal parameters of VEMP responses. This study tends to investigate whether VEMPs evoked by bilateral stimulation (B-VEMPs) could substitute those by unilateral stimulation (U-VEMPs)as a rapid screening test for evaluating bilateral sacculo-collic reflexes on the same time.
Objectives: The aim of this study is to examine the difference between unilateral and bilateral stimulation on VEMPs in healthy volunteers.
Methods: Fourteen healthy volunteers (9 males, 5 females; ages ranged from 24 to 41 years, with a mean of 31 years), without previous ear disorders, were enrolled in this study. VEMPs were evoked by unilateral clicks for each ear first, followed by bilateral clicks on the same subject in those with odd registration number, and vice versa in those with even registration number. The latency of each peak (p13, n23), peak-to-peak interval and amplitude (p13-n23) were measured by computer and compared.
Results: The mean latencies of p13 and n23, peak p13-to-peak n23 interval and amplitude of U-VEMPs were 11.62±0.99 ms, 19.74±1.30 ms, 8.12±1.66 ms, and 110.79±61.37 μV, respectively, whereas those of B-VEMPs revealed 11.16±0.51 ms, 19.22 ±1.61 ms, 8.06±1.66 ms, and 111.77±40.98 μV, respectively. There exhibited a significant difference in the latencies, but not for the interval and amplitude between U-VEMPs and B-VEMPs
Conclusion: This study might suggest that B-VEMPs could substitute U-VEMPs as a rapid screening test for evaluating bilateral sacculo-collic reflexes on the same time by amplitudes . However, prolonged latencies of U-VEMPs might not be applicable to those of B-VEMPs for diagnosing lesions in the retrolabyrinthine.
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P053

Analysis of Gender Differences in the Vestibular Evoked Myogenic Potentials

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Background: Vestibular evoked myogenic potentials (VEMPs) vary with stimulus methods, stimulus parameters, and electrode placement, and all of these factors need to be considered when waveforms are evaluated. Stimulus protocol and electrode configuration can be held constant, but subject characteristics such as age and gender, cannot and this increases VEMP variability.
Objectives: The aim of this study is to investigate whether any gender difference exists among VEMP parameters.
Methods: Twenty-eight healthy volunteers (14 males, 14 females, ages ranged from 20 to 40 years with a mean of 28 years in males and 29 years in females)without hearing or vestibular disorders were divided into two groups by gender and enrolled to receive VEMP tests. The response rate in each group is defined as ear number of positive VEMP over total 28 ears in each group. The latency of each peak (p13, n23), peak-to-peak interval and amplitude (p13-n23)of males (M-VEMP) and females (F-VEMP) were measured by computer and compared.
Results: The mean latencies of p13 and n23, peak p13-to-peak n23 interval and amplitude of M-VEMPs were 11.87 ± 0.86 ms, 19.38 ± 1.15 ms, 7.52 ± 1.31 ms, and 109.9 ± 46.5 μV, respectively, whereas those of F-VEMPs revealed 11.33 ± 0.95 ms, 18.23 ± 1.38 ms, 6.90 ± 1.29 ms, and 127.0 ± 45.2 μV, respectively. There exhibited a significant difference in the latencies, but not for interval and amplitude between M-VEMPs and F-VEMPs.
Conclusion: The latencies are earlier in F-VEMPs than in M-VEMPs whereas the peak to peak interval and amplitude are independent to gender. While interpreting the VEMP parameters, we suggest establishing different reference values by gender to evaluate VEMP responses in those of vestibular diseases.
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P054

Computerized Electronystagmography in Diagnostics of Labyrinthine and Perilymph Fistulas

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Background: Vertigo accompanying chronic suppurative otitis media and otosclerosis remains incompletely resolved problem, especially in surgery of these diseases [Ludman H.,1997; Smyth G.D.L.,1997]. One of the serious complication in these instances is labyrinthine or perilymph fistula [Moon C.N., 1970; McCabe B.F., 1984].

Objectives: The aim of this investigation is assessment of diagnostic value of computerized electronystagmography in test on presence of fistula sign.

Methods: 32 persons suffering from unilateral chronic suppurative otitis media and otosclerosis complained of vestibular disturbances triggered at a toilet of an ear and (or) by simply compressing to tragus. With an increase of pressure in external auditory meatus with Politzer bag the patient was asked to keep a look aside stimulation and with underpressure of air – in the opposite direction. Computerized electronystagmograms were made both with fixing a look on light, and with elimination of visual fixation (eyes opened in darkness and eyes closed). There were 4 main components of computerized ENG: epicutaneous chlorinated silver electrodes; original AC-amplifier; original programs of record of an analog signal with processing with the help of analog-digital converter; original special software package for analysis of nystagmus.

Results: Pressing nystagmus was visually registrated in none cases in suspected labyrinthine and perilymph fistula. Test on presence of fistula sign (with application of computerized ENG) turned out to be positive in 22 cases with circumscribed labyrinthitis and in all 7 patients with perilymph fistula. In all instances pressing nystagmus was revealed in condition(s) without ocular fixation. The revealing of the pressing nystagmus was considered to be diagnostically significant at least in one of the procedural conditions.

Conclusion: Peculiar nystagmographic attribute of infringement of integrity of otic capsule serves often (in 91% cases in suspected fistulas) detection of pressing nystagmus. Application of the computerized ENG in test on fistula sign allows pressing nystagmus to be found out in condition(s) with elimination of ocular fixation. This approach is essential for increase of diagnostics of circumscribed labyrinthitis and postoperative perilymph fistula. Detection of pressing nystagmus in chronic suppurative otitis media and otosclerosis is one of most important indications, especially, for revision surgery.

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P055

Vestibular Evoked Ocular Responses to AC/BC Sound II: A Neuroanatomical and Physiological Interpretation of AC-OVEMPs

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Background: In Todd et al. (these proceedings) we showed that VEPPs are most likely OVEMPs.

Objectives: A characterisation of the spatio-temporal properties of AC-OVEMPs in order to determine the underlying pathways.

Methods: Four normal subjects were studied using 2 ms, 500 Hz AC pips. Thresholds (V_T) for AC stimulation were first obtained using the VEMP test. OVEMPs at 18 dB re V_T were obtained using four pairs of electrodes placed superior and inferior to both eyes.

Results: AC-OVEMPs consist of biphasic waves obtained in each of the four electrode pairs. Contralaterally these occur superiorly at 9 and 13 ms, with amplitudes +0.6 and -0.7 muV, and inferiorly at 10 and 17 ms, with amplitudes -1.4 and +1.7 muV. Ipsilaterally these occur superiorly at 10 and 17 ms, with amplitudes -0.5 and +1.0 muV, and inferiorly at 10 and 17 ms, with amplitude -0.9 and +1.0 muV.

These are preceded by an earlier a P6 (+0.2 muV) which is largest in inferior electrodes.

Table:

Proposed pathways generating AC-OVEMPs (adapted from Feldon and Burde).

Stimulation Mode	Receptor	Effect	Relay Nucleus	Tract	Muscles Targeted
AC	Sacculus	Excitation	Y Group	Brach. Conj.	i-SR + c-IO
		Inhibition	SVN	MLF	i-IR + c-SO

Conclusion: In conjunction with the observed movements for AC sound (Todd et al., these proceedings), previously established neuroantomy (Feldon and Burde, 1992) and physiology (Murofushi and Curthoys, 1997) we wish to suggest that the above results are consistent with the pathway summarised in Table. Thus the initial phase is interpreted as inhibition/excitation of contralateral SO/IO muscles and excitation of ipsilateral SR muscle driven by acoustic activation of the sacculus. The P6 may correspond to rapid inhibition of the ipsilateral IR muscle or a midbrain dipole source. The larger contralateral potentials may be indicative of contralateral dominance. The second component of the biphasic wave may correspond to recovery from adaptation whereby excitation is followed by inhibition and vice-versa. The spread of latencies in each phase may be indicative of different conduction times corresponding to different path lengths.

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P056

Vestibular Evoked Ocular Responses to AC/BC Sound III: A Neuroanatomical and Physiological Interpretation of BC-OVEMPs

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Background: In Todd et al. (these proceedings) we showed that VEPPs are most likely OVEMPs.

Objectives: A characterisation of the spatio-temporal properties of BC-OVEMPs to determine the underlying pathways.

Methods: Four normal subjects were studied using 2 ms, 500 Hz BC pips. Thresholds (V_T) for BC stimulation were obtained using the VEMP test then OVEMPs at 18 dB re V_T were obtained in four pairs of electrodes placed superior and inferior to both eyes.

Results: BC-OVEMPs also consist of bi-phasic waves, but differ markedly in their morphology from AC-OVEMPs, most clearly in the contralateral superior position where the polarity is reversed. Contralaterally these occur superiorly at 11 and 17 ms, with amplitude -0.9 and +1.3 muV, and inferiorly at 8.0 and 13.5 ms, with amplitude +0.5 and -0.5 muV. Ipsilaterally these occur superiorly at 9.5 and 17 ms, with amplitude -0.6 and +1.6 muV, and inferiorly at 9 and 13 ms, with amplitude +0.3 and -0.7 muV. These are preceded by a P6 (+0.8 muV) in the ipsilateral superior electrodes.

Table:

Proposed pathways generating BC-OVEMPs (adapted from Feldon and Burde).

Stimulus Mode	Receptor	Effect	Relay Nucleus	Tract	Muscles Targeted
BC	Utriculus	Excitation	MVN	MLF	i-SO + c-IR
		Inhibition	SVN	MLF	i-IO + c-SR

Conclusion: In conjunction with the observed differential movements (Todd et al., these proceedings), previously established neuroantomy (Feldon and Burde, 1992) and recent single neuronal recording results (Curthoys et al. 2003) we wish to suggest that the above results are consistent with the pathways summarised in Table. BC-OVEMPs are complicated by cross-conduction to the contralateral ear, and consequent superposition of sources. However, the observed potentials may be interpreted as bilateral inhibition/excitation in IO/SO muscles in the activation phase, driven by a dominant input from the utriculi, followed by bilateral excitation/inhibition of IO/SO muscles in the recovery phase. Like AC-OVEMPs the BC-OVEMPs appear to be largely generated in the obliques with a weaker contribution from the rectus muscles, which may reflect dominance of the contralateral projection to i-SO.

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conducted (BC) acoustic stimulation I: Eye movements and timing in relation to vestibular evoked peri-ocular potentials (VEPP).

P057

Three-Dimensional Vestibulo-Ocular Responses to Rotation and Translation in Patients with Canal and/or Otolith Defects

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Background: In previous studies we found that tests of the vestibulo-ocular reflex with high acceleration impulses result in reliable assessment of canal function. During the first 100 ms the measured VOR is of pure vestibular origin without interference of the visual system. So far head impulse tests have mainly been restricted to rotary stimuli in the horizontal plane. With a new 3D motion platform we extend the technique of impulse testing to linear and rotary stimulation in 3D.
Objectives: Our objective is to investigate the semicircular canals and the otoliths in all three dimensions. This allows us to assess vertical canal and/or otolith disorders. Here we present the first results of this test method in a patient with superior canal dehiscence syndrome (SCDS) and a patient with Tullio phenomenon.
Methods: Patient 1 had SCDS on both superior canals with the following symptoms: Tullio phenomenon, Hennebert sign and chronic equilibrium problems. Patient 2 had Tullio phenomenon and oscillopsia of unknown cause. Both were measured and compared to a control group. We measured the angular VOR and linear VOR in light and darkness. Subjects were exposed to rotary and linear impulses with a 100 ms constant acceleration of 100 deg/s^2 and 2m/s^2 respectively. 3D eye movements were registered with a double infrared camera system (Chronos Vision). Gain and delay of the eye reflexes in the first 100 ms were measured.
Results: We observed hypo reflexive eye movement responses in patient 1 in response to linear impulses in darkness but not in the light. Patient 2 also had abnormal eye movements in response to translation. However, in this patient there was only an asymmetry in forward / backward direction with an abnormal high gain to forward motion in light and darkness. In response to rotary impulses the gain of the eye movement responses in patient 1 was similar to our control subjects. So the dehiscence of bone over the superior canal had no effect on the AVOR. Also in patient 2 the AVOR responses were largely indistinguishable from our control group, albeit that responses to pitch stimulation were asymmetric.
Conclusion: We conclude that SCDS in patient 1 had no effect on the AVOR. Instead, the causes of dizziness reported by both patients may be an abnormal contribution of the otoliths to the vestibulo-ocular responses.
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P058

3-D Exploration of Otolith and Canal Function with Whole-Body Impulses

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Background: Common devices to test the function of semicircular canals and otoliths are the rotational chair and linear sled, respectively. These devices stimulate the vestibular system around or along one axis. However, our vestibular system is 3-D in nature (orientation and function). A novel 3-D motion platform enables us to deliver rotary and linear motion in any direction. It is capable of whole body rotation and translation (like rotational chair and linear sled) instead of head only (like head impulse tests by a torque-helmet or investigator).
Objectives: The objective is to study 3-D rotary and linear vestibular responses with this device in healthy human subjects and in patients with vestibular disorders.
Methods: Subjects are immobilized in a chair on the platform. Eye movements are recorded with an infrared eye tracker system (Chronos Vision), capable of 3-D eye position measurement. Its headset with infrared cameras is attached to a rigid arm mounted on the platform. A bite board connected to this arm further ensures fixation of the subject. The center of rotation of the platform is set midway between the ears. Both impulsive and sinusoidal tests are performed in light as well as darkness. As a first test of our device, eye responses to stimulation about axis covering a full 360 degrees range were measured in healthy human subjects. The rotational and translational impulsive tests consist of 120-ms constant accelerations of 100 deg/s^2 and 2 m/s^2, respectively. The sinusoidal tests are performed at 2 Hz with a peak acceleration of 80 deg/s^2 for rotations and 1.8 m/s^2 for translations.
Results: First results on healthy subjects show that the gain of responses depend on the direction of stimulation. Heave stimulation results in high gains in vertical eye movements. Sway stimulation results in horizontal eye movements with high gains. In addition, we observed vertical divergence of the eyes. Surge stimulation induces only small tilt reactions (vertical eye movements). Responses during the first 100 ms after onset of the impulsive movement show hardly any difference between the light and darkness condition. For rotations the gain also depends on stimulus direction, with high gains for pitch and yaw and low gains for roll.
Conclusion: Our device enables us to measure eye responses to 3-D rotations and translations in any direction and will be useful for studying healthy subjects as well as patients with canal and/or otolith dysfunction. In the near future our set-up will be expanded with stereo visual stimulation to investigate vestibular-visual interactions at varying viewing distance.
(Supported by ZonMW grant 912-03-037)

P059

The Video Impulse Test Assesses Function in All 3 Canals in Patients with Impaired Vestibular Function

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Background: Vestibular lesions may impair function in the 3 different semicircular canals (SCC) aw well as the otolith organs. In most office procedures we test only the lateral canals SCCs and in the lower frequency range. Tests for vertical canal SCC function and possibly assumed otolith function are complicated and therefore not generally pursued. The head impulse test, however, may be extended to the vertical canals SCCs but require search coils or possibly video techniques in development. We recently developed a technique using video-frenzels for assessing vertical canal function (1). The impulse tests also assess function of the higher frequency range of these vestibular receptors (2) and may therefore contribute complimenting information on vestibular function

Objectives: To assess pre-op patients with impaired vestibular function due to vestibular schwannomas and correlate findings of horizontal and vertical canal function to tumor size and caloric responses as side difference and caloric sensitivity

Methods: A total of 50 patients were evaluated with tumors of 0 to 40mm extrameatal size. The vestibular impulse test was performed with video-frenzels covering one eye, the other eye viewing an object. Impulses were performed in the 6 different canal planes i.e. bilateral horizontals, the LARP and the RALP planes. Data were independently reviewed.

Results: Impulses were decided pathologic in 32/50 for horizontal 23/49 Anterior and 25/49 for the posterior canal respectively; the vertical canal test was more often deemed inconclusive than the horizontal. 2 patients with pathological posterior and horizontal canal function had normal anterior canals. Caloric sensitivity strongly correlated to the appearance of a pathologic impulse test for all three canals, as did caloric side difference. Patients with normal impulse tests had significantly smaller tumors then those with pathologic tests (p=0.022).

Conclusion: The video impulse test is a viable test for vertical as well as horizontal canal function that can be applied in office. There seem to be differences in the effects on horizontal and vertical canals. Differences were also found between tumors that were approached suboccipital to save hearing and those with unserviceable hearing.

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P060

Preliminary Study for Vestibular Evoked Myogenic Potential Induced by Bone Conducted Stimuli

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Background: Vestibular evoked myogenic potential (VEMP) has been established as an examination for saccular function. VEMP was stimulated with click sound delivered from headphone, thus it could not be recorded in the patients with conductive hearing loss. It has been known that bone conducted tone burst stimuli could evoke VEMP (B-VEMP). If B-VEMP can show the similar results of conventional air conducted VEMP (A-VEMP), saccular function may be examined in the patients with conductive hearing loss.

Objectives: The purpose of this study is to define the optimum stimulation for B-VEMP recording and to compare the results between A-VEMP and B-VEMP.

Methods: The optimum stimulus condition for B-VEMP was studied in 20 normal healthy volunteers. Delivered tone burst sound was with 4, 8, and 12 msec duration and at 250, 500, 1000, 2000 and 4000 Hz. In each condition, p13-n23 amplitudes were recoded. To compare between A-VEMP and B-VEMP, 30 normal healthy volunteers and 30 patients with balance problem were employed. Both examinations were performed in each subject and p13-n23 amplitudes were recoded. Click sound stimuli with 95 dBnHL (normal hearing level) was used to record A-VEMP. Tone burst sound with 50 dBnHL was delivered over the mastoid processes by a BR41 bone vibrator (Rion Co., Japan) to record B-VEMP.

Results: The amplitudes induced by tone burst with 4 msec duration were smaller than those with 8 msec and 12 msec. The amplitudes at 250 Hz were larger than those of other frequencies. A tone burst with 8msec duration at 250Hz was considered as the optimum stimulus in B-VEMP. There were no differences of the inter-aural ratio of p13-n23 amplitude and of the latency between A-VEMP and B-VEMP in either the normal subjects or the patients.

Conclusion: These findings suggested that B-VEMP was as useful as A-VEMP for at least the patients without conductive hearing loss. Saccular function might be examined in the patients with conductive hearing loss by B-VEMP.

P061

Far and Near Target Dynamic Visual Acuity: A Functional Assessment of Canal and Otolith Performance

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Background: Upon their return to earth, astronauts experience the effects of vestibular adaptation to microgravity. The postflight changes in vestibular information processing can affect postural and locomotor stability and may lead to oscillopsia during activities of daily living. However, it is likely that time spent in microgravity affects canal and otolith function differently. As a result, the isolated rotational stimuli used in traditional tests of canal function may fail to identify vestibular deficits after spaceflight. Also, the functional consequences of deficits that are identified often remain unknown.
In a gaze control task, the relative contributions of the canal and otolith organs are modulated with viewing distance. The ability to stabilize gaze during a perturbation, on visual targets placed at different distances from the head may therefore provide independent insight into the function of these systems.
Objectives: Our goal was to develop a functional measure of gaze control that can also offer independent information about the function of the canal and otolith organs.
Methods: Dynamic Visual Acuity (DVA) was assessed for 10 subjects using both FAR (4m) and NEAR (0.5m) viewing distances. A custom-written acuity threshold determination program was used to display Landolt C optotypes on a laptop computer screen for the FAR condition and on a micro-display for the NEAR condition. Actively-generated perturbations were created by having the subjects walk (1.79 m/s) on a treadmill. The changes in acuity that are attributable to inadequate compensation for body movements were isolated by subtracting each subject's standing acuity from their walking acuity at each viewing distance.
Results: With a mean decrement of 0.26 logMAR (range: 0.16 to 0.36), the decrease in visual acuity between standing and walking was significantly greater ($p < 0.00001$) in the NEAR target condition when compared to the FAR condition (mean: 0.02, range: -0.02 to 0.1). This result is consistent with the subjective reports of relative target motion in the NEAR condition and provides quantitative evidence that gaze stabilization mechanisms do not fully compensate for the body movements in the NEAR condition in normal subjects.
Conclusion: The locomotion paradigm described here provides a functionally-relevant measure of gaze control that may be useful for measuring readaptation in returning astronauts or recovery of patients with vestibular disorders. If the perturbations can be sufficiently isolated, DVA at different viewing distances may also be useful for investigating the differential effects of an intervention, (e.g. spaceflight) on the canal and otolith organs.

P062

A New Otolith Test: The Subjective Horizontal

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Background: Otolith function remains the primary area of human vestibular physiology needing a battery of reliable clinical tests. Neither the subjective visual vertical nor vestibular evoked potential tests have been fully accepted as the "gold" standard in this regard.
Objectives: Our aim was to use a dynamic posturography platform, which could simultaneously tilt in the pitch (backwards-forwards) and roll (side-to-side directions) to develop an otolith test based on the subjective horizontal and link the differences in the results of unilateral otolith deficit patients to their stance and gait instability.
Methods: Thirteen patients with a neurectomy of the vestibular nerve, following removal of a cerebellar pontine angle tumor, and 39 age-matched healthy subjects were tested under eyes open and eyes closed conditions. The platform was tipped 5 deg at 1 deg/sec in each of 8 directions (3 left and backwards, 3 right and backwards and 2 forwards to the left and right) twice in random order. Subjects were asked to move the platform back to their subjective "horizontal" position using a hand-held joystick controller. The deviation of the platform in the roll and pitch directions from the true horizontal was then measured.
Results: Normal subjects had similar roll and pitch deviations from horizontal of 0.5 deg on average that did not vary with tilt direction or visual condition. Deviations in the roll direction did not change with age, however, those over 50 years of age had larger pitch deviations for backwards tilts. Patients had roll deviations that were twice as large as those of controls with the biggest differences for tilts to the lesion side under eyes closed conditions. Pitch deviations were larger than for controls tilts forwards under both eyes open and closed conditions. When the patients' balance control was tested with several stance and gait tests, differences with respect to controls were, without exception, most evident for roll trunk deviations. Significantly, stance on foam was larger than normal in both the roll and pitch directions.
Conclusion: We conclude that this test of the subjective horizontal may prove to be a simple and effective means to test otolith function. Inability to perform the test with results within normal limits will probably be correlated with a roll instability during stance and gait, particularly when ankle proprioceptive inputs are compromised.

P063

New Methods for Stimulating Otolith Organs by Linear Acceleration

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Background: The standard data regarding the 3-D shape of the human utricular macula that were reported in our previous study [1] could be utilized in the new testing methods for stimulating the utricular macula effectively.

In our previous study, it was reported that human utricular macula was inclined with the lateral side down approximately 10 degrees. When a subject was placed with the left ear, for example, tilted down 10 degrees, the right utricular macula lay almost in a plane parallel to the head's left-right axis in the head's horizontal plane in the Reid stereotaxic coordinate system, and the left utricular macula was tilted down 20 degrees from the head's left-right axis in head's horizontal plane. In the above-mentioned head position tilted left ear down 10 degrees, when the sinusoidal linear acceleration was applied to the head within the horizontal plane in a left-right direction, the different stimuli were applied to the utricular maculae within right and left ears, respectively, because different acceleration components were applied to the otolith membranes of the utricular maculae with the tangential planes, respectively. It was possible that the individual functions of the utriculi could be measured by accurately measuring the compensatory eye movements in one head position tilted right ear down 10 degrees, in another head position tilted left ear down 10 degrees.

Objectives: Seven healthy adults (4 males, 3 females; age range 21-52 years; mean age 29.1 years) were included in present study.

Methods: With three different trials (1), (2) and (3) listed below, experiments were carried out. (1) The subjects were seated and not tilted. The sinusoidal linear acceleration stimulus with frequency: 0.7Hz in left-right directions and 0.25G at the maximum acceleration was applied. (2) They were seated and tilted right ear down 10 degrees. Then, the same linear acceleration stimulus was applied. (3) They were also seated and tilted left ear down 10 degrees. Then, the same linear acceleration stimulus was applied. The compensatory eye movements were measured by EOG under these three conditions. The compensatory eye movements were sinusoidal movements in left- right directions, whose amplitudes were measured.

Results: In all subjects, there were the significant differences between the amplitudes of compensatory eye movements in the head positions tilted right and left ear down 10 degrees ($p<0.01$). These results confirmed the report on an asymmetry in function between left and right otolith organs [2].

Conclusion: It was thought that present new testing methods could detect the individual functions of the utriculi.

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P064

Effect of Tone Burst Frequency on the VEMP Response Reliability

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Background: The integrity of the sacculocollic reflex can be tested by means of the VEMP-test (vestibular evoked myogenic potentials). In this test, the saccules are stimulated with loud intensity clicks or tone bursts which are delivered unilaterally by way of e.g. an insert earphone while the subject exerts a contraction of the ipsilateral sternocleidomastoid muscle. The stimulated saccule inhibits the contracted muscle, which can be measured by means of surface electrodes. The result of a normal response is a positive peak at 13 ms and a negative peak at 23 ms at the EMG-registration. The peak-to-peak amplitude is dependent on the intensity of the stimulus and on the magnitude of the contraction of the sternocleidomastoid muscle.

Objectives: The purpose was to determine which tone burst frequency and intensity produces the most reliable (and thus evoked the highest amplitudes) responses for the VEMP-test.

Methods: 26 healthy ears were tested at frequencies of 500 Hz, 250 Hz and 750 Hz consecutively. Within each frequency, an intensity of 100 dB, 95 dB and 90 dB was applied.

The data were analyzed with 2 way ANOVA.

Results: When considering the intensity range 90-100 dB, there is only a difference between short tone bursts of 250 Hz and 750 Hz ($p = 0.001$) and the amplitudes at 250 Hz and 500 Hz are higher than those at 750 Hz. At 250 Hz ($p = 0.999$) and 750 Hz ($p = 0.516$) there was no difference in amplitude when considering the intensities 90 dB, 95 dB and 100 dB separately. When stimulating at 500 Hz the amplitudes were significantly different at 90 dB and 100 dB ($p = 0.031$).

Conclusion: Judging on our findings, we can conclude that 250 Hz is the optimal frequency for the tone bursts to perform the VEMP-test because at this frequency the amplitudes are the highest and not subject to changes as the result of a changing intensity in the range 90-100 dB.

P065

Torsional Eye Movement Responses to Galvanic Vestibular Stimulation in Vestibular Disorders

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Background: Recently, torsional eye movement responses to monaural and binaural galvanic vestibular stimulation were described for healthy subjects. Static ocular torsion and torsional nystagmus increased from the third to the sixth decade and decreased in older subjects, e.g., slow phase velocity increased from 1.5 deg/s (20-29 years) to 2.9 deg/s (50-59 years) and decreased to 2.5 deg/s for the seventh decade (60-69 years). Thus, an inverse U-shaped curve was found for the dependence of torsional eye movement responses on age. Further, mean differences between left- and right-sided stimulation of about 30% were found.

Objectives: The aim of the present study was to investigate changes in vestibular function in different vestibular disorders by using galvanic vestibular stimulation. Under physiological conditions vestibular stimulation by head accelerations always involves multisensory activation of the vestibular, somatosensory, and visual systems. While galvanic vestibular stimulation provides non-physiological stimulation, it is more selective than natural head accelerations and is thus an attractive tool for experimental testing of vestibular function.
Methods: Torsional eye movements were measured in patients by means of binocular video-oculography. The eye position angles (including ocular torsion) were determined from a pair of artificial markers that were applied to the sclera just outside the left and the right edges of the iris. Rectangular, unipolar electrical direct current pulses of 10 s duration were delivered by a battery-powered current generator. After calibration (10 deg viewing angles), binaural (1 mA and 3 mA) and monaural (left and right, 3 mA) Galvanic vestibular stimulation was performed in each subject during fixation of a space-fixed target.
Results: Patients investigated suffered from vestibular neuritis (n=30), Meniere's disease (n=10), vestibular paroxysmia (n=10), and bilateral vestibulopathy of different causes (n=20). Responses were completely abolished in bilateral vestibulopathy after bilateral neurectomy for neurinoma. In all other cases bilateral responses could be measured. Side to side asymmetries were outside the normal range for vestibular neuritis and Meniere's disease. The amplitudes of static torsional responses were within the normal range for most patients and showed generally a wide variation. Differences between patient groups might point to the site of action of galvanic stimulation and it might reflect compensatory mechanisms.
Conclusion: Increased sensitivity of vestibular afferents could maintain normal function despite reduced peripheral with increasing age in healthy subjects and with hair cell dysfunction in vestibular disorders. As galvanic stimulation acts at the vestibular nerve -thereby bypassing the hair cells- electrical stimulation should be more efficient with compensated hair cell dysfunction. The involvement of nerve fibers, ganglion cells, and central neurons can explain reduced responses in other patients.

P066

Adjustment for Vestibular Evoked Myogenic Potentials by Means of Normalization

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Background: Vestibular evoked myogenic potential (VEMP) has been evaluated with the peak-to-peak amplitude of p13-n23 biphasic wave; however, the amplitude was known to depend on the muscular contraction. Therefore, each investigator had paid attention to keep constant muscular tonus during recording. Since a muscular tonus is in proportion to the root mean square (RMS) value of the electromyogram, p13-n23 amplitude of evoked potential divided by the RMS is constant. This adjusted method was called normalization in the signal processing, may be in applicable to quantify determination of VEMP. The adjusted value does not have any dimension, because it indicates relative ratio to the mean RMS.
Objectives: In this paper, we evaluate usefulness of the adjusted method of VEMP with normalization.
Methods: Subjects were 6 healthy volunteers who did not have any otological or neurotological disorders. VEMP were recorded in each subject with following situations. Condition A; they were instructed to keep their head elevated and turned to the opposite side, and then constant tonus of the SCM was expected. Condition B; they were instructed to turn their head without constant muscular contraction. Normalized amplitude of p13-n23 waves were measured from original waves. Also, coefficient of variations (CV = SD / mean) were measured in both conditions. Our normalized algorithm consisted of 5 steps. Step 1: the original responses in each stimulus were stored. $F_n(t)$ (n=1 to 100). Step 2: RMS values of 20 msec before stimulus were calculated in each stimulus. RMS_n Step 3: original waves were divided by RMS value in each stimulus (normalization). $normal[F_n(t)] = F_n(t) / RMS_n$ Step 4: each normalized waves was averaged. $averaged[F(t)] = (\Sigma normal[F_n(t)])/n$. Step 5: p13-n23 amplitude was detected.
Results: In condition A, CV of the original amplitude showed 0.12 ± 0.06, and that of normalized showed 0.09 ± 0.08. There was no significant difference between both methods. In condition B, CV of the original amplitude showed 0.71 ± 0.22, and that of normalized showed 0.20 ± 0.07. Therefore, a variation of the normalized amplitude was significantly smaller than that of the original amplitude. (P=0.000033)
Conclusion: Adjustments are not necessary in measuring of VEMP; only patients are instructed to keep constant contraction of the muscle. However, to keep constant tonus is difficult during repeating tests such as measuring frequency dynamics, threshold or effect of diuretic loading. In such situation, normalized VEMP might be useful to reduce the variance of repeated examinations.

P067

Comparison Between Bone Conducted and Air Conducted Vestibular Evoked Myogenic Potential

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Background: Vestibular evoked myogenic potential (VEMP) is a muscle reflex recorded by surface electrodes following repeated high intensity stimulation. It is classified according to the mode of stimulation into air conducted & bone conducted VEMP. Bone conducted VEMP was first described by Sheykoleslami et al. (2000). They reported that bone VEMP has same response pattern& the

same diagnostic value as air conducted VEMP. Few studies were done on B-VEMP & results are not standardized.
Objectives: Comparison between air conducted VEMP and bone conducted VEMP in normal subjects & those with conductive hearing loss
Methods: The present study was conducted on twenty normal hearing subjects& 25 patients with conductive hearing loss. Both groups have no past or present history of dizziness episodes or vestibular disorders. All subjects were submitted to full history taking, otological examination, basic audiological evaluation& bone and air conducted vestibular evoked myogenic potentials
Results: Bone conducted acoustic stimuli as well as air conducted acoustic stimuli can evoke similar VEMP in normal subjects. Air conducted VEMP showed attenuated amplitude and delayed latencies in patients with conductive hearing loss. On the other hand, bone conducted VEMP was not affected by the presence of conductive hearing loss& the response pattern was similar to the normal hearing subjects
Conclusion: Air conducted VEMP is affected by the presence of even mild to moderate degree of conductive hearing loss while bone VEMP can be recorded reliably in patients with conductive hearing loss.
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P068

Habituation of Eye-Movement Responses Induced by Galvanic Vestibular Stimulation (GVS) in the Alert Guinea Pig

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Background: Recently, it was shown that galvanic vestibular stimulation (GVS) delivered at low intensities (around 1mA-2mA) in humans produces eye movement responses containing nystagmus and tonic eye deviations (MacDougall et al., 2003). However, surface GVS delivered in rabbits was found to produce nystagmus at intensities above 2mA, while tonic deviations of the eye were observed at much lower intensities (Swaak & Oosterveld, 1975).
Objectives: We sought to characterize the threshold at which eye movements may exhibit phasic behavior to GVS in the guinea pig. This was done in order to determine whether a sensitivity difference between SCC-ocular and otolith-ocular pathways exists among rodents, a difference not seen in human eye-movement responses to surface GVS.
Methods: A recently validated method was used for tracking three-dimensional changes in eye position (Kim, 2004) in four awake and alert guinea pigs. During recording, bilateral GVS was delivered in the form of ten five-second pulses separated by inter-stimulus intervals of ten seconds. Each series of ten pulses was of constant peak intensity, and four series of 10 pulses were delivered in pseudorandom order of intensity: the first at 80 micro-amps, the second at 20 micro-amps, the third at 40 micro-amps, and the fourth at 60 micro-amps.
Results: At high intensities of GVS (above 40 micro-amps), quick-phase eye movement responses were observed with slow phases toward the anode and quick phases toward the cathode. A reduction in average frequency of quick-phase eye movement responses induced between successive galvanic pulses was observed. This was accompanied by a reduction in the average slow-phase eye velocity induced between successive galvanic pulses. At low intensities of GVS (40 micro-amps and below), eye movements were predominantly tonic and were consistently directed toward the anode with no signs of adaptation or habituation.
Conclusion: These observations appear to reflect the divergence between otolith-ocular and SCC-ocular projections, whereby the SCC-ocular pathway has a higher threshold for activation and is subject to neural habituation. While these apparent physiological differences appear to indicate the existence of central neuronal differences between humans and guinea pigs, influences involving basic morphological differences in primary hair-cell abundance patterns between guinea pigs (Lindeman, 1969) and humans (Merchant et al., 2000) may also be involved.
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P069

Simple 'Cuff Pressure Based' Feedback Procedure for Increasing the Reliability of VEMP Response Amplitude

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Background: The peak-to-peak amplitude (p13-n23) of a VEMP-response (vestibular evoked myogenic potentials) is highly dependent on the muscle contraction of the sternocleidomastoid muscle (SCM). With standard ABR-equipment used in most clinical practices, it is virtually impossible to measure simultaneously the intensity of the muscle contraction and the VEMP-response. This makes the interpretation of differences in amplitudes between the left and right side ambiguous.
Objectives: The primary objective is to determine a simple method, which provides feedback of the muscle contraction, without the need for specialized equipment. This method is based on the use of a sphygmomanometer that is

connected with an inflated cuff against which the test subject pushes with the lower jaw. The subjects hold the cuff themselves in their hand. Prior to the VEMP test, the mean rectified voltage (MRV) of the contracted SCM for a given sphygmomanometer pressure level is measured, for left and right sides. Consequently, through simple linear regression calculation the pressure is obtained that generates on each side the same muscle contraction during the subsequent VEMP test. For this reason we investigated the existence of a linear regression between cuff pressure and muscle contraction (MRV) as well as VEMP amplitude. Next, we examined whether reliable VEMP-results can be obtained with this method.

Methods: 18 healthy normal hearing subjects underwent the tests. At cuff pressures of 10, 20 and 30 mm Hg (above a basal level of 20 mmHg, for gentle inflation) we measured MRV responses and consequently VEMP amplitudes with 500 Hz 100 dB Tone bursts. During the registration of either MRV or VEMP, the subjects monitored the pressure on the indicator of the sphygmomanometer and adjusted the pressure if necessary. The EMG-registration at each cuff pressure was measured in intervals of 5 seconds over a total period of 15 seconds, which correlated with the duration of a VEMP-registration with 100 tone bursts.

Results: In every subject an increasing cuff pressure resulted in increasing MRV-values, which were stable during the EMG-registration at each cuff pressure. In most subjects, differences between MRV-results from the left and right side, for the same pressure levels, were observed, corroborating the hypothesis that the same pressure does not provoke the same muscle contraction between left and right ($p=.016$). Significant linear relationships were observed for the total of subjects between cuff pressure and MRV ($p<0.001$) as well as between MRV and VEMP amplitudes ($p<0.001$). The slopes for the individuals were very close to each other.

Conclusion: Because the cuff pressure is significantly related with the MRV-values, this feedback method can be used as a control for muscle-contraction during the VEMP-test. Since it is essential that both left and right SCM contract with the same amount, the appropriate cuff pressure can be determined that generates the same MRV on both sides. This results in a more reliable VEMP response.

P070

Vestibular Evoked Myogenic Potentials and Caloric Tests in Profound Pre-Lingual Deafness

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Background: Vestibular functions of patients with non-inherited pre-lingual deafness are still not well evaluated in comparison with Vestibular evoked myogenic potential (VEMP) and caloric test.

Objectives: Vestibular evoked myogenic potential (VEMP) has been established as a clinical test to explore the integrity of sacculo-collic reflex (SOR). This study aims to investigate whether VEMPs are intact in patients with non-inherited pre-lingual deafness in addition to caloric testing to evaluate vestibulo-ocular reflex pathway (VOR).

Methods: Study Design: Prospective study. From January 2002 to December 2002, ten consecutive patients with bilateral and profound non-inherited pre-lingual deafness were enrolled in this study. All patients were subjected to pure-tone audiometry, auditory brain response, caloric test, VEMPs and magnetic resonance image. Delayed VEMP was defined as the latency of peak I exceeding 12.97 milliseconds or of peak II exceeding 20.9 milliseconds. Canal paresis was defined as a greater than 25% difference between maximum slow-phase velocity measurements for each ear, when compared with the sum of slow-phase velocities.

Results: The VEMP tests revealed that 8 ears (40 %) were normal, the remaining 12 (60%) abnormal, consisting of absent VEMPs in 11 and delayed VEMPs in 1. The caloric testing disclosed that 13 (65 %) ears were normal, whereas 7 (35 %) ears displayed abnormal caloric response including canal paresis in 2 and absent in 5.

Table:

Results of Vestibular Evoked Myogenic Potentials (VEMPs) and Caloric Responses

	Normal	VEMPs Test Delayed	Absent
Normal caloric response	7	1	5
Canal paresis	1	0	1
Absent caloric response	0	0	5

Conclusion: 60 % of VEMPs versus 35 % of caloric tests showed abnormal response in twenty ears of non-inherited pre-lingual deafness. In other words, the SOR pathway might be more liable to dysfunction than the VOR pathway in these patients. These findings might suggest that par inferior of inner ear should be more vulnerable to ear insult than pars superior.

P071

The Human Angular Torsional Vestibulo-Ocular Reflex: Effects of Eye Position and Head Rotation Plane

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Background: For head rotations about the cardinal head axes starting with the eyes looking straight ahead, the roll VOR gain is low compared to the yaw and pitch VOR gains. In this case, the roll component of VOR gain relative to head coordinates (RE head) and the torsional component of VOR gain relative to each eye (RE eye) are identical. If this relatively low roll gain is a property of sensory transduction and/or neural signal processing mechanisms that occur in head-fixed coordinates, then the lower gain should

exist for the roll component of VOR (RE head) independent of target position, target distance and axis of head rotation. Torsional VOR gain measured (RE eye) would, on the other hand, vary with target position, target distance and axis of head rotation.

Objectives: We sought to determine the effects of starting eye position, target distance and axis of head rotation on the roll component of VOR (RE head) and torsional component of VOR (RE eye).

Methods: Using the three-dimensional scleral search coil technique, we measured head rotation and binocular eye rotations in response to roll, left anterior-right posterior (LARP) and right anterior-left posterior (RALP) head impulses in 4 normal subjects. Each head impulse was a passive, transient, head-on-body rotation (peak ~20^o , ~150^o/s, ~$3000^o/s^2$). The subject was instructed to fixate one of 6 targets; targets were either 15 cm or 124 cm in front of the subject, and either straight-ahead, 20^o left or 20^o right from midline. We measured VOR gains RE both head and eye coordinates.

Results: The roll component of VOR gain RE head did not change with target position, target distance or axis of head rotation. In contrast, the torsional component of VOR gain RE eye did change with target position and distance and was generally greater than the roll component of VOR gain RE head. For LARP and RALP head rotations, when both optic axes were ~parallel to the axis of head rotation, the torsional component of VOR gain RE eye of both eyes increased with near viewing. Thus, unlike the roll component of VOR gain RE head, the torsional component of VOR gain RE eye varied with starting eye position, was lower in primary position than for the eccentric positions, and increased with near viewing for eccentric starting positions.

Conclusion: These findings are consistent with the hypothesis that the roll component of head movement is a less effective stimulus for the VOR than are the pitch and yaw components. However, we cannot rule out other mechanisms that may contribute to the lower gain of the roll component of VOR (RE head), such as a limitation of extraocular muscle mechanics or a lower adaptive drive secondary to the lesser effect of torsional retinal slip on visual acuity.

P072

Vestibular Evoked Potential in Guinea Pig by Angular Acceleration

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Background: Auditory brainstem response (ABR) is a potent tool in the research field of otology and also useful in clinical trial for the evaluation of human auditory system, from periphery to central area. Like ABR, many trials have been done for the development of vestibular evoked potentials (VsEP) and some successful recording of VsEP was done. The main stimulus condition was linear acceleration.

Objectives: Using angular acceleration in animal, the vestibular evoked potentials (VsEP) were measured and analyzed.

Methods: Using guinea pigs after deep anesthesia with ketamine & xylazine, the head was held 30 deg down from horizontal plane, and counter clockwise rotation around vertical axis was applied. The vertical axis (motor axis) was set parallel to Lt. ear and VsEP was recorded in Lt. ear. Angular stimulus intensity was 7,000 deg/s^2 using stepper motor, and rise time was 5 ms with mechanical delay of 1.1 ms following trigger. The maximal displacement of motor by one stimuli was 1.8 deg, and the frequency was 2 times a second. Using surface electrode, the electric signals were captured and averaged.

Results: We consistently recorded 10 waves in 15 msec duration after initial acceleration. The average latencies were measured and analyzed using Matlab. After labyrinthectomy, the VsEP responses disappeared. The waveforms and latencies of wave IV, VI and IX were relatively consistent and useful landmarks for the identification of VsEP waves.

Conclusion: We recorded VsEP after angular acceleration and measured the duration. We can found waves with relatively consistent waveforms and durations.

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P073

Massager Muscle EMG Responses to Loud Clicks in Healthy Humans

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Background: Meier-Ewert et al [1] originally reported that loud clicks or tone bursts induce a silent period in the voluntary interference pattern of masseter muscles (MM). They attributed this to cochlear activation and excluded a vestibular contribution. More recently however, Colebatch et al [2] have identified a click-induced response in sternomastoid muscle EMG and shown that this has a vestibular origin. In view of the fact that we have recently described a short-latency response in MM to electrical stimulation of

the vestibular nerve (EVS) we have reassessed possible vestibular contributions to sound-evoked short latency reflex responses in MM.

Objectives: To investigate MM responses to loud click stimulation to test whether vestibular receptors in addition to cochlear receptors could contribute to short latency reflexes.

Methods: Averaged responses in unrectified (unr) and rectified (r) MM EMG induced by loud clicks were examined in 12 healthy subjects. Experiments were carried out with the subjects seated, with the head straight and the trunk upright. Loud clicks (0.1 ms, 3/s, 100-70 dB NHL) were delivered to the right, left or both ears during a steady MM contraction.

Results: Unilateral and bilateral clicks at 100-90dB induced a clear short latency p11 wave (onset 7.0 - 9.0 ms) bilaterally in the unr EMG. This was followed by a less defined n15 wave and by an n21 wave. In some subjects, the n15 was not visible and a simple biphasic p11/n21 wave was seen. Ipsi- and contralateral responses to unilateral stimulation were of equal amplitude and latency. Responses to bilateral clicks were significantly larger than those to unilateral clicks. The magnitude of these responses was linearly related to the stimulation intensity and scaled with the mean level of EMG activity. At intensities lower than 90dB the p11/n15 wave disappeared, while the n21 was still present. At these lower intensities, the n21 was always preceded by a clear p16 wave that had not been clear at higher intensities. We suggest that at high intensities, the n16 wave overlaps with an earlier n15 wave. Click stimulation at all intensities induced a long lasting (10-12 ms) decrease in the r EMG mean level that had an onset latency of 12-14 ms.

Conclusion: Loud clicks induce two partially overlapping short latency reflexes in masseter muscle EMG. The initial response is a short-latency p11/n15 wave similar to the EVS-induced vestibulomasseteric reflex [3] and like this one it is detectable in the unr EMG but not in the r EMG. This response has a high threshold, comparable to that of the vestibulocollic reflex [2]. The second response in MM is a low-threshold p16/n21 wave, which also appears in the r EMG as a late long-lasting inhibitory period. We suggest that this later response is equivalent to the previously described jaw-acoustic reflex [1].

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P074

A New Test to Evaluate the Vertical Canal Function

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Background: Usual vestibular tests do not study the vertical canals responses. The Impulse Rotatory Test (IRT) (Vitte Semont 1995) is able to detect the weak asymmetries of the horizontal canals (Barany Congress 2002). We adapted IRT to study the vertical canals in the following protocol.

Methods: The patient is lying down (dorsal decubitus) on a table that moves around the vertical axis. If we tilt the patient's head to the left, 45° in the yaw, the left anterior canal and the right posterior canal (LARP) are located in the rotational plane of the table. If we tilt the patient's head to the right, 45° in the yaw, the right anterior canal and the left posterior canal (RALP) are in the rotational plane of the table. We tested IRT, successively in LARP and RALP, with the 4 following sequences: clockwise rotation during 9 sec. at 20°/sec.; 10 sec. pause; counterclockwise rotation during 9 sec. at 20°/sec.; 10 sec. pause. The registration of the different nystagmus was performed with 3D videonystagmography. We analyzed the prevalence of the slow phase velocity (SPV) and of the angular cumulation through the vertical and torsional nystagmus. We also analyzed the reflectivity in the LARP and RALP.

Results: Over one year, we applied this protocol to 556 subjects: 495 subjects suffering from vestibular symptoms and 61 subjects without any vestibular complains. In the normal group, we found a posterior sagittal prevalence, no prevalence in the frontal plane and an equal LARP and RALP reflectivity. In the vestibular group: - In case of unilateral deficit, the statistical analysis reveals a dispersion of the sagittal prevalence, a frontal prevalence toward the pathological labyrinth (compensation phenomenon). The reflexivity, in RALP and LARP, are equivalent. – In case of irritative syndromes (ex. Ménière disease), the frontal and horizontal prevalence have the same direction. – In case of central syndromes, the posterior prevalence is very significant, especially for the falling subjects. – In case of primitive vestibular dissymmetry (PVD) the reflexivity, as in the LARP and RALP, are not equivalent, especially in vertical PVD.

Conclusion: IRT can be applied for all kind of patients to test their vertical canal function. The results attest the protocol is reliable and reproducible. IRT, as in horizontal and vertical planes, give essential information making possible a complete evaluation of the semi-circular canals.

P075

Comparison of Caloric and Vibratory Tests in Patients Suffering from a Unilateral Acoustic Neurinoma

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Background: Vibratory and caloric tests are currently performed in clinics to detect a potential dysfunction of the horizontal semicircular canals.

Objectives: To compare the efficacy of caloric and vibratory tests in 141 patients suffering from an unilateral acoustic neurinoma before surgery.

Methods: Caloric tests were performed using two methods 1. simultaneous and 2. closed loop sequential bithermal irrigation with water at 30 C and 44 C. In bilateral simultaneous caloric test, normal patients did not exhibit any horizontal nystagmus whereas an horizontal ocular nystagmus was induced in patients with unilateral vestibular dysfunction. During bilateral cold water stimulation, the direction of the fast phase indicated the lesioned side whereas during bilateral warm irrigation, the direction of the fast phase indicated the intact side. In unilateral caloric tests, percent caloric paresis was calculated using Jonkees' formula: (UW+UC)– (AW+AC)/(UW+UC+AW+AC) *100, where UW, UC, AW and AC are frequency of the induced nystagmus to unaffected side warm, unaffected side cold, affected side warm and affected side cold irrigation's, respectively. These tests were always performed under videonystagmoscopy and by the same nurse.
Results: Vibratory tests were done by applying a vibrator on the each mastoid process during 10 sec. In normal subjects, the vibrations induced no ocular nystagmus whereas in unilateral peripheral lesions, a nystagmus without latency and which persisted during all the time of the stimulation was induced. For the unilateral caloric test, the caloric response was decreased on the lesioned side in 72% of the patients, whereas 28% exhibited normal responses. Only 1/141 patient (0.7%) presented an abnormal response on the intact side. For the simultaneous bilateral test, 88% showed an abnormal response whereas only 12% of these patients exhibited a normal test. These data showed the greatest sensitivity of the simultaneous bilateral caloric test compared to the unilateral sequential test. For the vibratory test, 27% exhibited no induced ocular nystagmus whereas 73% showed an horizontal nystagmus with the fast phase oriented towards the intact side.
Conclusion: The vibratory test was an interesting test, whose sensitivity could be compared to the unilateral caloric test. The simultaneous bithermal irrigation with water at 30 C and 44 C appeared to be more sensitive than unilateral caloric testing. In addition, it was easy to perform and brought complementary information about a potential asymmetrical excitability of the horizontal ampulla.

P076
Vestibular Evoked Myogenic Potentials in Children
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Background: For complete inner ear function evaluation in children with hearing loss or equilibrium problems a complete vestibular evaluation has been performed in our department for over 15 years and becomes part of the first evaluation for all hearing loss and cochlear implant. Vestibular evoked myogenic potential (VEMP) are recognized as a test for saccular function. VEMP can be evoked after stimuli (clicks or tone burst) delivered by air (A-VEMP) or bone conduction (B-VEMP). The latter can bypass the problem of conductive hearing loss that (when present) does not permit sufficient level of stimulation for VEMP to be detected. Conductive hearing occurs frequently in children because of chronic tubo-tympanic dysfunction.
Objectives: The purpose of this study is to show the special adaptations we developed to apply VEMP protocols to children. We also demonstrate the value of using VEMP in the diagnosis of inner ear function impairments in a paediatric population.
Methods: We used tone burst (750 Hz, 6.6ms duration) delivered (at a rate of 4/s) through headphones for the A-VEMP and through a vibrator (B71 Radioear, placed on the mastoid with occlusion of the external meatus) for B-VEMP. The neck muscle EMG activity was recorded with contact electrodes. The program used (RACIA-ALVAR France) permits recording in real time and simultaneous screen visualization of the amplitude of the EMG and the responses (P13-N23). EMG sampling is done every 500 ms and the analysis of the response as a function of EMG amplitude can be done after selection of periods with best EMG. Visual feedback was provided with the EMG traces displayed on the screen to find the best posture for maximal neck muscle active contraction. The best contraction was obtained when head was turned on the opposite side of the sound stimulation, and two posture were adapted to the age: very young children were seated on parent laps, their trunk tilted backwards while they are trying to straighten up to reach a toy, older children were seated and asked to press on their fist to increase the EMG traces displayed on the screen.
Results: VEMP is feasible as soon as the child can hold his head (2 months of age). VEMP can be obtained with our analysis program with no more than 20 to 30 stimulation; this increases greatly the tolerance to the test. P13-N23 have the same latencies in children as in adults but require fewer stimuli to be obtained and their amplitude seems larger than in adults for the same amplitude of EMG. Thresholds vary from 85 to 100 dB in normal children. B-VEMP was chosen to assess saccular function when no response was found with A-VEMP because of a conductive hearing loss.
Conclusion: VEMP is a practical test for vestibulospinal function evaluation for children as well as for adults. VEMP (by air or bone conduction) should be part of the complete vestibular evaluation for hearing loss and particularly before cochlear implant.

P077
Convexity of the Basilar Artery in Vertiginous Patients Due to Neurovascular Compression - Is It a Diagnostic Finding?
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Background: We recognize the fact that 92% of the cases with hemifacial spasm caused by neurovascular compression (NVC) at the root entry zone of the facial nerve have dolichoectatic ipsilateral convexity of the basilar artery (BA) on a MR image (MRI) [1,2].

Objectives: The purpose of this report is to evaluate convexity of BA in vertiginous patients due to NVC on a MRI.
Methods: T2-weighted MRIs of 37 vertiginous patients suspected as due to NVC and 18 patients with sudden deafness or vestibular neuronitis as controls were evaluated for the displacement and distance of the cross section of BA from the midline at the level of the internal auditory meatus in the axial view.
Results: The displacement was ipsilateral to the affected side in 32 (86.5%), contralateral in 4 (10.8%) and not recognized in one (2.5%) of 37 patients, whereas it was ipsilateral to the lesion in 4 (22.2%), contralateral in 7 (38.9%) and not recognized in 7 (38.9%) of 18 controls. The mean distance in 33 patients and 17 controls was 5.7 mm and 2.9 mm, respectively.
Conclusion: The ipsilateral convexity of BA in vertiginous patients suspected due to NVC was significantly more severe and seen at a significantly high incidence. The ipsilateral displacement of BA on the axial view of MRI at the level of the internal auditory meatus has been suggested to serve as a diagnosis of vertigo due to NVC.
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P078

Effects of Cognitive Tasking on Postural Control in Early Dementia of Alzheimer's Type (DAT) Patients

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Background: Investigations of postural control and cognitive tasking have shown significant negative effects of dual tasking on postural stability in patients with vestibular dysfunction. We hypothesized that mental tasking would have similar effects on postural stability in patients with early cognitive deficits secondary to Dementia of Alzheimer's Type (DAT), which may help explain their higher incidence of, falls compared to the healthy community-dwelling elderly.
Objectives: This study was designed to characterize the effect of mental tasking on postural stability and postural tasking on cognition in young and elderly control subjects with normal cognition versus elderly patients with early dementia.
Methods: In our study, we evaluated the interaction of mental tasking and posture control in 20 healthy young subjects (ages 21-25 years), 20 healthy elderly subjects (ages 65-85 years) and 20 elderly patients with early (Clinical Rating 0.5) DAT (ages 65-85 years). Subjects were carefully screened to exclude known disorders of balance, gait or neuromuscular problems. All subjects performed Computerized Dynamic Posturography (CDP- NeuroCom Intl, Inc, Clackamas, OR, USA) with and without mental tasking using serial 3's backwards from a 3 digit base number. Outcome measures included CDP Equilibrium Score on Sensory Organization Test conditions 1,3 and 4, sway frequency analysis and speed and accuracy of the cognitive task.
Results: Results demonstrated that both DAT and healthy elderly control subjects yielded nearly identical stability scores on CDP trials in the absence of mental tasking. Performance of the counting task was worse overall in the DAT patients, but was not affected by the imposition of the posturography task. Of critical importance, in keeping with our hypothesis, is the highly selective finding that postural stability on SOT4 was significantly impaired under dual tasking conditions, only in the DAT patients.
Conclusion: These results illustrate the detrimental effects of dual tasking in patients with early cognitive dysfunction. In particular, we have shown that concurrent mental activity reduces postural stability and may contribute to falls in this group compared to age-matched or younger control individuals. This has significant implications for the formulation of rehabilitative strategies and fall prevention in these patients.

P079

Traumatic Perilymphatic Fistula Presenting Direction Changing Positional Nystagmus

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Background: Sudden hearing loss and vertigo after penetrating injury to the tympanic membrane strongly suggest a traumatic injury to the inner ear, such as perilymphatic fistula (PLF). In PLF, audiovestibular symptoms may be fluctuant and aggravated with the affected ear down. The positional nystagmus in PLF was known to have very short or no latency and the direction of nystagmus was either toward or away from the affected ear. However, direction changing nature according to the head position has not been reported in the previous literature.
Objectives: We report on a case of traumatic PLF presented with direction changing positional nystagmus (DCPN) after Q-tip injury and suggest the involved mechanism of DCPN in this case.
Methods: Patient was 5 year old boy and visited ER for bloody otorrhea and ataxia with nausea and vomiting after Q-tip injury. Diagnostic work up was done including audiovestibular function test and high resolution temporal bone CT.
Results: The patient showed moderate sized right tympanic membrane perforation at the posterior superior quadrant. Audiogram showed mixed hearing loss with bone/ air conduction pure tone averages of 20/ 50 dB. On video nystagmography, spontaneous nystagmus was beating to the left and it was increased during head turning to the left. With

head turning to the right side, the nystagmus changed into right beating (geotropic nature). High resolution CT showed pneumovestibule on axial scan and fracture of stapes footplate was detected at the anterior part.
Conclusion: Perilymph drift by air bubble movement against gravity in the vestibule seems to be responsible for the generation of DCPN in this PLF patient.

P080
A Report of Two Cases of Unilateral Vestibulopathy After Systemic Ototoxic Treatment
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Background: Although cases of unilateral vestibular hypofunction (bVH) after aminoglycoside use have been well characterized, surprisingly unilateral vestibular hypofunction (uVH) has only been reported in 6 patients . These subjects suffered a systemic illness for which intravenous gentamicin was administered. Symptoms of bVH appeared in a characteristic fashion but vestibular examination disclosed that a unilateral vestibulopathy existed that rapidly produced a chronic vestibular insufficiency: oscillopsia and ataxia even when there was no evidence of vestibular impairment in the functioning labyrinth.
Objectives: Here, we describe two recently diagnosed cases of uVH after systemic treatment with aminoglycosides and we present the results of the complete vestibular examination that was performed in each case.
Methods: Two patients were studied here who were originally thought to be suffering from bVH. The basis of their diagnosis was a clinical profile congruent with this condition following prior systemic treatment with aminoglycoside. The initial bedside examination was followed by an audiometry. The caloric test was performed using standard 30ºC and 44ºC water irrigation, and ice water for confirmation of a severe canal paresis. Vestibular Evoked Myogenic Potentials. Patients were examined in the recumbent position on a couch with their trunks at 25-30º from the horizontal plane, whilst lifting their heads against gravity. Surface EMGs were recorded using conventional adhesive electrodes applied in both stenocleidomastoid muscles (SCM). The stimuli were clicks (of 0.1 ms duration) applied mono-aurally through headphones (TDH49, Telephonic corporation, Huntington, NY, USA). Rotational testing was performed using a CHARTR®RVT system (ICS Medical Corporation, Schaumburg, Ill.). Computerized dynamic posturography, CDP (Equitest, NeuroCom International, Inc., Clackamas, OR), was carried out using the SOT battery.
Results: The patients were seen after having recovered from their initial illnesses, and both of them denied suffering any spells of vertigo, loss of hearing during the treatment or tinnitus. In both patients, oscillopsia and vestibular ataxia were of varying intensity. Bedside vestibular examination, caloric and rotatory chair testing, and vestibular evoked myogenic potentials were congruent with a complete unilateral loss of vestibular function. Audiometry was normal in one case whereas in the other, there was a moderate bilateral sensorineural loss of hearing that was present before treatment and that did not change during the course of the treatment.
Conclusion: The existence of unilateral vestibular loss was an unsuspected finding but after careful bedside examination, it was confirmed through extensive vestibular testing. However, this infrequent finding responded very well to vestibular rehabilitation. Different mechanisms are proposed to explain this phenomenon, although there is still no clear evidence of which may account for the responses observed.

P081
Clinical Features of Migraine-Related Dizziness
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Background: Both migraine and dizziness are very frequent complaints, but the comorbidity of the two disorders is higher than it would be expected by chance. This implies a possible causal relationship, but "migraine-associated vertigo" still lacks definite diagnostic criteria. Very recent attempts in this direction showed that migraine may be the third cause of vertigo and that it may be effectively treated.
Objectives: To evaluate the clinical features of vertigo in patients with no other causes than being migrainous to explain their balance problem. We compared our findings with those already reported in the literature [1-5].
Methods: We considered two groups of patients. The first group (G1) derived from 452 patients with balance problem referred to either a neurological or ENT outpatient consultation; 41 of them presented at least 5 attacks of vertigo/dizziness for which migraine was the most likely explanation. The second group (G2: 27 patients) derived from 75 migrainous patients who also presented with dizziness or vertigo.
Results: In both groups the onset of dizziness was delayed of several months/years with respect to migraine onset (G1: 83.8%; G2: 92.3%). The balance problem more frequently consisted in dizziness (G1:68.3%; G2:77.7%) rather than in rotatory vertigo, and, within a single spell, might present not in association with headache (G1:30,6% always, 17.9% sometimes; G2: 26.9% and 11.5%). When associated with headache within a single spell, the balance problem usually occurred first (G1:51%; G2:52%). The occurrence and the duration of the spells showed a great variability, and some G1 patients reported that the disorder progressed to an almost constant feeling of dizziness.

Conclusion: Migraine is a complex disease, and the comorbidity with vertigo deserves special attention since according to the data from our and previous studies up to about 9% of dizzy patients may have migraine-related vertigo, and migraine would be the third cause of vertigo.
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P082

Clinical Investigations of the Patients with Acute Vertigo

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Background: There are a large number of patients examined on an emergency outpatient basis at our university hospital with the primary complaint of acute vertigo. The most important factor in diagnosing acute vertigo is to determine whether the underlying cause is a peripheral disorder or a central disorder.
Objectives: During the period from April 1998 to December 2001, we examined 321 patients with acute vertigo on an emergency care unit at our university hospital.
Methods: Neurotological examinations consist only of a simple hearing test using a tuning fork, spontaneous and various provoked nystagmus tests.
Results: The patients included 205 (63.9%) with acute vertigo were transferred to the hospital by ambulance. The overall averaged age of the patients was 55.2 years and 37% of patients were men while 63% were women. Spontaneous and gaze nystagmus were found in 49.2%, positional nystagmus 33.3% and anystagmus 17.4%. A classification of these patients according to disorder consists of 18.0% BPPV, 9.7% Meniere's disease, 4.0% sudden deafness accompanied by vertigo, 3.7% vestibular neuritis, 2.8% central disorders, 50.5% so-called "inner ear vertigo" and 11.3% other disorders. The hospitalization rate of acute vertigo patients treated on an emergency outpatient basis was 28.7%. There were six cases (2.8%) observed for which a definitive diagnosis of cerebrovascular disorder was made based on repeated CT scans or MRI tests performed during hospitalization. Four of these cases were diagnosed with cerebellar infarction, and two cases were diagnosed with Wallenberg's syndrome.
Conclusion: A classification of the disorders encountered consists of 85.9% peripheral disorders, 2.8% central disorders, and 11.3% other disorders in the patients with acute vertigo. Since some form of nystagmus is observed in 83% of all emergency vertigo patients, nystagmus examinations using Frenzel glasses or an infrared CCD camera are essential for diagnosing vertigo. Cases of lower cerebellar infarction in the territory of the posterior inferior cerebellar artery manifest in the form of so-called “isolated vertigo”, and it was difficult to distinguish these cases from peripheral vestibular disorders [1]. However, these cases were characterized by complaints of heavy-headedness and astasia persisting even after the vertigo had subsided. It is necessary to consider the possibility of the vertigo being caused by cerebrovascular disorders in particular among emergency vertigo patients having a history of hypertension, hyperlipidemia, diabetes and atrial fibrillation.

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P083

Audio-Vestibular Involvement in Patients with Behçet’s Syndrome

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Background: Behçet’s syndrome, originally described by Dr. Hulusi Behçet in 1937, is a chronic systemic relapsing disorder of young adults with a generalized vasculitis of small vessels with unknown etiology. It has been demonstrated that central nervous system, cardiovascular system, pulmonary and gastrointestinal tract involvement are present. However, there are few articles about ear and vestibular involvement in Behçet’s syndrome.
Objectives: The present study prospectively investigated the results of the audiologic test and the vestibular function tests in patients with Behçet’s syndrome and analyzed their characteristics.
Methods: Twenty consecutive patients with Behçet’s syndrome (7 male and 13 female) who were diagnosed and followed by the Department of dermatology (Behçet’s clinic) were included in this study. The mean age of the group was 38.9(21-54) years. The patients were divided into three groups according to the number of criteria (involved site), complete, incomplete, and suspected type. Three of patients were in complete type, nine were in incomplete type, and eight in were suspected type. All the patients were performed the pure tone audiometry and vestibular function test. The patients groups were compared with 20 age- and sex matched healthy controls.

Results: The patients complained auditory symptoms (hard of hearing, tinnitus, and aural fullness) in three (15.0%), and dizziness in eleven (55.0%) of 20 patients. Sensorineural hearing loss was present in three patients (15.0%), one of them were treated with cochlear implantation due to bilateral sudden deaf. Spontaneous nystagmus was detected in two patients (10.0%). And abnormal findings were noted in one (5.0%) in saccadic movement, five (25.0%) for bithermic caloric test, and nine (45.0%) in rotation chair test. Totally, audiological and/or vestibular involvement were noted in fourteen (70.0%) of patients with Behçet's syndrome, including all three in complete type and eight of nine in incomplete type, and three of eight in suspected type. However, audio-vestibular abnormalities were not noted in age- and sex matched healthy controls.
Conclusion: Audio-vestibular involvement is not infrequent in Behçet's syndrome compared with healthy controls. We consider that the audio-vestibular assessment and management may be helpful for the diagnostic evaluation and consultation for the patients with Behçet's syndrome.

P084
Common Misconceptions in the Evaluation of ED Dizzy Patients Parallel Those Found in Emergency Medicine Texts
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Background: Recognized, preventable medical errors are estimated to account for 44,000-98,000 deaths annually in the United States. In the Emergency Department [ED], errors in diagnosis may represent the majority of errors. Though in the outpatient setting fewer than one in ten cases of dizziness is attributed to a 'serious cause' such as cerebrovascular accident (6%) or cardiac dysrhythmia (1.5%), in the ED up to 25% of patients over age 50 may have ischemic stroke as a cause of new, isolated vertigo. In the ED setting, therefore, there is an added premium on accurate diagnosis and a need for simple bedside methods to identify those at greatest risk. Although bedside techniques to distinguish 'benign' from 'malignant' causes of dizziness have been described previously by academic sub-specialists trained in neuro-otology, it is unclear to what extent these methods have been incorporated into the knowledge base of front-line healthcare providers.
Objectives: We asked if misconceptions about bedside evaluation of dizzy patients in the ED were common, and, if so, whether Emergency Medicine [EM] textbooks were potential sources of misinformation.
Methods: We quizzed 28 physicians attending a dizziness lecture at two university hospitals (including 14 ED and 14 primary care physicians [PCPs]) using 10 true-false questions about evaluating dizzy patients. In an unmasked, retrospective, anonymous survey study, we calculated the percent correct responses for individuals and for each question across individuals, which we then compared to 50% (for guessing alone) using a binomial exact statistic. Qualitative comparisons were made to textbook findings.
Results: Among 14 ED physicians, the mean individual score was 31% (range 0-60%). The same results were found among the 14 PCPs (mean score 29%, range 0-70%). Across both groups, 6 of 10 questions were answered correctly at rates below that expected by guessing (8-26%, $p = 0.00002$-0.02), implying misconceptions, rather than lack of knowledge. We identified three misconceptions thought to distinguish a benign (e.g. labyrinthitis, benign positional vertigo) from serious (e.g. stroke) cause of dizziness: (1) dizziness worsened by head movement is benign, (2) direction-changing nystagmus (right in right gaze and left in left gaze) is benign, and (3) vertigo lasting 5-10 minutes is most likely to be benign positional vertigo. Similar misconceptions were identified in EM textbooks.
Conclusion: Our results indicate that misconceptions in the bedside approach to dizzy patients may be commonplace, and perhaps derive from published misinformation in EM texts. Such misconceptions could increase the risk of misdiagnosis and reduce patient safety. Limitations include the small and potentially-biased sample, retrospective design, and lack of instrument validation. Despite these limitations, the strength of the associations, consistency across disparate groups, and concordance between survey responses and textbook findings provide strong support for our conclusions.

P085
Charted Records of Emergency Department Dizzy Patients Suggest Overemphasis on Symptom Quality May Be Associated with Diagnostic Errors
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Background: Dizziness is a common chief complaint in the Emergency Department [ED], and poses a significant diagnostic challenge. Preliminary research using paper-and-pencil tests suggests that ED physicians harbor misperceptions about the bedside evaluation of dizzy patients. These misperceptions relate to an overemphasis on the qualitative, rather than temporal, features of dizziness, and appear to derive from antiquated information presented in Emergency Medicine [EM] textbooks.
Objectives: The purpose of this study was to test the hypothesis that ED physicians overemphasize the quality of symptoms when attempting to diagnose 'real' dizzy patients, thereby placing such patients at risk for misdiagnosis.
Methods: We conducted a retrospective chart review of patients coming to an urban, tertiary care ED with dizziness. We identified 1144 patients with a triage complaint of "dizzy," "dizziness," "vertigo," "lightheaded," "presyncope," "faint," "syncope," "ataxia," "unsteady gait," or "off balance." From 92 charts selected at random, a single, unmasked reviewer (neuro-otologist) abstracted 5 elements of history: (1) date or time of first symptoms, (2) quality of

dizziness, (3) associated pain, (4) triggers for dizziness, and (5) episode duration. The reviewer then assigned a tentative diagnosis on the basis of the complete charted ED record, and compared it to the final ED diagnosis.

Results: Of 43% (40/92) charts recording at least one of five, the elements were documented as follows: 90% date or time of first symptoms, 70% quality of dizziness, 50% presence or absence of pain, 30% presence or absence of triggers, and 13% episode duration. In 30% of charts, no mention was made of pain, triggers, or episode duration. Tentative diagnoses were possible in 48% (44/92) of charts. There was discordance between specialist and attending ED physician diagnosis in 39% (17/44). Although most of the suspected misdiagnoses were of minor clinical significance (e.g. diagnosis of BPPV in a patient suspected to have vestibular migraine), 7% (3/44) of records harbored probable missed cerebrovascular events, translating to approximately one missed TIA or stroke per week in our hospital ED.

Conclusion: The quality of dizziness (charted in 70%) is given more diagnostic weight than other attributes of patient history, especially episode duration (charted in 13%). However, insights gained through vestibular research over the past 30 years have established that episode duration, triggers, and presence or absence of pain provide diagnostic information far more important to triage decisions than symptom quality. In conjunction with our other studies demonstrating a correlation between physician misperceptions and outdated information in EM texts, we believe our results point towards a system-level flaw in the way ED physicians are trained to diagnose dizzy patients that could be responsible for a substantial number of misdiagnoses of significant clinical impact. Prospective, masked studies examining diagnosis of ED dizzy patients are required to confirm these suspicions.

P086

Pulse-Synchronous Eye Oscillations Revealing Bilateral Bone Superior Canal Dehiscence

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Background: Superior canal dehiscence syndrome is characterized by transient sound-induced and/or middle ear and/or intracranial pressure-induced vertigo and nystagmus.

Objectives: We report on a patient with bilateral superior canal dehiscence syndrome who presented with unusual manifestations including pusle synchronous vertical oscillopsia.

Methods: Eye movements are recorded using the technique of video-oculography. Eye movement and electrocardiogram recording are also synchronized.

Results: The recording shows pulse synchronous vertical pendular nystagmus and Valsalva-induced upbeat jerk nystagmus.

Conclusion: These unusual symptoms may be a clue to a better understanding of pathophysiology of the superior canal dehiscence syndrome. Abnormal communication between both inner ears and intracranial space may explain the vertical pendular and pulse-synchronous nystagmus, modulated by increased intracranial pressure.

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P087

Caloric Stimulation for New Treatment of Persistent Dizziness in Vestibular Neuritis

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Background: Unilateral peripheral vestibular disorders such as vestibular neuritis, cause severe vertigo, nausea, nystagmus and postural imbalance. These characteristic symptoms improve spontaneously with time in a process of behavioral recovery known as vestibular compensation unless peripheral vestibular function restores. However, some patients who still have a transient dizziness with head movements or unsteadiness over the long term are likely to be in a retardation of the compensation.

Objectives: In this study, we propose a new therapy for those on the basis of the hypothesis that warm caloric stimulation to the healthy ear named as compensation re-initiating therapy (CRT), which excites horizontal semicircular canal up to vestibular nucleus neurones of an intact side and leads an enhancement of difference in the excitability between bilateral nuclei, possibly initiates the compensatory process again.

Methods: CRT, 5 times at one month interval, was performed on 16 patients with vestibular neuritis who suffered dizziness with head movement and head-shaking nystagmus toward intact side with persistent caloric canal paresis for more than one year after the onset of the disease.

Results: Analogue scale of dizziness and time in appearance of nystagmus after head-shaking decreased to less than 50 % of the value before CRT in 11 of 16 (68.8 %) and 9 of 16 (56.3 %) cases, respectively.
Conclusion: These results suggest that CRT, which reinitiates the vestibular compensation, is a rational new therapy for persistent vestibular symptoms in a chronic stage of vestibular neuritis.

P088
Vestibulo-Ocular and Postural Deficits in Spinocerebellar Ataxia 5, 6, and 8
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Background: The autosomal dominant spinocerebellar ataxias (SCAs) are a group of neurodegenerative diseases characterized by progressive instability of posture and gait, incoordination, ocular motor dysfunction, and dysarthria due to degeneration of cerebellar and brainstem neurons. Some genetic SCA subtypes exhibit characteristic abnormalities that imply selective vulnerability of certain populations of neurons to the actions of different SCA genes. SCA5, 6, and 8 are considered "pure" cerebellar ataxias that lack extracerebellar deficits and clinically are difficult to distinguish. Since the cerebellum is important for controlling the gain and direction of the vestibulo-ocular reflex (VOR) and postural stability, those subtypes were chosen.
Objectives: The horizontal VOR and postural stability were examined in patients who had SCA5, 6, and 8. We hypothesized that a) quantitative measures of postural stability would be correlated with the clinical severity of the disease and b) the VOR would provide evidence of differential neural involvement among these SCAs.
Methods: Data were collected from 11 patients with SCA5, 14 with SCA6, and 9 with SCA8. There were 17 control subjects for the VOR and 24 for posturography. The patients were grouped according to a clinical assessment of the disease: mild and moderate/severe. EOG electrodes were used to record the horizontal VOR during sinusoidal rotations (0.15 to 0.4 Hz with a peak angular velocity of 50 to 100 deg/s) and ramp changes in angular velocity (constant angular acceleration of 10 deg/sec2 (for 18 seconds) or 20 deg/sec2 (for 9 seconds)). For posturography the Equitest (Neurocom) protocol was expanded to include sway-referenced gains of +0.5, +1, and +1.5. Matlab programs were used to process the sampled EOG data. Simulink was used to model the eye velocity storage mechanism proposed by Raphan et al [1977] that included an additional eye position feedback pathway. Four parameters in the model were adjusted to fit the eye velocity data. Statistical analyses were performed with Matlab and Systat: ANOVA, linear discriminant analysis, and the Kolmogorov-Smirnov test.
Results: It was found that (a) in SCA5 both the gain of the VOR in the dark and visual suppression of the VOR were normal; (b) in SCA6 the VOR gain also was normal, but visual suppression was low; (c) in SCA8 the VOR gain was greater than normal, visual suppression was very low, and the distribution of slow phase eye velocities was shifted to higher values compared to SCA5, 6, and the normal controls; (d) in SCA8 the ramp VOR showed a greater reversal in the direction of eye velocity; (e) in all the SCAs the extent of the vestibulo-spinal deficit was correlated with the clinical state.
Conclusion: These results demonstrate that genetically defined forms of SCA can be distinguished by multivariate analyses of physiological variables that manifest as genotype-specific patterns. This suggests a differential involvement of neurons in the cerebellum by the disease process.

P089
Immunohistochemical Study for Monoamine Neurons in Brain of Unilateral Inner Ear Impaired Rats
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Background: Patients with inner ear impairment have complaints of vertigo and also occasionally depression. However, the mechanism and relation between vertigo and depression are unclear.
Objectives: The present study was undertaken in order to evaluate changes in monoamines that have reportedly been closely related to depression, using cisplatin-induced unilateral inner ear impaired rats.
Methods: A dose of 0.5mg/kg of cisplatin was injected into the right tympanic cavity under pentobarbital Na^+ anesthesia. One or two weeks later, animals were fixed with paraformaldehyde, and thereafter immunohistochemical staining for monoamine-containing cells in the brain were carried out. For visualizing 5-hydroxytryptamine (5-HT), noradrenaline (NA) and dopamine (DA) neurons, we used mouse antibodies against 5-HT, NA, and DA syntheses, i.e., tryptophan hydroxylase (TRH), tyrosine hydroxylase (TH) and dopamine-B-hydroxylase (DBH).
Results: Number of TRH immunoreactive neurons significantly decreased in lateral dorsal raphe nucleus of the ipsilateral side when compared with that of contralateral. Number of DA neurons, which were immunoreactive to TH, but not to DBH, significantly decreased in hypothalamus of the ipsilateral side. Number of NA neurons, which were immunoreactive to both TH and DBH, significantly decreased in locus coeruleus and ventral lateral pons of the ipsilateral side. Additional study with saline-injected rats showed a lack of differences in monoamine syntheses between injected and contralateral sides, the expressions of each syntheses being similar to that obtained in the contralateral side in cisplatin-injected rats. These results indicated the decreases in monoamine syntheses at the ipsilateral side in the cisplatin-administered rats.
Conclusion: We conclude that inner ear impairment may diminish the ipsilateral amount of monoamines in the brain but not the contralateral, possibly inducing a vestibular

compensation such as an up regulation of monoamine receptors.

P090

Distance and Direction Deficits in a Path Integration Task After Unilateral Vestibular Loss Depend on Task Complexity

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Background: During navigation, spatial updating of the current position and orientation in the environment may be carried out either on the basis of exteroceptive information about the environment, and /or on the basis of proprioceptive and vestibular information from self-movements through the environment (path integration).

Objectives: The aim of the study was to investigate the effects of peripheral vestibular disorders on the ability to perform path integration. The distance and direction components of the internal spatial representation of Menière's patients were assessed in spatial tasks of variable complexity (route reproduction, route reversing and spatial inference), with different available sensory cues (proprioceptive, vestibular, or visual), and were analyzed as a function of the side of the exploration path (towards the healthy versus the lesioned side).

Methods: After exploring two legs of a triangle, participants were required either to reproduce the exploration path, or to follow the reverse path, or to take a shortcut to the starting point of the path (triangle completion). Patients' performances were recorded before unilateral vestibular neurotomy (UVN) and during the time-course of recovery (one week and one month), and were compared to those of matched control participants tested at similar time intervals. All participants were tested in three conditions requiring various sensory cues: proprio-vestibular (blindfolded locomotion), visuo-vestibular, and visual. In the two latter conditions the displacements were performed in a visual virtual environment; participants were seated on a rotating chair and wore a helmet. In the visual condition, both rotations and translations were performed via a joystick, while in the visuo-vestibular condition the participant's rotations on the chair produced equivalent rotations in the virtual environment.

Results: The results indicated that both angular and linear path components of the trajectory were impaired for patients: they showed more turn and distance errors than controls, specifically in the complex spatial tasks (shortcutting and/or path reversing). Such deficits remained one month after UVN. Moreover, patient's performances were impaired whatever the available sensory cues, but errors were minimal in the blindfolded locomotor condition (with proprioceptive and vestibular information) and maximal for conditions involving visual and/or vestibular information. Finally, concerning the side of the exploration path, unilateral vestibular loss led to global impairment of path integration, yet some asymmetrical spatial performances were observed one week after UVN.

Conclusion: On the whole, these results suggest that vestibular lesion impairs both angular and linear path components, thereby strengthening the idea that vestibular cues are necessary in the elaboration of an accurate internal representation of the environment, especially for complex spatial tasks.

P091

Humans Use Vestibular Signals to Update the Locations of Visual Targets in Space

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Background: As visual creatures we constantly move our bodies to scan objects in the environment. The location of these objects are typically static in space, however, their location relative to the observer changes because the observer is moving. It is well known that primates can update, and thus keep track of, the locations of targets in space. Specifically, they can accurately look to the remembered location of a briefly flashed light even if the eyes/head are subsequently moved from their initial location (Hallett & Lightstone, *Vision Res*., 1976; Medendorp et al., *J Neurosci*. 2002). To do this, the brain requires information regarding the amplitude and direction of the intervening movement. Such information can be provided either by motor signals (in the form of efference copies of the outgoing motor command) or by sensory signals. These sensory signals include proprioceptive means (directly from the muscles) and vestibular signals (from the canals and otolith organs).

Objectives: To determine if vestibular signals alone can account for spatial updating in three-dimensions, all motor and proprioceptive signals were eliminated from a torsional, spatial updating task.

Methods: Subjects sat, with their heads immobilized, on a chair that was mounted on a three-dimensional turntable. In complete darkness, (1) subjects were tilted torsionally about a space-fixed, dorsal-ventral axis (i.e., either left ear down or right ear down), (2) a central target appeared on which the subjects had to fixate, (3) a peripheral target briefly flashed (subjects had to ignore the target, but remember its location), (4) subjects were returned to an upright position (while continuing to fixate the central light), and (5) the central target was extinguished. The latter cued the subjects to make a saccade to the remembered target. Using this paradigm, we tested subjects' abilities to update from various tilt angles (0^o=control, $\pm30^o$, $\pm45^o$, $\pm90^o$), target directions (4 cardinal and 4 oblique), and target amplitudes (10^o and 20^o).

Results: We found that subjects were able to update the locations of the remembered targets from all tilt angles and all amplitudes. Slopes of directional errors vs. tilt angle ranged from -0.011 to 0.15, were not significantly different from a slope of zero 0 (indicating perfect updating), but were significantly different from a slope of 1 (no compensation for head-in-space torsion) and a slope of 0.9 (no compensation for eye-in-space torsion). Horizontal and vertical errors, as well as errors in amplitude were also similar for all tilt angles and amplitudes. In addition, differences in saccade latency and number of corrective saccades were not found for different tilt angles and amplitudes.
Conclusion: Since the eyes and head were fixed relative to the body throughout these rotations, subjects could not use efference copies or proprioceptive cues to assess the amount of tilt. Thus, we conclude that vestibular signals alone can update the locations of targets in space.

P092

Cognitive Impairment by Spatial Disorientation

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Background: Cognitive impairment is reported by pilots during spatial disorientation [1] and patients with vertigo [2]. The nature of the impairment is unclear.
Objectives: Our studies examined cognitive task performance during vection and vertigo.
Methods: Tests comprised: the spatially loaded Mannikin test **(M)**[3] presented on a laptop PC mounted as a head up display; spatially and verbally loaded Stroop tasks **(ST)**[4], presented over headphones and to which the subject responded with a joystick. Disorientation scenarios were: **M** was performed i) during continuous visual field motion in roll at 90°s-1 and pitch at 20°s-1 (12 subjects); ii) during yaw rotation at 90°/s interleaved with epochs of coriolis-provocative head movements (6 subjects); iii) immediately after sets of 10 paced voluntary head rolls [5] producing coriolis-disorientation (16 subjects); **ST** was performed during steps in rotational velocity and 3s start-stop stimuli at 100°/s in yaw (12 subjects). Control conditions were subject and visual field stationary.
Results: During both peripheral field motion and subject rotation transient increases in error rates and latencies were observed following the onset of a stimulus condition regardless of whether this was intervention or stationary control! Coriolis head movements increased **M** errors throughout with evidence for a protective effect of practice. Latencies were unaffected.
Conclusion: The results support a '2 factor' theory: for mild disorientation impairment is due to novelty and disorientation is 'quarantined' so it has little impact [6]. During vicious dizziness (e.g. vertigo, aircraft spin) impairment is sustained, possibly because it is an ecological threat and the attempt to resolve the disorientation makes excessive demands on attentional resources [7].

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[4] Devised by L. Yardley and M. Gresty. Spatial task: the words "right" or " left" are presented to one ear randomly. The subject signals 'correct' when the word is presented to the ear of similar laterality (e.g. "right" to the R ear) and incorrect if the word is presented to the ear of opposite laterality. Verbal task: a female or male name is heard spoken in either a male or female voice. If the sex of the voice matches the sex of the name the subject signals 'correct' and 'incorrect' if the sexes do not match.
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P093

Vestibular Imbalance Alters the Perception of the Heading Direction During Visually Induced Linear Vection

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Background: Although the perception of the heading direction (or where we are going) has been intensively studied during the last decades, its sensory basis remains controversial. While the role of the visual information (optical and retinal flows) had been thoroughly investigated, the dependency of the heading perception upon the vestibular afferents has only been marginally studied.
Objectives: In order to investigate that question, we have studied the effect of vestibular imbalance on the heading perception in earth stationary subjects during the visual

vestibular interaction known to occur in the visually induced illusory self motion (or vection).
Methods: Twelve Healthy Control (HC) subjects and 17 patients after Unilateral Vestibular Neurotomy (UVN) were studied. Five patients were examined early (1 week) and 12 late (from 1 to 24 months) after UVN. Both HC and UVN populations were exposed to translatory optokinetic stimulations known to induce pure linear horizontal (like in a train) or vertical (like in an elevator) vections, while normally seated. They coded the perceived vection path "on line" by way of a manipulandum and "off line" by appropriate mime afterwards. In HC subjects only, binaural bipolar trapezoidal Galvanic Vestibular Stimulations (GVS) were delivered 6 seconds after vection started. The GVS varied in terms of their polarity (anode left and cathode right or vice versa), their magnitude (1 or 2 mA) and the duration of their current ramps (3 or 6 seconds). The GVS plateau had a constant duration (10 seconds). The HC subjects were exposed to "with GVS" (experimental) and "without GVS" (baseline) trials.
Results: The main results can be summarized as follows. With respect to normal linear vections, the vestibular induced deviations of the heading perception regarded the shape (the vection followed a curved path) or the direction (the vection followed an oblique linear path). In HC subjects, the GVS deviated vections toward the cathode side. These deviations occurred more frequently under higher GVS magnitudes and after steeper GVS ramps. In early UVN patients, the vections were altered in most (77 %) trials. The vections deviated toward the side opposite to surgery in most (76 %) alterations. In late UVN patients, the linear vection was normal in most (90%) trials.
Conclusion: The present results show that the heading perception does not rely on the visual inputs only but also on the vestibular ones. They suggest that the balance between left and right vestibular afferents would be crucial in the perception of the heading direction, which tends to deviate toward the more firing side (the cathode side in HC subjects and the side opposite to surgery in early UVN patients). The recovery of the normal heading perception in late UVN patients may rely on vestibular compensation.

P094
Vestibular System and Spatial Orientation
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Background: Vestibular system is known to code motion of head. We want to know if vestibular input is necessary in spatial orientation?
Objectives: The aim of this study was to evaluate the consequences of vestibular canal paresis in spatial orientation.
Methods: We have studied 3 groups of vertigo patients, group A with unilateral vestibular deficit, group B with major bilateral paresis, and group C with no peripheral vestibular anomalies anymore during otoneurologic investigation. We compared these groups with a control group (HS). Each subject had to perform 3 tasks: subject eyes closed and standing in darkness, had to actively turn CW or CCW for successively 90°, 180°, 270° and 360°. In second task, subject eyes closed and sitting in darkness had to estimate amplitude of passive rotation at 30°/s in CW or CCW direction with rotation of 45°, 90°, 180°, 270° and 360°, then the patient was required to say after the end of rotation, how he felt motion during and after rotation. In third task, rectangle-triangle path: subject eyes closed and standing in darkness, had to walk straight on for 3 meters, to stop with indication of the observer, then to turn 90° right or left, walk again 2 meters and stop with indication of observer and had to return directly at the starting point (hypotenuse).
Results: For the first task, patients as HS made mistakes of only a few degrees and infrequently.
For the second task, vestibular patients frequently underestimated the amplitude of rotation in the direction of the canal paresis. The trigger to feeling counter rotation at the end of rotation was analyzed as the sensation. In vertigo patients, this feeling seemed sometimes to be replaced by symptoms usually experienced by patients in daily life (head-ache, unilateral tinnitus, full ear sensation unilaterally, or major disorientation). For the third task, vestibular patients (group A and B) more often made mistakes, than HS and vestibular patients of group C, especially when the first angle (90°) is in the direction of canal lesion. So, patients with a canal paresis underestimate the second angle and do not "close" the triangle, although HS and patients of group C usually overestimated the second angle and so "close" too early the triangle. Often, the mistakes were as quickly corrected for unilateral vestibular defective patients (group A) as for group C and HS. Bilateral patients (group B) did not much correct their mistakes.
Conclusion: In active rotation when subject is standing, vestibular input does not seem necessary as we observed mistakes very rarely when subjects were actively turning themselves or during the first angle of the triangle. In contrast, the vestibular system plays an important role in estimation of passive rotation. Finally, for complex task as active turning of the second angle of the triangle, which need mental spatial representation of the subject in motion in the room and or computation, vestibular lesion had different performance from HS and group C, suggesting that vestibular system was useful.

P095
Optic Field Flow Signals Update the Activity of Head Direction Cells in the Rat Anterodorsal Thalamus
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Background: Head direction (HD) neurons fire selectively as an animal orients its head in different directions relative to the environment. The subset of active neurons updates as the head rotates. Normally as a subject moves about, turning the head in one direction produces an opposite shift of

the visual image. Hence rotations of the visual scene convey information about rotations of the head in space.
Objectives: Our working hypothesis is that the optic flow of the visual scene during movements helps to update the directional firing of HD neurons. Here we test whether such updating may result from optic field flow cues.
Methods: In 7 Long-Evans rats, 14 anterodorsal thalamic HD neurons were recorded. The animals were placed on a circular platform (diam 75 cm) surrounded by a large cylindrical black curtain (diam 3 m). A planetarium-like projector presented a field of points evenly distributed on the curtains of the otherwise dark cylinder. First, preferred directions (PD) were recorded with the points still. Then, they were rotated at constant velocity for 90 s, while directional firing was recorded. Baseline recordings were again made with the dot array stationary.
Results: In 28 sessions for a total of 42 rotations at 4.5 /s (i.e., about 405 over the 90 s period) yielded a mean coherent drift of 204 (SD=54) in the PD of the neurons relative to the room reference frame. However shifts were also not reproducible at more rapid field rotations at 10 /s.
Conclusion: This may be due to the optic field rotation inducing vection, and the HD system registering this as a shift in the animal's orientation. However this would have created a conflict with vestibular, motor command and efferent copy signals indicating no such self-rotation. Consistent with this, the optic field flow signals provoked directional shifts only when the animal was actively moving, not when it was immobile, where the intermodality discrepancy would be highly salient. This is coherent with the absence of effects at higher velocities – these also correspond to the values where vection is also less inducible.
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P096
Multisensory Information Interaction During Spatial Navigation and Memorization: Not a Mere Bottom-Up Procedure
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Background: Multisensory information is necessary for spatial encoding of navigated trajectories. We support the theoretical idea that this multisensory processing is supported not only by bottom-up, but also by top-down cognitive mechanisms.
Objectives: In the present study, we examined potential influence of multisensory conflict to the reproduction of already memorized paths non-associated with it in Virtual Reality. Furthermore, we investigated the contribution of conflict awareness to path memorization.
Methods: The experiment consisted of three tasks in virtual corridors; first, subjects navigated in each corridor effectuating passive translations and active whole body rotations and memorized their trajectory (Task 1). Two different sensory conflict gains between visual and non-visual information were randomly introduced during navigation. Afterwards, subjects navigated an interference corridor, where identical or different to the experimental corridor conflict gains were introduced, without memorizing it (Task 2). Finally, subjects reproduced the memorized passive translations and active body rotations in total darkness (Task 3).
Results: Data collect included amplitudes' measurements on realized body rotations during reproduction and answers on semi-structured questionnaires, according to which subjects were classified in three groups of conflict awareness level: (0) 'No conflict Awareness'; (1) 'Total conflict Awareness'; and (2) 'Something's Strange' group. Both types of data were analyzed and correlated between them. Consistent with our previous studies, results show that path memorization takes place in association with the introduced conflict. Additionally, in accordance with our present hypotheses, results suggest that trajectory reproduction cannot be influenced by a sensory conflict non-associated with its navigation and encoding. Importantly, results also show significant influence of conflict level awareness to memorization despite multisensory conflict.
Conclusion: These two main results provide evidences for top-down mechanisms contributing to multisensory integration processing during spatial encoding.

P097
Temporal Delays During Locomotor Interactions Between Human Subjects
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Background: The question of how humans coordinate their own movements with the movement of others is of particular interest though only few studies have been devoted to this topic. Inter-subjects movement coordination has been studied by Schmidt et al. (1990) in a specific paradigm: seated subjects were watching each other's lower oscillating leg and were asked to coordinate the movement of their own leg with the movement of their partner's leg in two phase modes. Results showed that rhythmical oscillations of the lower leg of the two subjects were coordinated according to the same patterns as those already observed during rhythmical bimanual tasks in a single subject (Kelso et al., 1981). However, little is known about the rules used by the CNS when subjects have locomotor interactions with one another rather than behave in isolation.
Objectives: In this study, we characterize the interactions between pairs of subjects during locomotion.
Methods: Subjects were asked to maintain constant the initial distance (1, 2 or 3 meters) separating them while walking back and forth within a corridor (8 x 2 meters) comparable to a fencing track. One of them initiated the movement and was considered as the leader (L) whereas the other was considered as the follower (F). Markers were placed on the bodies of each one of the two subjects and

data were recorded using a Vicon system (Vicon 8 - Oxford Metrics Ltd.).
Results: Cross-correlation analysis performed on the linear displacement of the two subjects revealed i) a variation of the nature of the coordination of the displacement (in phase or out of phase) depending on the walking direction of F ii) the time lag was similar across subjects and comprised between 200 and 300 ms depending on the relative distance between subjects: the greater the distance the longer the temporal delay with L being always in advance with respect to F.
Conclusions: These preliminary results show that the CNS relies on coordination mechanisms depending on social roles of the subjects (L vs. F) and probably shifts from an absolute metric representation of distance into a more inter personal space in order to coordinate our own movement to the one of another.
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P098
Site of the Lesions in Sudden Deafness with Vertigo: Study by Click and Galvanic VEMP
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Background: Idiopathic sudden hearing loss (sudden deafness, SD) is defined as acute onset of sensorineural hearing loss, most often unilateral. It has been reported that recovery of hearing is poorer in patients with vertigo than in those without vertigo. However, site of the lesion causing vestibular symptoms in SD still remains unclear. Vestibular evoked myogenic potentials evoked by clicks (click VEMP) have been considered as a useful clinical test of the saccular afferents whereas caloric test is a clinical test of the lateral semicircular canal. VEMP evoked by short duration galvanic stimulation (galvanic VEMP) has been reported to be useful for differentiating labyrinthine lesions from nerve lesions in patients with an absence of click VEMP.
Objectives: We studied the site of the lesion causing vestibular symptoms in SD using click VEMP, galvanic VEMP and caloric test.
Methods: Twenty-two patients (14 men and 8 women) with SD with vertigo were enrolled into this study. The diagnostic criteria for SD with vertigo included a more than 30-dB sensorineural hearing loss occurring in at least three continuous frequencies in less than three days, single attack of vertigo occurring almost simultaneously with hearing loss, and no other neurological signs.
VEMPs were recorded from the sternocleidomastoid muscle that was activated bilaterally by maintaining an elevated head in the supine position. To record click VEMP, 95-dBnHL clicks (0.1 millisecond) were used. The stimulation rate was 5 Hz and the analysis time was 50 msec. The responses were averaged twice with and without SCM contraction. To record galvanic VEMP, 3mA (1 millisecond) electrical stimuli were presented. To remove electrical artifacts in galvanic VEMP, we subtracted the average obtained without SCM contraction from the average obtained with SCM contraction. Caloric responses were recorded using electronystagmography. Canal paresis (CP) was calculated using the maximum slow-phase eye velocity of caloric nystagmus.
Results: Among the 22 patients, 17 patients (77%) showed no click VEMP on the affected side. In caloric testing, 10 patients (45%) had decreased caloric responses (CP > 20%) on the affected side. Most patients with decreased caloric responses (9 of 10 patients: 90%) did not show VEMPs on the affected side. On the other hand, a part of patients who showed abnormal VEMPs showed decreased caloric responses (9 of 17 patients: 53%). All the 9 patients who had undergone VEMPs evoked by galvanic stimulation showed normal responses, suggesting that the site of the lesion in sudden deafness were located in the labyrinth.
Conclusion: These results suggest that site of the lesion in sudden deafness with vertigo may be largely divided into "otolith" type and "otolith and semicircular canal" type.

P099
Effects of Visual Stimulation on Equilibrium; Study with a Portable System
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Background: Visual information deeply affects sensation of motion and body balance. An easy operating system for visual stimulation is desirable for testing patients complaining of dizziness possibly induced by visual stimulation or of motion sickness.
Objectives: We investigate effects of visual stimulation on equilibrium by such a compact and portable visual stimulating system that is easily carried and used without a darkroom.
Methods: Eleven healthy adults, 6 men and 5 women, with age of 27-40, were enrolled in this study. None of them had complained of any dizziness or vertigo. None of them had any problem of body balance, ears or eyes with the exception of slight shortsightedness. We made a portable visual stimulating system of a head mount display (HMD), a digital versatile disc (DVD) player with a display and batteries. A display part was only 95 grams in weight, virtually showed 62 inch-wide (16:9) screen 2 meters ahead, which we adapted to a battery-powered system. This system did

not need a darkroom and was so light that its weight hardly had influence on a subjects' balance. This compact battery-powered system could be easily carried to the bedside if necessary. This time we made an animation on a computer as visual stimulation that a random dot pattern rotated and converted it to DVD for easy operation. The lengths of the total track of the center of the foot pressure and the power vectors of the movement of the center of the foot pressure were measured by a stabilometer with eyes open and closed, and with visual stimulation on HMD.
Results: The results were classified into 3 groups. In the first group including 6 subjects the lengths of the total track got more than 1.2 times as long as with eyes closed. In the second group including 2 subjects the lengths of the total track did not obviously change, but the power vector on either side of the body increased more than 1.2 times as long as with eyes closed. In the third group including 3 subjects there were no obvious change between with eyes closed and with visual stimulation.
Conclusion: Our visual stimulating system was compact, battery-powered and was used without a darkroom. With this system even healthy subjects could be classified into three groups; the group that was easily influenced by visual stimulation, the group that was hardly influenced by visual stimulation, and the group moderately influenced. This system was effective to classify subjects by the sensitivity to visual stimulation.

P100

Patients with Unilateral Vestibular Lesion Are More Unstable in the Frontal than in the Sagittal Plane: A Dynamic Posturography Study

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Background: Postural deficits in vestibular loss patients are well described. However, because of support perturbations were mainly restricted to the sagittal plane (Allum et al., 2001; Horak et al., 2002), the interest of dynamic posturography in case of unilateral vestibular loss is still a matter of debate.
Objectives: Therefore, we studied balance of vestibular loss patients on an unstable platform moving both in the sagittal and in the frontal plane. Our aim was twofold: first, to compare body sway obtained in these two planes; second, to appreciate the possible recovery of abnormal postural findings over time because of the vestibular compensation process.
Methods: Postural stability of 11 bilateral and 88 unilateral vestibular loss patients at different times following the lesion, was probed using a non-motorized seesaw platform. Caloric, vestibular evoked myogenic potentials (VEMPs) and vestibular evoked myogenic potentials evoked by short duration galvanic currents (VEMPg) were used to confirm unilateral or bilateral vestibular loss. Only subjects with subnormal vestibular function before surgery were selected. Subjects were tested upright on the platform tilting forward to backward (sagittal plane) and side to side (frontal plane) for both visual condition: eyes open and eyes closed. Sway area and total power spectrum of the displacements of the center of pressure were analyzed.
Results: Our results showed that except in bilateral vestibular loss patients (BVL), eyes open condition was not sensitive enough to distinguish unilateral vestibular loss (UVL) patients from control subjects. In contrast, in eyes closed condition, dynamic posturography allowed to differentiate BVL and UVL patients from controls. BVL patients were unable to stand up without falling. UVL patients during the first post-lesion week, also fell whatever the mobilizing plane of the platform. At the second week, patients succeeded with difficulty in maintaining balance in the sagittal plane, but always fell in the frontal plane. From two months post-lesion stage, postural parameters were higher than controls and much higher in the frontal than in the sagittal plane. After one year, high values tended to normalize in both planes but they remained higher than normal in the frontal plane.
Conclusion: In conclusion, postural control of UVL patients is more impaired in the frontal than in the sagittal plane. This could mainly result from properties of the two labyrinths, which function in a synergistic fashion in the sagittal plane and in a push-pull fashion in the frontal one. These data suggest that dynamic posturography on a seesaw platform could be a valuable tool in clinical diagnosis and quantitative analysis of imbalance in the patients suffering from vestibular loss.
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P101

Multi-Segmental Measurement of Body Sway During Undisturbed Upright Stance in Normals

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Background: Both in static and dynamic posturography, measuring the centre of pressure (CP) sway by force platform and modeling the body as rigid inverted pendulum doesn't allow comprehensive description of body kinematics. However, only a few reports have been so far concerned with the sway of either the whole body or specific body segments.
Objectives: In order to get insight into the strategies of orthostatic posture and the relevant body kinematics, and to help clinical interpretation of posturography, CP, trunk, and head sways were simultaneously measured during quiet upright stance.
Methods: CP sway in the antero-posterior (AP) and medio-lateral (ML) planes was measured by force platform, trunk

oscillation by two inclinometers at the sternum level [1], head angular velocity by two miniature gyroscopes secured to the head. Subjects were 10 healthy young adults (age 23 to 34). The test conditions were close to those suggested in [2].

Results: All sways exhibited random pattern. Their mean ranges (5th to 95th percentile of sway distribution) over the 10 subjects, with eyes open, were: in AP CP 1.5 cm; trunk 2.8°; head 0.3°; in ML CP 0.7 cm; trunk 1.6°; head 0.2° and weren't significantly modified by eye closure. No correlation could be proven between sways measured at different levels.

Conclusion: Smaller head than trunk movement suggests that head stabilizing mechanisms are counteracting the perturbations due to postural sway. Similar head stabilization had so far been proven during complex dynamic equilibrium tasks [3]. The inverted pendulum model predicts that, for small angles, the projection of the body centre of gravity (CG) sway on the platform is proportional to trunk inclination. Following this assumption, CG sway larger than CP one would result from our measurements. This is incompatible with pendulum stability, but would be compatible with the presence of embryonic hip strategy also in young normal people. The above arguments suggest that multi-link inverted pendulum (with pivots at ankle, hip, and neck, and probably also at knee level) is a more faithful scheme for human body in upright position, even in young normal people. Experimental data consistent with this conclusion are available [4] and modeling attempts have been proposed [5,6]. Multi-link strategy helps keeping CG vertical inside the body support, although it requires more complex control. Nevertheless, due to the smallness of body sway, the rigid inverted pendulum may still be a useful, first approximation, heuristic scheme for undisturbed postural sway in young normal people.

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P102

A New Conceptual Framework for Investigating Human Upright Stance: 3D Time-Frequency Charts

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Background: Until now, the frequency analysis of the recorded statokinesigrams has been usually performed via the Fast Fourier Transform (FFT). Unfortunately, this analysis is subject to fundamental flaws that are mainly due to the primary (mathematical) definition of the Fourier Transform, which states that it is applicable to periodical functions only. Indeed, applying this technique to any recording (i.e. function) without taking into account its temporal properties is equivalent to the statement that: the result of a sum of periodical functions may be an aperiodic function, which is obviously wrong. Since – clearly – the statokinesigrams are not periodical functions, some of the conclusions drawn from this analysis have to be discarded.

Objectives: Our main objective has been the time-resolved frequency analysis of statokinesigrams, in order to check some of the conclusions drawn by using the FFT. Also, a more refined approach in dealing with stabilometric recordings from pathological subjects, along with the definition of new stability and control merrit grades has been sought of, in order to help the practitioner in his diagnosis and further treatment of diseases influencing the upright stance.

Methods: In order to get a suitable time-resolved frequency analysis of a statokinesigram, one mathematical method proved to be particularly suited: the wavelet analysis. Widely used across very different fields of research (seismology, radar signature analysis, voice recognition, etc.), the wavelet analysis provides a 3D chart using frequency and time as planar coordinates and power as « altitude ». One of the most important features of this technique is that it yields real values for the instant power of the frequencies considered, enabling thus the definition of different postural stability criteria, and – of course – of different postural control criteria.

Results: Using the aforementioned analysis method, we found the following:

i) the assumption that the frequency spectra are constant over the whole time range of the stabilometric recording is false.

ii) the values of the power peaks resulting from the FFT are false

iii) the FFT analysis is misguiding since it tends to show that some frequencies are predominant, but in reality they may be present only a very small fraction of the recording time

Conclusion: The wavelet analysis is providing the time-resolved frequency analysis 3D charts, unobtainable from the classical FFT approach. These charts led us to a number of new hypothesis concerning the human upright stance control mechanism, which were validated by means of studying different statically significant subjects populations (aged, pathological, in good health condition, etc).

P103

Early VOR Suppression During Clinical Testing with Velocity Trapezoids

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Background: It has been repeatedly shown that humans can partially suppress the horizontal VOR even in total

darkness by imagining a head-fixed target (Barnes and Paige 2003).
Objectives: We wondered if suppression by an imagined head-fixed target could affect the results of standard clinical VOR testing with velocity trapezoids.
Methods: The basic stimulus was a 5 sec velocity trapezoid at a constant angular acceleration at 20 deg/sec/sec in a standard clinical rotating chair (Halmagyi et al. 1997). Three stimuli were given in each direction. The room was dark apart from a single chair mounted (i.e. head-fixed) fixation light, which was extinguished 3.5 sec before the onset of acceleration. Subjects were instructed to "look straight ahead". Slow phase horizontal eye position was recorded by infrared oculography and analogue differentiation produced an eye velocity signal (Wade et al. 1999).
Results: In over half of the normal subjects, eye velocity in response to this stimulus had 3 distinct phases. The initial 150-200 msec of the response (phase 1) had a gain of close to 1.0; it is followed by an anti-compensatory slowing, or even reversal of velocity, which could last for up to 1 sec (phase 2). Phase 3, which lasted until the end of the stimulus, followed with an eye velocity gain of 0.4 - 0.6 in the compensatory direction. The other subjects did not show the phase 2 decline in the eye velocity response but only a drop in gain from phase 1 to phase 3 levels after 150 to 200 msec.
Conclusion: In many normal subjects there is suppression or reversal of the expected VOR response, with a latency of about 200 ms. We attribute this to fixation of an imagined head-fixed target.
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P104

Does Caloric Stimulation Have Influence on Vestibular Evoked Myogenic Potentials?

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Background: In animals, convergence of neural inputs from semicircular canals and otolith organs onto a single vestibular nucleus neuron was demonstrated. The vestibular evoked myogenic potentials (VEMPs) are evoked by acoustic stimulation delivered to the saccule, transmitted via inferior vestibular nerve. Caloric responses are evoked by deflection of the cupula of the lateral semicircular canal via superior vestibular nerve. Interactions between these two have not been elucidated.
Objectives: To investigate whether non-physiological stimulation of unilateral lateral semicircular canal affects VEMPs or not.
Methods: The latencies and amplitudes of the first positive-negative peaks (P13-N23) of the VEMP ipsilateral to the stimulated (ice water irrigated) ear were evaluated. Short tone bursts of 500 Hz were presented through a headphone. The mean background amplitude was calculated from the integral of rectified background activities. The corrected amplitude (CA) of VEMP was defined as the ratio of (amplitude of P13-N23) / (mean background amplitude) in each run. First, in supine position, subjects kept their horizontal canal in vertical position and activate the sternocleidomastoid muscle by twisting the body at the neck during recording. Responses to 100 tone bursts were averaged, and two recordings were made in each condition. After irrigation of the external auditory canal with 2 ml ice water for 20s, it was confirmed that hearing threshold to the tone burst was not elevated and that evident nystagmus was induced. VEMPs were recorded in the early cooling period of 45s (from 60s to 105s after the irrigation started) and in the late cooling period of 45s (from 105s and 150s). In approximately 7-10 min, after the nystagmus ceased completely, another VEMP recording was made. The averages of pre- and post-cooling conditions were regarded as CA for control condition. Differences between CAs in control and cooling conditions were assessed by Student's paired t test.
Results: Seven ears of six healthy volunteers (5 males and 1 female; mean age 30.5 years) were examined. Highly significant statistical correlation (Pearson's coefficient > 0.8) was observed between amplitude of P13-N23 and mean background amplitude both in control and cooling condition, confirming the validity of the normalization procedure. In both conditions, VEMPs of the seven ears showed distinct peaks of P13 and N23, and no significant difference of latencies were confirmed in P13 or N23. In the early cooling period with intense nystagmus, CAs were reduced compared to control condition ($p<0.05$), while no significant difference was found between the late period and control condition.
Conclusion: Slight diminution of CAs during early stimulated period with intense nystagmus may show that semicircular canal input interacts with saccular inputs to a certain degree. However, this may also be caused by the direct cooling effect on the saccule, which has not yet been investigated, either.

P105

Dynamic Changes and Analysis of Electronystagmography

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Background: In order to explore the characteristics, correlation and significance of electronystagmography (ENG) in the different stages of vestibular lesion, compensation and convalescence after unilateral peripheral vestibular lesion.
Objectives: we chose 150 cases that have the vestibular disorders in the different stages of vestibular lesion, compensation and convalescence after unilateral peripheral vestibular lesion.
Methods: 150 patients were performed caloric, damped torsion swing test (DTST), head-shaking nystagmus (HSN), spontaneous nystagmus (SN), and 15 of whom were followed up for at least half a year.
Results: 15 of patients who had a complicated course were existed after reversible unilateral peripheral vestibular lesion, in which vestibular function was from imbalance to compensation, and then restoring decompensation, rebalance finally; while after irreversible lesion, the course was simple and only included function imbalance to compensation. In different stages, ENG was presented with characteristic variations, multiple, non-unified contradiction forms.
Conclusion: It was concluded that systemic and dynamic analysis of ENG characteristics was useful not only to determine which side the lesion was on but also to determine and monitor the course, central compensation and prognosis to help monitor the effectiveness of clinical therapy and vestibular rehabilitation training.

P106

The Interaction Between Accelerated Rotation and the Vestibular Evoked Myogenic Potentials

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Background: In animal experiments, convergence of semicircular canal and otolith nerve input onto single vestibular nucleus neurons was demonstrated electrophysiologically (Zhang X. 2001). The vestibular evoked myogenic potentials (VEMPs) represent myogenic responses evoked by acoustic stimulation received in the saccule.
Objectives: The interaction between the inputs from semicircular canals and saccule were explored by measuring VEMP during rotation.
Methods: Eleven healthy volunteers (8 males and 3 females, mean age 28.9 years) were examined. Angular acceleration around the axis was provided by a computer-controlled rotational chair. Subjects were seated upright and their heads were tied to the headrest with a rubber belt. During the recording, the subjects kept stretching the rubber belt to activate the SCM in a dark condition. The latencies and amplitudes of the first positive-negative peak (P13-N23) of the VEMP ipsilateral to the stimulated ear were evaluated. In order to eliminate the effect of variance of muscle activities, the mean background amplitude was calculated from the integral of the amplitude of rectified background activities. Short tone bursts of 500 Hz were presented through a headphone. The corrected amplitude (CA) of VEMP was defined as a ratio of (amplitude of P13-N23) / (mean background amplitude) in each run. First, responses to tone bursts were measured in static state. Then, two clockwise rotations and two counterclockwise rotations were performed alternatively. For example, when the right ear and SCM were selected for recording, clockwise rotation from the view over the subject was regarded as "ipsilateral rotation", and counterclockwise rotation from the view was regarded as "contralateral rotation". The chair was accelerated at 12°/s2 from static state to the final velocity of 180°/s, and VEMP were measured during rotation of 15 seconds. The average of two runs was regarded as CA for ipsilateral and contralateral rotations, respectively. The averages of four runs in pre- and post-rotation were regarded as CA for static state. Differences between CAs in static state and the ipsilateral or contralateral rotation were assessed by Student's paired t test.
Results: Highly significant statistical positive correlation with Pearson's correlation coefficient over 0.8 was observed between amplitude of P13-N23 and mean background amplitude both in static state and rotation. In both conditions, VEMPs of the eleven subjects showed distinct peaks of P13 and N23, and no significant difference of latencies were confirmed in P13 or N23. No significant differences of CAs were found between the static state and either rotation.
Conclusion: Evaluation using VEMP amplitude corrected by background muscle activities was useful in comparison among various conditions. Rotation with positive acceleration showed no significant effect on VEMP.
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P107

Major Role for Proprioceptive Input from Neck Muscle in Controlling Equilibrium During Walking

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Background: Recent studies (Bove et al, 2001; Courtine et al, 2003) have shown that unilateral perturbation of neck muscle proprioceptive input during locomotion causes whole-body deviation toward the side opposite to the stimulation and suggests that neck muscle sensory information is critical for controlling balance when walking. As such, the significance of neck muscle afferent input may increase in parallel with the increase in equilibrium constraints.
Objectives: To test this hypothesis, we investigated the effect of neck muscle vibration during walking along curved vs. straight paths. We anticipated increased vibration-induced walking deviations when steering curves, a

locomotor execution requiring fine-balance control (Courtine et al, 2003).
Methods: Eight subjects were asked to walk blindfolded along three different paths with straight, curved and very curved shapes. Subjects performed the locomotor tasks in normal condition and under continuous vibration applied to the left side of the neck. Vibration (80 Hz) is a selective stimulus for primary endings connected to Ia fibers (Roll et al,1989). Body kinematics was recorded by means of the optoelectric ELITE System.
Results: All the subjects showed significant deviation from the required trajectory as early as one step after vibration onset toward the side opposite to stimulation. Amplitude of body deviations was quantified as the angular difference between the change in heading per cycle during vibration versus control trials. Mean amplitude of vibration-induced body deviations was 13±6.3 deg per cycle during straight walking. Interestingly, body deviations significantly ($p<0.05$) increased when walking along curved (34±7.7 deg) and very curved paths (68±15.9 deg) compared to straight path. Significant trunk tilt toward the side opposite to stimulation accompanied whole body deviation ($p<0.01$). The amplitude of lateral trunk tilt was -0.8±0.6 deg during straight walking but significantly ($p<0.01$) increased during curve walking; the trunk tilted by -2.6±0.5 deg and -3.5±0.4 deg when walking along the curved and very curved path, respectively.
Conclusion: This study showed that unilateral neck muscle vibration induces a systematic deviation from the required trajectory during walking, and that the amplitude of this deviation increases with locomotor path tightness. Vibration generates sensory conflict evoking changes in postural references. Significant modification of trunk orientation results, which is likely directed to restore the illusory body unbalance (Ivanenko et al, 2000; Bove et al, 2002). Equilibrium constraints substantially increase during curve walking (Courtine et al, 2003). Accordingly, the necessity to maintain the otherwise threatened balance may explain why the effect of neck muscle vibration increases during curve compared to straight walking. In conclusion, the current study shows that the proprioceptive input from the neck is integrated in the control of locomotion and is processed in the context of the actual postural requirements.

P108

Application of Infrared CCD Camera for Detecting Nystagmus in Sudden Deafness Without Vertigo, Facial Nerve Paralysis and Acute Low Tone Hearing Loss

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Background: The infrared CCD camera (iCCD) is a very sensitive diagnostic tool for detecting vestibular nystagmus. ICCD is 1.7 to 1.8 times more sensitive than Frenzel's glasses in observation of eye movements and nystagmus. There have been few reports concerning nystagmus findings of cases of sudden deafness (SD) without vertigo, Bell's palsy (BP) and acute low tone hearing loss (ALHL).
Objectives: In order to investigate the presence of nystagmus in the cases of SD without vertigo, BP and ALHL, in which vertigo and nystagmus are seldom recognized, we applied iCCD to detecting the nystagmus of these casews and prospectively evaluated the usefulness of this equipment in detecting nystagmus.
Methods: Fifty-two SD patients, 71 facial paralysis patients (30 were cases of BP, 30 were incomplete Hunt syndrome, 6 were Hunt syndrome and 5 were Zoster sine herpete cases) and 32 ALHL patients were examined. All subjects were hospitalized, received therapy without ALHL patients and underwent examination by the iCCD nystagmus test every two days. Twenty normal control subjects were examined. The results were then collated and compared using appropriate non-parametric statistical methods.
Results: Spontaneous nystagmus was recognized in 23/25 (92%) cases of SD without vertigo, 21/30 (70%) cases of BP and 12/32 (38%) cases of ALHL, in contrast to the cases of SD with vertigo 27/27 (100%), 6/6 (100%) cases of Hunt syndrome and 0/20 (0%) cases of control subjects. These findings demonstrated that the iCCD nystagmus test was able to provide more detailed vestibular information compared to conventional reports based on the use of Frenzel's glasses.
Conclusion: These results suggested that vestibular dysfunctions were present not only in SD with vertigo and Hunt syndrome, but also even in SD without vertigo, BP and ALHL cases and that they reflect the severity of inner ear and nerve lesions. Neurootologist may also consider the iCCD as an efficient clinical tool for diagnosing various vertiginous disorders.
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P109

Frequency Dependence of Galvanic Induced Body Sway

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Background: Galvanic stimulation of the vestibular system is an technique to be developed for clinical application because of the ability to stimulate the left and right vestibular system separately and the involvement of both vestibulo-ocular and vestibulo-spinal reflexes. To standardize the technique both amplitude and frequency characteristics need to be well documented. Frequency dependence of galvanic stimulation was analyzed before by Petersen et al. They compared the log transformed torque variance (lttv) for the different conditions and frequencies and observed no frequency dependence. However, during the clinical application of galvanic stimulation, we got the impression that the power responses depend on the stimulus frequency.

Objectives: Verification and quantification of the frequency dependence of galvanic induced body sway.
Methods: The study was performed on 8 healthy subjects. Every subject was stimulated in a similar way as described by Petersen et al. Subjects underwent the galvanic stimulation with eyes closed and bare feet placed against each other, the arms crossed on the trunk. The electrodes were attached to the retro-auricular skin. Movements of the center of pressure were measured using a force platform. Both the log transformed torque variance (lttv) and the power response (body sway) were calculated to determine the frequency dependence of the responses.
Results: The lttv for anterior-posterior and lateral galvanic induced body sway was almost invariant with stimulus frequency ranging from 1.45 to 2.18(SD < 0.48). In contrast, the power response of the galvanic induced body sway (lateral and anterior posterior) showed a clear optimum at 0,3 Hz to 1.8 degs/mA and decreases with increasing frequency down to nil. The Lttv (lateral and anterior-posterior) did not depend on the stimulus frequency as the responses per frequency showed to be not significant different ($p>0.05$).
Conclusion: In agreement with Petersen et al, the Lttv does not depend on the stimulus frequency. Our results are similar to those presented by Peterson et al. However, the power responses show a clear dependence on the stimulus frequency. Maximum responses are obtained at 0.3 Hz and decline strongly at higher frequencies. The discrepancy can be explained by the fact that in case of the calculation of the log transformed torque variance' the response per frequency is composed of contributions of all frequencies in the response profile, which masks a possible frequency-dependence. In case of calculation of the power response per frequency, the response is composed by contribution of response of the associated frequency only.
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P110

The Latency of Fast Foot Trajectory Adjustments Are Unaffected by the Addition of a Balance Task

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Background: When walking, an attempt to avoid an obstacle, or a change in where one wishes to place a foot, must incorporate the act of balancing into the leg adjustment. This requirement may place constraints upon the speed and success with which we can change our foot placement when we are walking or standing. Hence, there may be a compromise between maintaining upright balance and achieving a desired foot placement.
Objectives: Therefore, we have measured the performance of subjects during a task that involved accurate placement of the foot onto a target that sometimes would jump to a new position during the movement. We wished to know whether the adjustment of the leg trajectory would be different when the body was fully supported with no balance constraints compared to when taking a step onto the target.
Methods: Five subjects were asked to take single steps to targets that shifted medially or laterally by 7cm in ¼ of trials, at the point of foot-off. Subjects then performed the same task while perched on the edge of a chair, fully supported by belts, in a posture similar to standing but without any balance component. Foot and whole-body center of mass trajectory, and hip abductor EMG were recorded.
Results: It was observed that during the stepping task successful steps to laterally-shifted targets were achieved more often, and with greater accuracy than to medially-shifted targets. This was because the former could be achieved simply by letting the body passively fall further laterally, whereas the latter required the center of mass trajectory to be reversed. Mean reaction time, as measured by the first change in hip abductor muscle activity from control trial data, was 100 ms. There was no change in the observed reaction time for the foot placement task with full body support (102 ms; $p=0.57$, two-tailed t-test).
Conclusion: The addition of a balance component to the leg movement i.e. stepping, did not affect the very fast reaction time observed when placing the foot onto a shifted target. This lack of interference may be because balancing on the one hand, and visually-driven reactions on the other, may be subserved by different neural areas. Evidence from cat locomotion studies would suggest that steady-state balancing and walking may be primarily subcortically controlled whereas visually-driven gait modification may be more cortex-dependent (Drew et al., 1996). However, given the very short latency of the reactions seen here, it seems likely that the foot trajectory modifications that subjects displayed are also sub-cortically controlled, as has been suggested for reaching with the arm (Day & Brown, 2001).
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P111

Asymmetrical Primitive Vestibular Function: A New Syndrome

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Background: Diagnosis of pathological vestibular function is reliable with usual vestibular tests and paraclinical inves-

tigations. However, in 20 to 40% of cases, the origin of the vestibular disorder remains unknown : because the lesion does not affect the horizontal canal or because the anomaly is under the threshold of detection with the usual tests.
Objective: To define the clinical and instrumental characteristics of these vestibular disorders with a set of tests focused on the canal function.
Methods: We tested 252 patients ranging in age from 7 to 72 (135 males and 117 females) classified in 3 cohorts: right head tilt (head to shoulder) (R), left head tilt (L), selected control group without symptoms (C). Criteria for inclusion: normal time-constant of the horizontal VOR (14+/-2sec. and asymmetry <20%). Criteria for exclusion: any previous otological or vestibular disease. We applied the following tests:- Impulse Rotatory Test (IRT) in horizontal plane(Barany Society Seattle 2002), IRT in vertical plane, -time-constant test in horizontal and vertical planes, vibratory test and –vertical ocular smooth pursuits. The tests were carried out with videonystagmography 2D and video-oculography 6D. We studied the prevalence in angular cumulation in the 3 dimensions of the space.
Results: 'R' and 'C' patients showed a left prevalence in the horizontal plane, 'L'patients showed a right prevalence. The table represents the results in angular cumulation.

Subjects	R	L	C
Mean value	+21.49	-17.71	+3.36
Standard deviation	15.99	18.37	4.73

Conclusion: This set of tests allows -to detect small vestibular disorders in both horizontal and vertical planes, -to analyse the distribution of the vestibular errors, -to define the best therapeutical strategy for the vestibular rehabilitation and to agree(or no) for optical prisms. This protocol highlights small vestibular dissymmetries among patients having normal results with usual tests. Among these patients, the variations to the threshold of normality depends of individual conditions. This study shows that primitive vestibular dissymetry is real and can introduce a bias in the responses to sensitive vestibular tests.

P112
Unilateral Visual Field Dependency for Patients with Vestibular Schwannoma

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Background: Patients with vestibular schwannoma (VS) have a non-homogenous vestibular function both before and after surgery and might rely more on visual cues for balance control [1,2].
Objectives: The objective was to investigate if patients with a more or less compensated, but defined, lesion of the vestibular nerve, i.e. VS, might be more visually field dependent than normal subjects.
Methods: The visual field dependence-independence was investigated with the Rod & Frame test in 21 VS-patients before surgery and correlated with tumor size, age, gender and other vestibular parameters of compensation such as the subjective visual horizontal and vertical (SVH-V), spontaneous and head shake nystagmus, caloric sensitivity and side difference, and smooth pursuit eye movements. These results were compared with the results for 28 normal subjects.
Results: Seventeen of the 21 patients had a normal SVH-V (mean 0.8±1.4º). These patients had a significantly larger tilt when the frame in the Rod and Frame test was tilted towards the ipsilesional side (mean 8.2±4.9 º), than towards the contralesional side (mean 5.5±6.0º) ($p<0.01$). There was a correlation between the ipsi- and contralesional tilt in the Rod & Frame test. No correlation was found between the tilt in the Rod & Frame test and tumor size, age, SVH-V, caloric sensitivity or canal pareses.
Conclusion: The results indicate a unilateral visual field dependency for patients with vestibular schwannoma indicating the side of lesion, and that the Rod & Frame test can be used to reveal a hidden imbalance in the vestibular system.
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P113
Acoustic Neuroma and Hearing Preservation with Modified Translabyrinthine Approach

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Background: In 1991 McElveen et al[1] preserved hearing function in one patient modifying the traditional translabyrinthine approach by sealing the vestibule with bone wax. However other authors failed to reproduce this result suggesting partial removal of the labyrinth as an alternative procedure to reach the fundus of the internal auditory canal[2-5].
Objectives: Our study aimed specifically at evaluating the effectiveness of the modified translabyrinthine approach in preserving hearing function in a group of patients with vestibular schwannoma that involved the internal auditory canal.
Methods: Our series consisted of 14 patients with vestibular schwannoma (average age 47.4). The schwannoma was less than 2 cm in size in all patients admitted to the investigation. Preoperatively, all the patients have a valid hearing function according to the classification proposed by Gardner and Robertson [6]. Follow-up ranged from 4 years to 9 months.

Results: None of the patients had postoperative persistence or tumoral recurrence on the MRI performed during follow-up. Immediately after surgery the whole group had excellent facial functionality. In seven patients the hearing function was preserved (4 class I and 3 class II according to the Gardner-Robertson scale). Four of the 7 patients with preserved hearing had persistent tinnitus. No complications or consequences of cerebellopontine surgery was observed.
Conclusion: In our series, 50% of the patients had a postoperative preserved hearing with no persistence or tumoral relapse. These results are promising. Obviously they need to be validated in a more comprehensive survey with a longer follow-up.
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P114

Responses of the Peripheral Vestibular Receptors Following Acute Hypotension in Rats

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Background: Excitation of peripheral vestibular receptors by postural changes produces functional changes in the aspects of the cardiovascular system. Conversely, patients with cardiovascular disorders complain of vertigo, which could be explained by changes in blood flow to the peripheral vestibular system.
Objectives: In this study, electrical activity and immunohistochemical responses in the vestibular nuclei and peripheral vestibular nerves were measured, to investigate the effect of acute hypotension on the activity of peripheral vestibular receptors in anesthetized rats.
Methods: Acute hypotension was induced by intravenous infusion of sodium nitroprusside (SNP) with 15 μg/kg or depletion of 4 ml of blood from the femoral artery. Electrical activity in the vestibular nuclei and peripheral vestibular nerves was recorded by means of extracellular single unit recording, and c-Fos and pERK1/2 protein were measured immunohistochemically in the vestibular nuclei in animals with intact labyrinths or with unilateral labyrinthectomy (UL).
Results: Intravenous administration of SNP or hemorrhage elicited less than 50% reduction of mean blood pressure. Electrical activity of the peripheral vestibular nerve at rest was a greater increase following acute hypotension, but the activity was not changed after pretreatment with MK-801, an NMDA receptor antagonist. Acute hypotension produced excitation of electrical activity in two-thirds of type I neurons and inhibition in two-thirds of type II neurons recorded in the medial vestibular nuclei (MVN) of intact labyrinthine animals. In UL animals, two-thirds of type I neurons ipsilateral to the lesion showed an inhibitory response, and two-thirds of contralateral type I neurons showed an excitatory response after the induction of acute hypotension. The response patterns of type II neurons were opposite those of type I neurons. Acute hypotension produced marked expression of c-Fos and pERK1/2 protein in bilateral MVN of intact labyrinthine animals, but the expression of proteins decreased more in ipsilateral MVN to the lesion than in contralateral MVN in UL animals. Pretreatment with MK-801 significantly decreased expression of c-Fos and pERK protein following acute hypotension in MVN.
Conclusion: These results suggest that the peripheral vestibular receptors play a significant role in the control of blood pressure following acute hypotension and NMDA glutamate receptor takes part in excitatory signal transmission for expression of pERK1/2 and cFos protein in the vestibular nuclei. (Supported by MRC in KOSEF)
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P115

Motion Sickness and the Menstrual Cycle

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Background: Surveys of transportation by sea, land and air, indicate that women are more susceptible to motion sickness than men, showing higher incidences of vomiting and increased symptoms such as nausea. The cause of this greater motion sickness susceptibility in women is un-

known. One suggestion is that it is due to the female hormonal cycle but there are contradictions between existing studies which have variously reported: enhanced susceptibility during menstruation [1], around the time of ovulation [2] and no change in susceptibility through the menstrual cycle [3].

Objectives: Our study attempts to circumvent the criticisms leveled at these reports of lack of adequate control and insensitivity of method by studying a cohort of women exposed to sessions of coriolis motion at various times of the menstrual cycle.

Methods: Twelve healthy females (mean±SD) age 24.4±6.6 years, not using contraceptive medication, were exposed to a provocative motion stimulus continued to the point of moderate nausea. The cross-coupled motion stimulus was whole body rotation on a turntable with a sequence (SEQ) of eight head moves every 30 s of approximately 45 degrees angle, with a staircase profile of rotational velocity incrementing from stationary by 3 deg / s steps every 30 s. Subjects were tested on: (A) day 5 'menstruation´; (B) day 12 'ovulatory´; (C) day 19 'mid-luteal´; (D) day 26 'pre-menstrual´, according to a design counter-balanced for order.

Results: Mean±SD SEQs required to achieve moderate nausea were: (A) 13.7±2.8; (B) 14.3±4.5; (C) 15.4±6.6; (D) 16.9±6.1. The difference between A and D was significant ($p<0.05$, 2-tailed).

Conclusion: There was trend indicating that motion sickness susceptibility was maximal at day 5 'menstruation´ decreasing through days 12 & 19 to a minimum at day 26 'pre-menstrual´, to a small but significant extent. This result is similar to the cycle of susceptibility found by Grunfeld et al [1] but delayed in phase by several days (3-4). However this minimal heightening of susceptibility observed through the female menstrual cycle is not likely to account fully for the overall greater susceptibility in females.

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P116

Off Vertical Axis Rotation Modulates Respiratory Timing in Humans

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Background: In cats, electric vestibular stimulation and otolithic stimulation during head rotation in the pitch plane on a stationary body alter the respiratory muscles nerve activity [1,2]. In Humans, although natural and caloric stimulation of the semicircular canals seems to mediate alterations in respiration [3,4], physiological importance of the relationship between the otolithic and the respiratory system remains poorly understood. Off vertical axis rotation (OVAR) produces a periodic and pure stimulation of the labyrinthine and of the non-labyrinthine (i.e. visceral) graviceptors.

Objectives: To determine whether OVAR affects ventilation and whether labyrinthine graviceptors are involved.

Methods: The ventilatory flow was measured in earth vertical axis rotation (EVAR) and OVAR (15° tilt) with a pneumotachograph in 21 seated subjects during rotations in two different head positions with regard to the body in order to distinguish the effects of the non labyrinthine and labyrinthine receptors on ventilation. In both positions, the head was in the body axis but turned on the left side in one position and turned on the right side in the other, in such a way that the angular difference between the head positions was approximately 120°. In each head position (applied in random order), 11 minutes EVAR was followed by 11 minutes OVAR. All the experiments were conducted in a dark room.

The frequency histograms of transitions between inspiration and expiration (I-E transitions) were calculated as a function of the angular position of the chair during OVAR and EVAR in both head positions. The histograms were constructed with eighteen 20° angular sections.

Results: In EVAR, the I-E transitions occurred with no preferred chair position (ANOVA between angular sections; head leftward: $p>0.5$; head rightward: $p>0.3$) whereas in OVAR, the distribution of the I-E transitions was not uniform among the 18 angular sections (ANOVA between angular sections; $p < 0.001$ in both head positions). However, in OVAR, the maximum frequency of occurrence of the I-E transitions took place at the same angular position of the chair (from the angular position where the front side of the thorax was facing down to about 60° after) whatever the position of the head.

Conclusion: The present study shows that OVAR affects the respiratory timing. However the synchronization of the respiratory cycle with the chair rotation appears to be mediated by the activation of non-labyrinthine graviceptors.

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Motion Sickness Susceptibility Associated with Visually Induced Postural Instability and Cardiac Autonomic Responses in Healthy Subjects

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Background: Visually induced postural instability has strongly associated with an individual susceptibility to motion sickness [1]. Autonomic responses to exposure to disorienting motion environments have also shown individual differences in healthy subjects [2]. However it has not determined whether the difference may be correlated with the susceptibility to motion sickness.

Objectives: Our objective was to determined whether subjects with high motion sickness susceptibility to motion sickness, which was assessed in this study by a questionnaire, show higher postural sway and cardiovascular responses to moving visual environment than subjects with low susceptibility.

Methods: Fifteen healthy subjects were exposed to sinusoidally oscillating visual motion in roll at frequencies of 0.1-0.4 Hz. Recordings were taken of postural sway, respiratory frequency and ECG from which heart rate variability (HRV) was computed to probe cardiac sympathetic and parasympathetic activity. They were asked how often they felt nausea and/or vomited whilst traveling on various types of vehicle with questionnaire. For purposes of analysis after collecting data of 15 subjects, 5 subjects of which the motion sickness susceptibility score (MSSS) were the highest, were classified as "high susceptibility to motion sickness" (high susceptibility group; mean score 28.0, SD 5.3), and 5 subjects of which the MSSS were lowest were classified as "low susceptibility to motion sickness" (low susceptibility group; mean score 12.6, SD 5.0).

Results: In subjects rating low susceptibility to motion sickness on a standardized questionnaire, there was no significant effect of visual stimulus on postural sway and HRV at any frequency of motion. Subjects with high susceptibility to motion sickness showed significant postural instability induced by the visual stimuli ($p<0.01$). The visual stimuli of 0.1 Hz significantly increased the low frequency power (LF) and LF/HF, and decreased the high frequency power (HF) of HRV in these subjects ($p<0.05$).

Conclusion: This study supports a hypothesis that the postural sway and autonomic responses to moving visual stimuli may be associated with motion sickness susceptibility. Characteristics of the cardiac sympathovagal balance during exposure to provocative stimulation may be a marker for individual susceptibility to motion sickness.

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Adaptive Changes of Vestibulospinal Reflexes Induced by Sustained Stimulation of Vestibular and Forepaw Receptors

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Background: In decerebrate cats, plastic changes of vestibulospinal reflexes (VSRs) occurred during sustained costimulation of vestibular and neck receptors [1]. In particular, an increase in gain of VSR affected the forelimb extensor triceps brachii (TB), when both VSR and neck reflexes acted synergistically on the TB.

Objectives: The EMG activity of TB increases during dorsiflexion, but decreases during plantar flexion of the forepaw [2].We investigated, therefore, whether i)wrist rotation could lead to adaptive changes in gain of VSR affecting the ipsilateral TB and whether ii)the cerebellar anterior vermis could be involved in this effect.

Methods: In decerebrate cats, the EMG responses of TB to sinusoidal roll tilt of the animal (0.16 Hz,±10°) were recorded every 8 minutes for 60-120 minutes. After this control period, roll tilt was continuously applied with simultaneous rotation of the ipsilateral forepaw (0.16 Hz, ±5°-10°). For a three hours period the stimuli were interrupted only for testing the isolated VSR every 15 minutes. In separate experiments, maximal rotation of the forepaw could occur either in-phase or out of-phase with respect to the extreme side-down animal tilt. After this adaptive period, the VSR was again recorded every 8 minutes for 60-120 minutes. The cerebellar anterior vermis could be inactivated ipsilaterally to the recording side by local microinjections of the GABA-A agonist Muscimol (0.5-1 µl, 8-16 µg/µl). The significance of the adaptive and post-injection changes in gain and phase of the TB responses was assessed by ANOVA.

Results: The average gain of control TB responses ranged from 0.43 to 0.80 imp/sec/°, the peak EMG activity always occurring during side-down animal tilt. In 6 animals, a three hours period of simultaneous, in-phase roll tilt and wrist rotation significantly increased the gain up to about 300% of the control values (range 163-391%; ANOVA, $P< 0.001$). This plastic modification remained quite stable for 60-120 minutes. No significant changes were observed in the response phase. In two experiments, functional inactivation of the cerebellar vermis significantly reduced the adapted gain from 340 to 174% of the control value. Finally, in three experiments, a three hours period of out of-phase animal tilt and wrist rotation did neither modify the gain, nor the phase angle of the TB responses.

Conclusion: Proprioceptive signals related to wrist rotation may lead to adaptive changes in the gain of VSRs. These changes depend on the direction of wrist rotation and are appropriate to reinforce the extensor tone when the wrist is bended by an increase in limb loading. Finally, the cerebellum is apparently implicated in this phenomenon.

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P121
Motor Learning in Adaptation to Altered Sensorimotor States
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Background: Patients with impairments of the vestibular system and astronauts returning from long duration spaceflight all experience difficulty interpreting vestibular signals, although for different reasons, and all have difficulty performing skills that require dynamic balance in standing and walking. Rehabilitation programs for these people are oft discussed but seldom studied and are not well-supported by empirical evidence. In the motor learning literature, however, the concept of variable practice in skill acquisition has been explored for sports training and laboratory skills tests. Few studies have temporarily altered sensory input and determined the effects of changing training strategies on the ability to adapt to that input.
Objectives: The goal of this series of experiments has been to determine if a regimen of training under conditions of a variety of visuomotor alterations is more efficacious than training with only one alteration or a sham alteration, when subjects are then exposed to a novel visuomotor change.
Methods: Several different experiments were performed. All subjects were normal adults, with no history of otologic disorder, no orthopedic or neurologic involvement and normal motor skills. Subjects trained on different obstacle courses in which they stepped over, under, or around objects, after training with clear, plastic sham lenses, one set of lenses that altered the size or spatial location of the visual image (blocked practice), or on three different lenses that altered the size or spatial location of images (variable practice). They were trained on several paradigms that involved training on the obstacle course, on a treadmill or balance board, or on a series of complex tasks. Post-tests used novel lenses while subjects traversed the obstacle course on which they were pre-tested.
Results: Training with variable practice was most beneficial when subjects trained on the course on which they were subsequently tested, so that the training and testing paradigms were most similar. When the training and testing paradigms were dissimilar, variable practice offered a protective effect against the contextual interference introduced by the lenses, as indicated by worse performance in the blocked practice groups.
Conclusion: Variable practice is a useful basis for motor training programs when subjects are exposed to alterations in visuomotor correspondences. When the testing and training paradigms are most similar, variable practice has a positive effect. In clinical practice, however, patients are usually trained on somewhat abstract clinical tasks but are expected to transfer training to the outside world. In that type of situation, i.e., when testing and training differ, variable practice is more efficacious than the blocked practice that is commonly used in the clinic. Therefore, using rehabilitation paradigms that incorporate variable practice may facilitate adaptation, or readaptation, of motor skills.
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P122
Relationship Among Age, Gender, Handicap and Functional Balance in Dizzy Patients
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Background: Dizziness is a common problem and often related to imbalance and falling. These imbalance and falling problems may prevent the patients from performing some of the activities of daily living and may consequently lead to handicap. The prevalence of dizziness increases with age, and is more prevalent among women. But little is known as to how age and gender would affect balance ability and handicap.
Objectives: The purposes of this study were to determine (1) the influence of age and gender on handicap and functional balance, and (2) the association between functional balance and self-reported fall history in dizzy patients.
Methods: 78 patients who had dizziness symptoms were included and divided into young and old (cutoff=65 years) age groups. Handicap situation was measured by Dizziness Handicap Inventory, and functional balance was measured by Dynamic Gait Index and forward reach test. All of the patients were asked to report the fall history in the last six months.
Results: Of the 78 subjects, 45 were under the age of 65 years, and 33 subjects above 65 (Table). There were significant age and gender differences in handicap. The young group had a significantly higher disability score than the older group in the physical aspect of handicap ($p=0.000$), while females had a significantly higher disability score than males in the functional aspect ($p=0.039$). The young group also had significantly greater distance of forward reach than the older group ($p=0.000$). The scores of Dynamic Gait Index were not significantly different between the two age and gender groups. No significant association between the score of Dynamic Gait Index and falling history in all subjects was found.

Table:

Patient Characteristics (Males / Females)			
Group	N	Mean age	SD age
Young (< 65 y/o)	19 / 26	45.16 / 44.69	13.64 / 10.84
Old (> 65 y/o)	22 / 11	71.00/ 73.36	3.61 / 5.24
Total population	41 / 37	59.02 / 53.22	16.15 / 16.30

SD: standard deviation; y/o: years old

Conclusion: In this study, young patients were found to be more handicapped than older patients, and women more than men. And older patients with dizziness have poorer balance ability than younger patients. Thus, age and gender appear to influence handicap and balance in dizzy patients. Clinically, special attention should be directed to improving functional capacity and preventing handicap for young and female patients, and improving balance ability for older patients.

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Correlation Between Falls, Balance Clinical Tests and Posturographic Parameters on Healthy Old People

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Background: The relations between balance clinical tests, falls in elderly people and the static posturographic parameters is a controversial subject. Static posturography includes Romberg test on firm surface with opened and closed eyes (OER and CER) and foam support surface with opened and closed eyes (FOR and FCR).
Objectives: The aim of this work is to know the relation between the three subjects mentioned above on a population of healthy elderly persons.
Methods: People: sixty four volunteer persons (19 men) without clinical history of disequilibrium and without known balance pathology, aged from 65 to 80 years (mean ± SD: 72,37 ± 3,4).
Methods: 1) History of falls during the last year (LYF). 2) Clinical tests: standing time on each foot, right and left (RFS and LFS), Timed Up and Go (TUG), Berg Balance Scale (BBS) and Tinetti Balance, Gait and Total Scores (TBS, TGS and TTS). 3) Static posturography (sway amplitude -sa- and sway velocity -sv-) with/without 13 and 9 centimeters foam (F13 and F9) with the NedSVE/IBV system. Statistics: Spearman's correlation.
Results: (*: significance with p<0,05; **: significance with p<0,01). 1) LYF-clinical tests: with TUG: r: 0,364*. 2) LYF-posturography results: no statistical significance. 3) Clinical tests-posturography results: RFS: with F13ORsa: r:0,364*; F13ORsv: r:0,359*; F9ORsv: r:0,295*. LFS: with F13ORsa: r:0,537**; F13ORsv: r:0,519**; F9ORsa: r:0,282*. TUG: with OERsa: r:0,264*; F13ORsa: r:0,410*; F13ORsv: r:0,470**. BBS: with F13ORsa: r:0,562**; F13ORsv: r:0,593**; F9ORsa: r:0,280*. TBS: with F13ORsa: r:0,577**. TTS: with F13ORsa: r:0,507**
Conclusion: 1. TUG can predict falls in this population better than the other clinical tests. 2. The parameters of the posturography aren't good predictors of falls on healthy old people. 3. The condition of the posturography that is better related with clinical tests is F13OR.
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Sensory Influences Involved in the "Broken Escalator Phenomenon"

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Background: It has been demonstrated that the 'broken escalator phenomenon', namely the sensation that when walking onto an escalator which is stationary one experiences an odd sensation of imbalance, represents a genuine motor aftereffect of gait adaptation (Reynolds and Bronstein, 2003). This aftereffect is a unique demonstration of dissociation between declarative and procedural systems in the CNS, in that the aftereffect occurs despite full awareness that the escalator is not going to move.
Objectives: However, the neural substrates of this aftereffect are less well understood. Therefore, the current study investigates the sensory influences on the 'broken escalator phenomenon' (Moving platform aftereffect).
Methods: The experiments involved, initially, walking onto the stationary sled (BEFORE). Then, participants walked 15 times onto the moving sled (MOVING), provided by a motorized sled moving at 1.3m/s, before completing a second set of stationary trials (AFTER). Six groups of participants in total were involved in similar experiments. The vision experiment included two groups of 8 normal healthy participants, aged 19-27yrs (x= 21.9), who either completed the AFTER trials with their eyes closed (EC group), or eyes open (EO group). In the vestibular experiment we tested 9 bilateral labyrinthine defective subjects (LDS), aged 42-69 years old (x=57.7). In the somatosensory experiment we tested 6 peripheral neuropathy patients (PNP), aged 31-62 years old (x=50.3). A group of 13 age-matched controls, aged 43-66 years old (x=57.5) and a group of younger controls, aged 19-30 years old (x=22.6), were also established. Measurements taken included gait

velocity, trunk position, foot contact and EMG of the ankle flexor-extensors.
Results: It was found, despite an unequivocal warning that the platform (in the AFTER trials) would no longer move, both groups in the vision experiment walked onto the stationary platform inappropriately fast and experienced a large overshoot of the trunk. There were no significant differences between eyes open or closed, indicative that vision is not critical for releasing this motor aftereffect. Both the LDS and PNP patient groups, as expected, were significantly more unsteady during the MOVING trials. During the AFTER trials, all patients and control groups experienced an increased aftereffect, assessed as gait velocity and a trunk overshoot. Overall, there were no significant differences in the size of the aftereffect.
Conclusion: These results confirm the prominent role of the vestibular and proprioceptive systems during external postural perturbations (e.g. as in the MOVING trials). When the perturbation is internally generated, as in the AFTER trials, the CNS relies less on sensory feedback and more on feed-forward mechanisms to maintain balance.

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Disturbed Postural Reflexes in Patients with Pusher Syndrome

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Background: Mittelstaedt (Neurosci & Biobehav Rev, 1998) postulated a dissociation between sense organs in the head and neck perceiving orientation of the visual world and sense organs in the trunk perceiving own body orientation. Recent findings proposed a selective disturbance of this second graviceptive system in stroke patients showing the so-called "pusher syndrome" (Karnath et al., Neurology, 2000). Using their ipsilateral limbs, these patients actively push from the non-paretic side until they loose stability and fall to the paretic side. In these patients, Karnath and co-workers found normal perception of the subjective visual vertical (SVV) indicating undisturbed visual-vestibular processing. The patients rather showed a marked ipsiversive tilt of the subjective postural vertical (SPV).
Objectives: In the present study, we focused on the pusher patients' postural reflexes during passive body tilt.
Methods: According to Magnus (1924) we investigated head and leg righting reflexes in pusher patients, patients with an acute peripheral vestibular disorder, and controls during passive body tilt in the roll plane with open and closed eyes. While sitting on the bedside with feet off the ground the subjects were laterally tilted with low frequency. Head, trunk and leg orientations were recorded in the frontal plane.
Results: Pusher patients showed an ipsiversive misalignment of the non-paretic leg with respect to the trunk during body tilts with both eyes open and closed. This misalignment remained constant regardless of trunk orientation. In contrast, patients with acute peripheral vestibular disorder showed normal postural reflexes.
Conclusion: Our findings corroborate the assumption that pusher patients demonstrate a selectively disturbed, tilted perception of body orientation. This disorder obviously also influences leg righting reflexes during passive body tilt movements. The dissociation between patients with a peripheral vestibular disorder and those with pusher syndrome argues for a separate pathway in humans for sensing the orientation of gravity apart from the one for orientation perception of the visual world.

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A Human Performance Crossover Model for Balance Control with Vibrotactile Feedback

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Background: We have demonstrated increased postural stability for unilateral and bilateral vestibulopathic patients donning a vibrotactile balance prosthesis during computerized posturography experiments [1,2]. The balance prosthesis device, which senses body tilt, consists of a motion-sensing system mounted on the lower back of the subject. Tilt estimates are displayed haptically in the form of vibrations to the subject's anterior and posterior torso by three rows of tactors.
Objectives: The purpose of this research is to develop a model that captures the dynamic response of a vestibulopathic patient wearing a vibrotactile prosthetic during computerized posturography. This research proposes using a human performance crossover model to characterize postural stability that is aided by a vibrotactile balance prosthesis.
Methods: The proposed model couples the dynamics of the plant, a single-inverted pendulum, with the dynamics of the human operator in the human-machine (vibrotactile prosthetic) system. The crossover model, developed for quantifying the human operator dynamics in human-machine systems, presumes that the human operator is capable of manipulating his/her transfer function parameters such that the open loop frequency response satisfies conditions for closed loop stability [3]. The vestibular system, modeled as simplified second-order angular and linear systems representing semicircular canal and otolith organ dynamics respectively, is included as the only physiological sensor of body tilt and acceleration in the anterior-posterior directions. All physiological factors used for the plant transfer function and vestibular end organs are obtained from previ-

ously published literature. The balance prosthesis is modeled as a proportional plus derivative system providing quantized tilt information to either supplement or replace compromised vestibular function.

Results: Theoretical results simulated in Matlab and Simulink are compared with experimental results obtained from vestibulopathic computerized posturography trials both with and without the aid of the balance prosthesis. Optimized feedback parameters are obtained from a linear quadratic regulator and suggest the possibility of increased operator performance.

Conclusion: Models incorporating human control capabilities can characterize postural stability for vestibulopathic patients donning a vibrotactile prosthesis. Additional experiments employing the optimized parameters are proposed.

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Combined Horizontal and Posterior Canal Benign Paroxysmal Positional Vertigo in 3 Patients with Head Trauma

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Background: Although benign paroxysmal positional vertigo of the posterior canal (PC-BPPV) or the horizontal canal (HC-BPPV) is usually idiopathic there is clear evidence that head trauma is the most common cause since it accounts for approximately 17 % of PC-BPPV(1) and 20 % of geotropic HC-BPPV[2]. Ageotropic HC-BPPV, which is less frequent than geotropic HC-BPPV, has rarely been reported after head trauma[3]. Interestingly, bilateral PC-BPPV is more prevalent in a post-traumatic group than in an idiopathic group[4]. However, in the context of head trauma, the association of PC-BPPV and geotropic HC-BPPV has rarely been reported[5] and, to the best of our knowledge, there has been no report of PC-BPPV combined with ageotropic HC-BPPV.

Objectives: To review the clinical features of combined HC-BPPV and PC-BPPV after head trauma.

Methods: In our clinic, positional maneuvers are systematically performed in the plane of the posterior canal (Dix Hallpike maneuver) and the horizontal canal (Patients where rolled to either side in a recumbent position with the head raised 30 degrees). A paroxysmal rotatory-upbeating nystagmus triggered by the Dix Hallpike manœuvre is concordant with a PC-BPPV and a direction changing horizontal positional nystagmus, either geotropic or ageotropic, triggered by lateral head turns is concordant with an HC-BPPV.

Results: Three patients complained of positional vertigo after head trauma with combined HC-BPPV and PC-BPPV. Two patients had a right PC-BPPV and an ageotropic HC-BPPV and one patient had a bilateral PC-BPPV and a left geotropic HC-BPPV. All 3 patients were rapidly free of vertigo after curing the PC-BPPV by the Epley maneuver, the geotropic HC-BPPV by the Vannucchi method while the ageotropic HC-BPPV cured spontaneously. Neuroimaging (brain CT and/or MRI scans) was normal in all 3 patients.

Conclusion: The Dix Hallpike maneuvers as well as supine lateral head turns are mandatory in all patients with dizziness, especially after head trauma, in order to diagnose PC-BPPV, HC-BPPV and the association of both. Early diagnosis and treatment of BPPV may help reduce the post-concussion syndrome.

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Stapedotomy and Benign Paroxysmal Positional Vertigo

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Background: Benign paroxysmal positional vertigo is one of the most common peripheral vestibular disorders. Many etiologies can provoke this disorder. One of these is represented by stapedectomy/stapedotomy [1-3].

Objectives: The aim of the present paper is to present our experience of postoperative benign paroxysmal positional vertigo in a series of patients suffering from otosclerosis operated on in the last five years.

Methods: The group examined consisted of 141 patients affected by otosclerosis who underwent stapedotomy operated on between 1999-2003. Unsuccessful stapedotomy with inadequate hearing recovery was ruled out. The patients suffering from benign paroxysmal positional vertigo

of the posterior semicircular canal underwent Epley maneuver, whereas the involvement of the horizontal canal was treated with Gufoni maneuver.
Results: 12 patients complained postoperative benign paroxysmal positional vertigo. In eleven patients, posterior semicircular canal was involved. Only one patient suffered from horizontal semicircular canal. Vestibular disturbances appeared between 5 and 21 days after surgery. First repositioning maneuver was successful in 10 cases. In the remaining two patients, it was necessary a second maneuver.
Conclusion: In our series, 8.5% of the patients with successful stapedotomy had a postoperative benign paroxysmal positional vertigo. This disorder is probably masked by the classic postoperative vestibular disturbances following otosclerosis surgery. In the counseling phase it should be presented as a potential complication.
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P129
Self-Treatment of Benign Paroxysmal Positional Vertigo
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Background: Current treatment approaches of benign paroxysmal positional vertigo of the posterior semicircular canal (PC-BPPV) include therapist-guided maneuvers such as the Epley's procedure and the Semont-maneuver with success rates of about 70-90% after single and nearly 100% after repeated application. Recently, we showed that self-treatment with a modified Epley's procedure (MEP) was more effective in relieving patients from PC-BPPV within a week compared to conventional Brandt-Daroff exercises ($p<0.01$).
Objectives: Since self-treatment may be a useful supplement for patients who remain symptomatic after single treatment, the aim of this study was to compare the efficacy of a self-applied Semont-maneuver and the MEP in 70 patients with PC-BPPV.
Methods: Patients with a history of positional vertigo and torsional nystagmus typical of PC-BPPV on Dix-Hallpike-testing were randomly assigned to self-treatment with a modified Semont maneuver (MSM; n=33) and the MEP (n=37). Patients performed the maneuver three times daily for one week according to an illustrated instruction that was explained to them at their first visit. Positional vertigo during self-treatment and treatment-related side effects were documented in a diary. Outcome measures after one week included absence of positional vertigo and absence of nystagmus on positional testing. Correct performance of the maneuver was evaluated by asking the patients to demonstrate self-treatment on their return visit.
Results: Self-treatment with the MEP was more effective in resolving PC-BPPV compared to the MSM: after one week, 35 of 37 patients (97%) who applied the MEP were free of positional vertigo and had no nystagmus on positional testing versus 19 of 33 patients (58%) in the MSM-group ($p<0.001$). The two maneuvers did not differ significantly with respect to treatment related side effects or correct performance of the maneuver. However, inaccurate performance had a negative effect on treatment outcome in the MSM-group.
Conclusion: Self-treatment is effective in resolving PC-BPPV within one week and should be considered as a supplementary therapy in patients who do not respond immediately to single physician-guided maneuvers or in patients with frequent recurrences. Since inaccurate performance of the maneuver decreases its efficacy, a thorough instruction is essential.

P130
Positional and Positioning Nystagmus in Healthy Subjects Under the Videonystagmoscopy
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Background: Recently the eye-focused video camera with infrared LEDs is often used for detecting nystagmus with open eyes in the dark. The existence of physiological nystagmus has been reported.
Objectives: We investigated how frequently physiological positional and positioning nystagmus are seen in healthy individuals under infrared video goggles.
Methods: 70 healthy individuals (44 male, 26 female) were examined in this study. Positional and positioning nystagmus were observed with infrared video goggles. Maximal speed of the slow nystagmus phases (degree/s) was measured.
Results: Positional nystagmus was seen in 72%, positioning nystagmus was seen in 72%. Horizontal nystagmus was seen in 47.6%, vertical nystagmus was seen in 4.8%, mixed nystagmus was seen in 47.6%. The maximal speed of the slow nystagmus was ranged from 0.83 degree /sec to 8.83 degree / sec. The average was 2.69 degree / sec. The frequency of nystagmus was 8.94 /15 sec.
Conclusion: Positional and positioning nystagmus frequently exists in healthy subjects. This finding means that the existence of physiological nystagmus must be considered when diagnosing dizzy patients using this equipment.
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Functional Model of Benign Paroxysmal Positional Vertigo Using an Isolated Frog Utricle

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Background: Vertigo of BPPV is well controlled by various physical therapies. However, most patients experience temporary worsening of dizziness right after the physical therapy.

Objectives: To examine the mass effect of otoconia on the utricle in BPPV patients after physical therapy.

Methods: Fifteen bull frogs (Rana catesbeiana) were used. The utricle was isolated together with the superior vestibular nerve in frog Ringer's solution. The superior vestibular nerve was sucked into a glass suction electrode to record compound action potentials (CAP) of the utricular nerve. The anterior and lateral semicircular canal ampullary nerves were cut. The whole specimen was rotated sinusoidally with frequency, 0.1Hz. In the first experiment (Experiment Ⅰ), CAP was recorded without otoconia loading. This served as a control. Next, the otoconia were washed out gently from the utricular macula and the CAP was recorded. In the second experiment (Experiment Ⅱ), a mass of the saccular otoconia was placed on the utricular macula, and then the CAP was recorded. This is a model of BPPV after the physical therapy.

Results: Experiment Ⅰ. The CAP changed both excitatory and inhibitory fashion in response to sinusoidal stimuli. The maximum spike counts increased about two times of the spontaneous discharge. CAP was markedly decreased after wash-out, indicating that the otoconia play a major role to effectively stimulate the hair cells. Experiment Ⅱ. Immediately after the saccular otoconia were placed on the utricular macula, the spike counts increased. The maximum spike counts in response to sinusoidal rotation also increased than that of Experiment Ⅰ.

Conclusion: Excitatory and inhibitory changes of the utricular CAP responding to the sinusoidal rotation were recorded. After the saccular otoconia were placed on the utricular macula, the maximum spike counts responding to sinusoidal rotation increased. This indicates that the mass effect on the utricular macula might be one reason that BPPV patients become dizzy after the physical therapy.

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Relationship Between Familial Osteoporosis and Recurrent BPPV: Two Case Reports

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Background: Benign paroxysmal positional vertigo, so-called "canalolithiasis" and "cupulothiasis", usually occurs after head trauma or viral vestibular neuritis. In many cases, the etiology remains obscure. We recently published a study showing a relationship between canalolithiasis and osteopenia/osteoporosis in women over the fifth decade.

Objectives: We report the cases of 2 young women who complained of recurrent canalolithiasis and who had a history of familial osteoporosis.

Methods: Case Nr.1: a 33-years-old woman had been suffered for 15 months from recurrent canalolithiasis on the left side. The Hallpike-Dix maneuver and electronystagmography showed transient rotatory nystagmus by head hanging-left. Despite repeated Semont and Toupet, Brandt and Daroff and Epley maneuvers, the symptomatology remained unchanged. Case Nr.2: a 43-years-old woman had been suffered for more than 10 years from recurrent canalolithiasis initially on the right side and, some years later, on the left side. Symptoms of erroneous movements and transient vertigo on head movement remained despite of semicircular canal occlusion performed first on the right side and then on the left side. The repeated Hallpike-Dix maneuvers showed alternatively transient down vertical nystagmus on the right side and transient geotropic nystagmus on left Hallpike-Dix maneuver. Under transcutaneous estrogen therapy, the positional vertigo decreased in intensity and frequency.

Results: The hearing examinations (pure-tone audiogram, auditory evoked potentials) and the cerebral-MRI were normal in both patients.

Because of the well-known osteoporosis in their fathers, a bone mineral density measurement was performed using the dual x-ray absorptiometry of spine and hip (T-score). The results of the T-score values were clearly lower compared to those of women of same age: T-score of hip neck was -1.5 SD in case #1, and –1.3 SD in case #2. These findings revealed osteopenia in both patients.

Conclusion: Familial osteoporosis might represent a predisposition to recurrent otolithic dysfunction in these patients. Disturbance of the calcium integration in the internal structure of otoliths and/or their interconnection to the gelatinous matrix might be possible pathophysiological mechanisms.

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Benign Paroxysmal Positional Vertigo in Germany: Prevalence and Health-Care Utilization

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Background: Benign paroxysmal positional vertigo (BPPV) is nowadays the most successfully treatable cause

of vertigo. In specialized dizziness clinics, BPPV is the most common vestibular disorder accounting for about 20% of referrals; however, its prevalence in the general population is not known.
Objectives: The aim of the study was to determine the prevalence of BPPV in the general adult population.
Methods: A nationwide computer-assisted telephone interview (CATI) survey was conducted with a representative sample of 4869 men and women aged 18 years and older residing in Germany. The CATI identified 1403 subjects with a history of moderate or severe dizziness or vertigo, 1157 of whom were willing to participate in a detailed dizziness interview conducted via telephone by medical students thoroughly trained in a dizziness clinic. Each interview was discussed with a specialized neurotologist. Diagnostic criteria for BPPV were: at least five attacks of vestibular vertigo lasting less than 1 minute provoked by changes of head position such as lying down and turning over in bed. In a concurrent validation study, 61 patients were interviewed by telephone and independently examined by a neurologist specialized in neuro-otology. BPPV was detected by telephone interview with a specificity of 92% and a sensitivity of 88%.
Results: From the original sample (n=1157) 1003 interviews were completed (response rate 87%, n=154 could not be reached or refused to participate). Vestibular vertigo was reported by 243 participants (178 women and 65 men), of whom 80 fulfilled the criteria for BPPV (24 men and 56 women). The mean age at onset of BPPV was 49.4 (SD13.9) years. BPPV attacks within the last 12 months were reported by 53 participants (66%). The proportion of BPPV in the dizziness group varied with age: 2.3% (men 2.0%; women 2.4%) in the age group 18-39 years, 10.6% (7.8%; 12.0%) in the age group 40-59 years and 14.9 % (14.6%; 15.0%) in the age group >60 years. The estimated lifetime prevalence of BPPV in the general population in the three age groups was 0.5%, 1.6% and 3.6% in men and 1.0%, 3.8% and 5.7% in women. Most patients (78%) had sought medical advice for positional vertigo but paraphrased diagnoses could be interpreted only in 21% of them as BPPV.
Conclusion: BPPV is a common cause for vertigo in the general population. The prevalence of BPPV increases with age and has a female preponderance. Misdiagnosis of BPPV seems to be frequent in Germany, in spite of high health care utilization.

P134
Benign Paroxysmal Positional Vertigo Predominantly Affects the Right Labyrinth

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Background: Benign paroxysmal positional vertigo (BPPV) is caused by freely moving particles that have entered a semicircular canal and cause short attacks of vertigo whenever the head is turned in the plane of the affected canal.
Objectives: The aim of the study was to clarify whether BPPV manifests equally in both labyrinths or whether there is a preponderance for one side.
Methods: PubMed literature search of BPPV case series which specify the affected side and retrospective chart review of 80 consecutive patients with BPPV of the posterior canal who presented to our dizziness clinic.
Results: Eighteen previous studies with 3426 patients were identified. The right ear was affected in 1999 patients and the left in 1427 patients, thus the right ear was involved 1.40 times more often than the left. In our own series the right side was affected in 54 of 80 patients (ratio right/left 2.08). Altogether, in 3506 patients the right labyrinth was involved 1.41 times more often than the left (95% CI 1.37-1.45).
Conclusion: We speculate that the predominant involvement of the right ear in BPPV can be explained with the habit of most patients to sleep on the right side.

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Effectiveness of Treatments for Benign Paroxysmal Positional Vertigo of the Posterior Semicircular Canal

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Background: Benign paroxysmal positional vertigo (BPPV) is the most common vestibular disorder. Non-medical, non-surgical treatments for this disorder have become popular recently. Despite approximately 25 years of reports describing active repositioning exercises, passive repositioning maneuvers and habituation exercises no single study has previously compared the most commonly used standard treatments to a sham maneuver.
Objectives: In this study we compared a modified version of Epley's canalith repositioning maneuver, Semont's liberatory maneuver, Brandt & Daroff's repositioning exercise, and our version of vertigo habituation exercises to a sham repositioning maneuver.
Methods: Adults with unilateral BPPV were subjects, randomized to the five groups. Subjects were either treated with a repositioning maneuver in the laboratory or instructed in exercises and given written instructions to do the exercises at home for one week. They were pre- and post-tested on vertigo intensity and frequency, computerized dynamic posturography, Dix-Hallpike responses and independence in activities of daily living. Post-tests were given 1 week after treatment and approximately 3 months and 6 months later. Data analyses used multilevel analyses.
Results: Semont and Epley maneuvers were the most effective, significantly better than the sham maneuver on most measures. Exercise groups were intermediate between repositioning maneuvers and the sham maneuver and not significantly different than any treatments.

Conclusion: These data suggest that the passive repositioning maneuvers are the most effective treatments, but repositioning exercises are also useful.
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Effects of Epley and Lempert Maneuvers on Positional Vertigo in Patients with Benign Paroxysmal Positional Vertigo

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Background: Benign paroxysmal positional vertigo (BPPV) is caused by canalolithiasis or cupulolithiasis and commonly affects the posterior semicircular canal (P-BPPV) and the horizontal semicircular canal (H-BPPV). The canalith repositioning maneuver is recommended therapy for the BPPV based on canalolithiasis. Nowadays Epley maneuver for the treatment of patients with P-BPPV and Lempert maneuver for the treatment of patients with H-BPPV have become popular. The efficacy of Epley maneuver is evident based on previously reported randomized control studies or systemic review. However, there is no randomized control study for the efficacy of Lempert maneuver.
Objectives: We assessed the efficacy of Epley maneuver on positional vertigo in patients with P-BPPV and Lempert maneuver on positional vertigo in patients with H-BPPV. Time courses in remission of positional vertigo after the maneuvers were then compared with those without maneuvers in patients with P-BPPV and H-BPPV.
Methods: This retrospective study includes 177 patients with BPPV (120 diagnosed P-BPPV and 57 as H-BPPV). In Tokushima University Hospital, patients diagnosed as P-BPPV were treated by Epley maneuver and those with H-BPPV were treated by Lempert maneuver. In Kansai-Rosai Hospital, patients diagnosed as BPPV were untreated. BPPV was diagnosed by the same criteria in both hospitals. All patients were asked to return to the hospital every two weeks after the initial visit. At every visit, they were interviewed and Dix-Hallpike maneuver on each patient with P-BPPV and lateral head rotation on spine position on each patient with H-BPPV were performed. After confirming the absence of positional nystagmus, the patients were asked when the positional vertigo had completely disappeared. The primary outcomes were self-reported onset and resolution of positional vertigo and time courses in remission of positional vertigo were calculated.
Results: After Epley maneuver, the remission of the positional vertigo in patients with P-BPPV was significantly faster than that in untreated patients with P-BPPV. On the contrary, after Lempert maneuver, the positional vertigo in patients with H-BPPV disappeared with the same time course as that in untreated patients with H-BPPV. Among the untreated patients, the positional vertigo in patients with H-BPPV was resolved significantly faster than that in patients with P-BPPV.
Conclusion: Epley maneuver was effective for the treatment of patients with P-BPPV, while the effects of Lempert maneuver for the treatment of patients with H-BPPV was limited. The natural courses in positional vertigo in untreated patients with H-BPPV showed significantly faster resolution, in comparison with that in patients with P-BPPV. This would suggest that Lempert maneuver had limited effect because a large spontaneous resolution rate overshadowed a genuine benefit of its treatment.

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Benign Paroxysmal Positioning Vertigo Affects Both the Horizontal and Posterior Semicircular Canals Simultaneously: Combinations of P-BPPV and H-BPPV

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Background: Benign paroxysmal positioning vertigo (BPPV) is caused by canalolithiasis or cupulolithiasis and commonly affects the posterior semicircular canal (PSCC) (posterior canal variant, P-BPPV) and the horizontal semicircular canal (HSCC) (horizontal canal variant, H-BPPV).
Objectives: Of patients with BPPV, we found eight patients with BPPV that was speculated to be affected both the HSCC and PSCC simultaneously (PH-BPPV). The purpose of this study is to show the three-dimensional eye movement of benign paroxysmal positioning nystagmus of PH-BPPV, and to show the ration of such cases to other type of BPPV.
Methods: From April 2001 to November 2003, we diagnosed 70 patients' BPPV as P-BPPV, 57 patients' BPPV as H-BPPV, and 8 patients' BPPV as PH-BPPV at Department of Otolaryngology of Kansai-Rosai Hospital.
Results: These cases showed typical mixed torsional and vertical nystagmus induce by Dix-Hallpike maneuver, followed by horizontal nystagmus. After they were returned from head hanging position to upright position, they showed reversal of typical mixed torsional and vertical nystagmus. They also showed a direction-changing geotropic or apogeotropic horizontal positional nystagmus triggered by lateral head rotation on spine position. By means of the three-dimensional analysis of positional nystagmus in these cases, when PSCC was stimulated by Dix-Hallpike maneuver, the rotation axis of positional nystagmus was perpendicular to the plane of PSCC. When HSCC was stimulated by lateral head rotation on spine position, the rotation axis of positional nystagmus was perpendicular to the plane of HSCC.

Conclusion: Their BPPV was combination of P-BPPV and H-BPPV. The ratio of patients with PH-BPPV to all patients with BPPV were about 6%.

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Model Experiment of Semicircular Canal Function of BPPV

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Background: It is reported that some of BPPV patients have reduced response to caloric test. In other words, the responsiveness of the semicircular canal may be decreased in BPPV patients.
Objectives: We performed an experiment using the isolated frog posterior semicircular canal (PSC) to examine if the semicircular canal response reduces in canalolithiasis and cupulolithiasis models.
Methods: The isolated PSC dipped in Ringer's solution was mounted on the turntable. The ampullary nerve was sucked into a glass suction electrode to record compound action potentials. The turntable was sinusoidally rotated and the action potentials were recorded. Next, the saccular otoconia were introduced into the canal lumen to mimic a condition of canalolithiasis. The otoconia were placed on the cupular surface to mimic the condition of cupulolithiasis. The same sinusoidal stimuli were given to these models. Experiments A and B were classified according to the amount of otoconia, large and small. The large otoconia (Experiment A) means the otoconial mass with the span longer than a half of the cupular height. The small otoconia (Experiment B) means the otoconial mass with the span shorter than a half of the cupular height.
Results: Experiment A: The spikes of the action potential reduced in both canalolithiasis and cupulolithiasis models. Cupulolithiasis showed more reduction than canalolithiasis. Experiment B: The spikes did not reduce either in canalolithiasis or cupulolithiasis. It is suggested that the larger piece of otoconia inhibits the endolymphatic move in canalolithiasis and inhibits the cupular shift in cupulolithiasis. The direct inhibition to the cupular shift is stronger than inhibition to the endolymphatic move. This is possibly the mechanism of reduced caloric response and VOR gain.
Conclusion: These experiments confirmed that some of the semicircular canal responses are reduced in canalolithiasis and cupulolithiasis.

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Horizontal Canal BPPV: A Function of Semicircular Canal and Prognosis

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Background: We reported a horizontal canal BPPV (HC-BPPV) on targeting its pathophysiology, an affected side and prognosis added with literature investigation.
Objectives: We focused on nineteen patients of HC-BPPV visiting our vertigo outpatient clinic on Nara medical university hospital and a related hospital in two years and six months until June 2003 from January 2000.
Methods: Neurotological examination was assessed in the subjects. We made pure tone audiometry, equilibrium testing, imaging test and circulation dynamics testing.
Results: The patients of HC-BPPV were classified to 9 patients of canalolithiasis and 10 patients of cupulolithiasis after a neurotological examination. CP positive rates showed 58% in all patients, 67% in canalolithiasis patients, and 50% in cupulolithiasis patients. A consistent rate showed 88% between an affected side and a CP positive side. Our series showed lower prognosis in CP positive patients than in CP negative patients.
Conclusion: To determine an affected side is a considerable matter in HC-BPPV, we have decided the affected side by using the law of Weald in canalolithiasis patients and by detecting a neutral position diminishing nystagmus in cupulolithiasis patients. CP positive rates in caloric testing indicated insignificant dysfunction of the horizontal semicircular canal in canalolithiasis patients compared with that in cupulolithiasis patients. A mechanism of caloric nystagmus was thought to be a convection of endolymphatic fluid, a convection phenomenon that was interrupted consequently by a otolith in the semicircular canal in canalolithiasis patients. In contrast, CP positive results were obtained in cupulolithiasis patients regarding as being innocent to a convection mechanism of endolymphatic fluid. The results indicated a cause of different prognosis between CP positive patients and CP negative ones required other focused patients and their further examination.

P140

Clinical Characteristics of Benign Positional Vertigo in Korea: A Nationwide Multicenter Study

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Background: Benign positional vertigo (BPV) is characterized by episodic vertigo and nystagmus provoked by head motion. However, nationwide study of BPV has not been conducted in Korea.
Objectives: To report the clinical characteristics of BPV in Korea

Methods: We analyzed the clinical features of 1,474 patients who had been diagnosed as having BPV in seven dizziness clinics in Korea from 1999 to 2003. The diagnosis of BPV was based on the typical nystagmus concurrent with vertigo elicited by positioning maneuvers. According to the semicircular canal involved, we classified BPV into posterior, horizontal, and anterior canal types. The horizontal BPV was subdivided into geotropic or apogeotropic type according to the nystagmus elicited by head turning while lying down.
Results: The patients included 1,002 women and 472 men. Mean age of the patients was 55.2 with no difference between women and men. Posterior (61.5%) and horizontal (32.0%) semicircular canals were most commonly involved. The horizontal BPV included 61.5% of geotropic and 31.5% of apogeotropic types. Most patients were idiopathic and were successfully treated with canalith repositioning procedure (89.9%).
Conclusion: BPV may involve each of the three semicircular canals. The horizontal canal is more commonly involved than previously known. High success rate of canalith repositioning procedure is expected only when appropriate method of repositioning maneuver is applied to each patient according to the canal involved.

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Monitoring the Progression and Remission in Multiple Sclerosis

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Background: Multiple sclerosis is characterized by the presence of multiple plaques within the central nervous system, manifesting as remission and exacerbation of neurological dysfunction over variable time courses.
Objectives: The aim of this study was to evaluate whether fluctuation of the auditory brainstem response (ABR) and vestibular evoked myogenic potential (VEMP) results correlate with remission and exacerbation of the neurological dysfunction over variable time courses.
Methods: Recently, we have encountered a patient with multiple sclerosis, audiometry, ABR, caloric test, VEMP test, and MRI scan were conducted for monitoring the progression and remission of this disease.
Results: Prior to treatment, ABR revealed bilateral prolongation. Caloric test showed canal paresis on the right ear, and normal response on the left. VEMP test displayed absent response on the right ear, and delayed response on the left. MRI scan demonstrated multiple diffuse high signal lesions at hemispheres, brainstem, and cerebellum. Six months post-treatment, demyelinating plaques resolved spontaneously on MRI scan. Recovery of caloric responses was anticipated. Prolongation of ABRs remained bilaterally, whereas VEMP test disclosed normal response on the right ear, and delayed response on the left ear.
Conclusion: In addition to MRI scan, caloric test, ABR and VEMP tests can be used to monitor the progression and remission of audiovestibular function.

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The Potential Values of Diffusion Tensor Imaging and Functional MRI in Evaluating Profound Sensorineural Hearing Loss

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Background: Diagnostic imaging techniques such as MRI and CT are helpful in providing an adequate morphologic pictures of profound hearing loss. However, functional changes of central auditory system, which might be important in sensorineural hearing loss, cannot be evaluated by these imaging techniques.
Objectives: In this study, we evaluate the potential value of new imaging techniques, which provide CNS functions in detail.
Methods: Profound hearing loss patients (4 males, 5 females; age: 2-9 years; mean age: 4.5 years) were examined by DTI and fMRI. A single-shot spin echo echo-planar imaging (EPI) and gradient-echo EPI sequences were used for DTI and fMRI measurements respectively. For DTI acquisition, diffusion gradients were applied in 25 directions to provide higher SNR and accuracy. Auditory fMRI acquisition was performed using block paradigm of 500/2000 Hz pure tone stimulation. The raw images from DTI and fMRI measurement were then transferred to independent workstation and post-processed. Five normal hearing subjects (2 females, 3 males; 3-26 years of age; mean age 17.8 years) were also included in this study. All subjects gave written informed consent prior to the study.
Results: The fractional anisotropy (FA) images, which obtained from post-processing of DTI data, shows the deficit on auditory tract fiber integrity in many of sensorineural hearing loss patients. The locations of neural deficit were cochlea nucleus, olive nucleus, inferior colliculus, and trapezoid body. The fractional anisotropy indices at various levels of central auditory pathway were compared between normal and profound SNHL group. The mean value of fractional anisotropy was lower in SNHL group. Especially the inferior colliculus showed statistically significant reduction in SNHL patients. Cortical activation study using fMRI showed the difference in response to auditory stimulation between normal group and profound sensorineural hearing loss patients. For normal hearing group, the primary auditory cortex, which is contralateral to normal ear, shows strong activation and the activation of secondary auditory cortex was seldom observed. However, in case of profound sensorineural hearing loss patients, the broad activation of secondary auditory cortex, rather than primary cortex, was observed

Conclusion: Our results seem to suggest that the neural deficits, which found on most of sensorineural hearing loss patients, make reorganization in auditory pathway and resulted in the broad activation of secondary auditory cortex, which is adjacent to primary cortex. In conclusion, our results suggest that DTI and fMRI provide very useful functional information of auditory pathway and auditory cortex, which will make significant contribution on the evaluation of profound hearing loss patient.

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CT and MR Microscopy of the Inner Ear

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Background: Anatomic definition of the bony and membranous labyrinth in the clinical setting remains limited despite significant technological advances in CT and MR imaging. Recent developments in ultra-high resolution imaging for use in the research laboratory on small animals and pathologic specimens have given rise to the field of imaging microscopy.
Objectives: We aim to demonstrate these new imaging techniques to display the inner ear labyrinthine structures.
Methods: We have taken advantage of these techniques to image human temporal bone cadaveric specimens using MicroCT and 9 Tesla MicroMR in order to delineate labyrinthine structures, previously only seen using standard light microscopy.
Results: We juxtapose high-resolution MicroCT images of the bony labyrinth with 9 Tesla MicroMR images of the membranous labyrinth to highlight the utility of these techniques. The temporal bone specimen was immersed in dilute gadolinium solution to avoid susceptibility artifact from air contamination during MR scan acquisition. Volume data acquisition resulted in 20um voxel size for MicroCT and 78 um voxel size for T2-weighted microMR imaging at 9T. Segmentation of the 9T dataset allowed separation of the endolymphatic vesicles and ducts from the perilymphatic space. These structures were then reconstructed into 3 dimensional images. 3D reconstruction of the microCT dataset permitted endoluminal projections of the bony labyrinth.
Conclusion: By utilizing recent advances in imaging technology, we have resolved finer detail views of temporal bone structures than ever possible before in undissected specimens. This approach to the study of the inner ear avoids tissue destruction inherent in histopathologic preparations. We highlight the utility of CT and MR microscopy in teaching neurotologists, neuroradiologists, and audiologists normal anatomy of the inner ear and further the understanding of its complex anatomy in an effort to aid practicing physicians in the clinical setting.

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MR Imaging of Vestibular Nerves Explains Residual Symptoms After Vestibular Neurectomy in Meniere's Disease

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Background: Some patients who have undergone vestibular neurectomy (VNx) as treatment for unilateral Meniere's disease, still report recurrent vertigo attacks. Our recent study showed these patients have residual semicircular canal (SCC) function on the operated side (Lehnen et al. 2004).
Objectives: To determine whether Magnetic Resonance (MR) imaging of the vestibulocochlear nerve shows partially preserved nerve fibres after vestibular neurectomy in Meniere's patients with residual vestibular function.
Methods: The vestibulocochlear (VIII) and facial (VII) nerves in the internal auditory canal were imaged with axial 3D Fiesta sequences using a 1.5T MR Imaging Unit, (0.8mm contiguous slices, GE Medical Systems) in 6 still symptomatic Meniere's patients who had undergone VNx with preservation of hearing. The MR images were reconstructed orthogonal to the axis of the vestibulocochlear nerves within the internal auditory canal. Images of the vestibulocochlear nerves on the operated side were compared to those on the intact side. We also assessed their individual SCC function (Lehnen et al. 2004) with the head impulse test in 3D (Aw et al. 2001), and saccular function was measured with vestibular evoked myogenic potentials (VEMP) (Colebatch et al. 1995).
Results: MR images from a typical patient who had undergone right vestibular neurectomy showed a small section of superior vestibular nerve preserved, and the inferior vestibular nerve appeared partially preserved in the superior portion. The cochlear and facial nerves were intact. Her head impulse tests were compared to patients who had no SCC responses following complete VNx (Lehnen et al. 2004). They revealed absent lateral canal function (0.20 ± 0.02, mean gain ± SE), slightly preserved anterior canal function (0.29 ± 0.04), moderately preserved posterior canal function (0.59 ± 0.05). VEMPs were absent on the operated side. This preservation pattern is consistent with the known innervation of the labyrinth.
Conclusion: MR imaging of the vestibulocochlear nerve can show whether uncut nerve fibres could be responsible for continuing symptoms of Meniere's disease, where 3D head impulse testing is not available.
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P145

3D Anatomical Orientations of the Human Semicircular Canals from CT Image Reconstruction: Functional Implications

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Background: Treatment of vestibular disorders such as benign paroxysmal positional vertigo (BPPV) is based on knowledge of the 3D geometry of the labyrinth. This knowledge when used in combination with positional nystagmus-based diagnostic strategy allows treatments such as particle repositioning maneuvers (Epley 1992) and semicircular canal (SCC) occlusions (Parnes and McClure 1991) to be reliably effective.
Objectives: To reconstruct the 3D anatomical orientation of the SCCs from CT images of the bony labyrinth and relate this to pathological eye movements observed e.g. in BPPV patients.
Methods: The temporal bone and the skull were imaged for 6 BPPV patients with a LightSpeed16 Spiral CT scanner using 0.625mm slices (GE Medical Systems). The bony labyrinths were reconstructed using PC-based 3D image processing software written in LabVIEW 7.0 (National Instruments). The software generates both surface and volume data, enabling the plane of best fit to be calculated for each SCC using least square optimization. These planes were related via vector analysis to the patient's actual 3D eye rotation axes determined from their positional nystagmus provoked by the Dix-Hallpike maneuver. The Reid stereotaxic planes were used as a basis for all measurements using published landmarks (Blanks et al. 1975).
Results: Even though the reconstructions indicated that the semicircular canals were often not entirely planar, we were able to directly compare the calculated SCC planes with the functional responses. This was found to significantly assist in the localization of the affected SCCs, particularly in the cases where multiple SCCs were involved. A typical set of planar equations for a left labyrinthine reconstruction is: Lateral SCC $0.259x + 0.004y - 0.966z = 0$. Anterior SCC $0.474x - 0.822y + 0.315z = 0$. Posterior SCC $0.744x + 0.665y + 0.062z = 0$.
Conclusion: We have shown that the bony labyrinth can be accurately reconstructed from standard CT imaging. We have also shown that the positional nystagmus eye rotation axes from BPPV patients are strong correlated to the reconstructed canal planes.
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An fMRI Study on Brain Activity During Imagined Stance and Locomotion in Healthy Subjects and Bilateral Vestibulopathy

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Background: Posture and gait are sensorimotor actions that involve peripheral, spinal, and supraspinal structures.
Objectives: To investigate brain activity during stance and locomotion, 13 healthy subjects and 7 patients with neurofibromatosis type II and complete vestibular loss due to chronic bilateral neurectomy for acoustic neurinoma were asked to stand, walk, run, and lie down; subsequently they were trained to imagine standing, walking, running, and lying (imagined lying as rest condition in fMRI).
Methods: Functional MRI was performed at 1.5 T. Subjects were instructed to imagine the four different conditions on acoustic (healthy subjects) or tactile (patients) stimuli. Data processing was done using SPM2 software. Results are reported at a threshold of $p<0.001$ for group analysis.
Results: In healthy subjects separate and distinct activation/deactivation patterns were found for the three imagined conditions: (1) standing imagery was associated with activation in the thalamus, basal ganglia, and cerebellar vermis; (2) walking imagery was associated with activation in the parahippocampal and fusiform gyri (areas involved in visuospatial navigation), occipital visual areas, and in the cerebellum; (3) running imagery caused a predominantly cerebellar activation in the vermis and adjacent hemispheres (six times larger than during imagination of walking or standing), but activations in the parahippocampal and fusiform gyri were smaller than during walking. Deactivations were found for walking and running, but not for standing imagery. They were located in the vestibular (posterior insula, superior temporal gyrus, supramarginal gyrus) and somatosensory (postcentral gyrus) cortex with right-hemispheric dominance. In patients, there was no activation in the cerebellum or in parahippocampal areas for walking and running. Deactivation in areas attributed to the vestibular (supramarginal gyrus) and somatosensory (postcentral gyrus) systems was smaller than that seen in healthy subjects.

Conclusion: These findings support the concept of a hierarchical organization of posture and locomotion. Automated locomotion, e.g., running, is based on spinal generators whose pace is driven by the cerebellar locomotor region. Deactivation in the vestibular and somatosensory cortex prevents adverse interactions with the optimized spinal pattern and sensory signals; this confirms earlier findings of a multisensory inhibition during unhindered locomotion. During slow walking, spatial navigation, mediated by the parahippocampal cortex, becomes more important. Recently, it has been shown that patients with complete vestibular loss have deficits in spatial learning and orientation due to the chronic lack of vestibular input. The lack of parahippocampal activation in patients might reflect these deficits.

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White Matter High Intensity Lesions in Elderly Patients with Dizziness

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Background: Deep white matter hyperintensity (DWMH) and periventricular hyperintensity (PVH) revealed by magnetic resonance imaging (MRI) are known as predictors of the risk of stroke in arteriolosclerosis patients. Recent study has shown that such structural abnormalities in cerebral white matter are more common in patients displaying dizziness than in those lacking this symptom.
Objectives: Our objective was to evaluate the relationships between clinical picture and the extent and intensity of white matter lesions in elderly patients with and without dizziness.
Methods: T2-weighted brain MRI scans were acquired in 162 patients 50 to over 80 years of age. None had obvious brain infarction or brain tumor. In order to examine age-related differences, subjects were divided in four groups (group 1: 23 patients aged 50 to <60 years, group 2: 70 patients aged 60 to <70 years, group 3: 55 patients aged 70 to <80 years and group 4: 12 patients aged 80 years and more. While 124 patients complained of disequilibrium, 38 patients were treated for other reasons. According to the history and vestibular function testing, 61 dizzy patients were considered to have peripheral vestibular dysfunction. Thirty-eight dizzy patients were considered to display dizziness of central origin. In 25 patients dizziness was caused by other reasons. The MRI lesions were scaled in all patients in the following way: DWMH were graded as no lesion or only a single one (Grade 0), multiple focal lesions (Grade 1), multiple confluent lesions (Grade 2), and large lesions (Grade 3). PVH were graded as no lesion (Grade 0), thin lesions (Grade 1), diffuse lesions (Grade 2), and irregular thick lesions (Grade 3). Postural abnormalities in dizzy patients were recorded by stabilography during vestibular testing.
Results: In group 2 and 3 patients, white matter lesions were severe in dizzy patients with central origin of vestibular dysfunction. We have observed that the number of patients showing lesions of Grades 2 and 3 was significantly larger in the group displaying dizziness than in the group of dizziness-free patients. Patients with postural abnormalities detected by stabilometry in standing position tended to have severe DWMH and/or PVH.
Conclusion: Severe DWMH and PVH tended to be more frequently observed in patients with dizziness. White matter lesion in MRI may therefore have a predictive value for the appearance of the dizziness symptom in elderly patients.

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Cortical Activation by Visual and Vestibular Stimulation: A PET Study

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Background: Although vestibular signals are primarily processed in the brainstem and in the cerebellum, recent investigations have revealed the importance of vestibular information processing in the cortex, where it is integrated with other sensory information.
Objectives: We compared cortical activation and deactivation patterns during caloric vestibular stimulation with those during small field visual stimulation in the same subject to investigate cortical networks for vestibular and visual information processing.
Methods: Regional cerebral blood flow (rCBF) during cold-air vestibular stimulation in the right ear and that during visual stimulation by horizontal rightward movement of stripes were compared with those during control conditions in 6 normal subjects by positron emission tomography (PET). Slow phase eye velocity during caloric vestibular stimulation was measured by computer aided infra-red eye camera system, and the velocity of stripe movement presented during visual stimulation was controlled so that the slow phase eye velocity become approximately the same during these two conditions.
Results: Caloric vestibular stimulation activated the left insula, left inferior parietal lobule, left middle temporal/middle occipital gyri, right precuneus, supplementary motor area and the cerebellar hemisphere, and deactivated the right insula. Horizontal visual stimulation activated the striate visual cortex, bilateral middle temporal/middle occipital gyri, precuneus, pre-central gyrus and the left hippocampus, and deactivated the right insular region, right temporal pole and the left cingulated gyrus. The locations of left middle temporal/middle occipital gyrus activation were close but not exactly the same for vestibular and visual stimulation.
Conclusion: The present results support previous observations that the parieto-insular cortex and inferior parietal

lobule are involved in processing of vestibular information. Deactivation of vestibular cortex during visual stimulation supports the concept of inhibitory visual-vestibular interaction in the cortex (Brandt and Dieterich, 1999). Significant activation of the precuneus and middle temporal/middle occipital gyrus during vestibular and visual stimulation further confirms their involvement in motion perception, while the difference in activation foci in middle temporal/occipital gyrus according to the stimulus mode suggests that the region may not be functionally uniform.

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Morphometry of the Labyrinths on T2 MRI (1.5T)

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Objectives: To obtain reproducible, intra and inter-individual measurements of the labyrinths angles using a reference plane: the neuro-medio-sagittal plane (NMSP). The different measurements would be: the 3 canals angles referred to the NMSP and the inter-canal angles coordinates.

Methods: 14 patients suffering from vestibular and/or postural disorders associated with basicranium asymmetry. Construction of the NMSP: using the software MRIcro (1.33 version), we get the (x,y,z) coordinates of the 3 required points situated on the neurosagittal midline and chosen in the third ventricle. Mathematically, we create a plane using the coordinates of the 3 points: A(x_a, y_a, z_a), B(x_b, y_b, z_b), C(x_c, y_c, z_c). We obtain the NMSP equation: ax + by + cz + d= 0 and the plane equations of the 6 canals. From these results, we calculate the angles of each canal plane to NMSP and the inter-canals angles.

Results: LAC: left anterior canal; LPC: left posterior canal; LLC: left lateral canal; RAC: right anterior canal; RPC: right posterior canal; RLC: right lateral canal. Angle α_g = NMSP-LAC; β_g = NMSP- LPC; γ_g = NMSP- LLC; α_d = NMSP – RAC; β_d = NMSP – RPC; γ_d = NMSP -RLC

Table:

	α_g	β_g	γ_g	α_d	β_d	γ_d
Mean	49.69	55.72	110.72	41.11	48.14	105.35
Std Dev	8.30	11.55	48.32	6.74	5.91	15.47
Theoretic Value	45	45	90	45	45	90

No patients presented 45° (theoretical value) angles between NMSP and vertical canals. No patients presented 90° (theoretical value) between NMSP and lateral canals, confirming the lack of gold standard in the human labyrinthine morphometry. We found angular values between NMSP and the lateral canals higher than 90°: in other words, they were both, found tilted out- and downward. The standard deviation was higher on the left side than on the right one for all the calculated angles confirming the implication of the basicranium asymmetry.

Conclusion: We found that the angular values of the anterior vertical canals were, on both sides, closer to the theoretical value than the posterior vertical canals values.

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In Vitro/In Video Demonstration of Neural Progenitor/Stem Cells in the Adult Human Spiral Ganglion

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Background: Neural progenitor/stem cells (NSCs) in adult CNS tissue are capable of neuronal, astrocytic, and oligodendroglial differentiation and retain properties of mature CNS neurons. We demonstrate that multipotent (neuronal-oligodendroglial) precursors with stem cell features can be isolated from the adult human spiral (SG) in Rosenthals canal.

Objectives: We tried to assess the presence of neural progenitor/stem cells (NSC) in the adult human auditory nerve by developing a technique to culture human spiral ganglion cells (hSGC) obtained during petro-clival meningioma surgery (19). This would allow for the first time fresh human auditory ganglion tissue to be cultured in vitro. The influence of neurotrophins and neurotrophic factors (brain derived neurotrophic factor, neurotrophin-3) and glial-cell derived neurotrophic factor (BDNF, NT-3 and GDNF) on cell survival and growth was assessed with and without preincubation with mitogens (EGF and bFGF) in hSGC and guinea pig (gp) SGC.

Methods: Materials and methods: The 1 and 3/4 coiled ganglion was excised during skull base surgery for petroclival meningioma after ethical consent from the ethical committee (1999 and 2003) and consent from the patient. Neurospheres were expanded with EGF and bFGF as mitogens and subcultured under time lapse video documentation. Expanded neurospheres were incorporated with bromdeoxyuridine (BrdU) and immunocytochemically stained for progenitor cell marker nestin. Cells were cultured either with glia cell line-derived neurotrophic factor (GDNF) or together with neurotrophins BDNF and NT-3 time-lapse video recordings were made.

Results: Cells cultured with glia cell-line-derived neurotrophic factor (GDNF) and neurotrophins (BDNF and NT-3) differentiated into elongated neurites up to 5844. GFAP-positive cells believed to represent Schwann cells also developed in cell culture. These human cells first strongly expressed cell marker nestin and then beta3-tubulin. Time lapse video recordings were made of proliferating neurospheres. Adhering cells developed into branching precursor cells that underwent symmetric cell division. Elongating neurites displayed elaborate branching, fasciculation and typical growth cones (GC) with filopodial processes on a terminal expansion or shaft. The GC seemed to control speed, direction, branching and outgrowth of the auditory neurite. GC displayed a remarkable locomotion paralleled with clockwise or counter-clockwise perikaryal rotation of

its axon like a minute hand optimizing GC "search-dog" activity. Retraction, elongation and rotation of axons altered neuron morphology entirely in 24h.
Conclusion: Time-lapse video recordings of sphere proliferation, clonal analysis and neurite development suggest that the human auditory nerve has the capability for self-renewal and replacement. Human auditory progenitor cells may provide a valuable resource for further improvement and strategies for repair and treatment of eighth cranial nerve damage including cochlear implantation

P151
Vestibular Function in Deaf Infants
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Background: There is a need to evaluate vestibular function also in small children and toddlers of 2 years and younger. This is especially true for children with suspected or known cochlear disorders. In deaf children with vestibular loss an Usher type 1 syndrome may be expected. As such children have a high risk of losing eyesight later with development of retinal manifestations of the disorders, a cochlear implantation must be even more strongly advocated and performed as an early age as possible. However, these children do not easily co-operate in investigations and usual recording techniques are not possible to apply. We have developed a set of techniques to determine vestibular loss that either depend on video frenzel and rotation tests and the impulse test.
Objectives: To assess vestibular function in deaf infants to detect bilateral or unilateral losses.
Methods: Method a) Rotating the child in the lap of the parents with video-frenzels to detect bilateral vestibular losses b) Head impulse tests in lateral plane and if possible the LARP and RALP planes to determine canal function losses. Up to now, 14 bilaterally deaf children between 12 and 89 months (mean age 31) were tested, 3 have been confirmed to have bilateral vestibular loss, one had CT and MR verified severe inner ear malformations and the other two are suspected to have an Usher 1 syndrome. Techniques will be demonstrated on computer-video.
Results: Both rotation tests and impulse tests yielded pathological responses in 2 of the 11 children. In children were eye contact are hard to establish, rotation testing provides a safety measure to avoid the risk of missing bilateral losses. The Usher diagnosis was later corroborated with electro-retinograms during anesthesia.
Conclusion: It is important to detect vestibular losses in as young a child as possible and especially in deaf children, not to miss the therapeutic window for a cochlear implant procedure. The techniques developed allow a possible in office assessment of children which is recommended to be applied in all instances were vestibular maladies are suspected or in sensorineural hearing losses in infants.
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P152
Signaling Capacity of Peripheral and Central Otolith Neurons in Coding Horizontal Head Movement in Postnatal Rats
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Background: Properties of peripheral and central otolith neurons in coding head orientations with respect to gravity have been extensively studied in adult animals. However, the postnatal development of spatial coding capacity in the otolith system has not been reported. To address this, the functional characteristics of these neurons in relation to the processing of gravity-related spatial information need to be elucidated.
Objectives: Our goal is to investigate the developmental profile of peripheral and central otolith neurons in coding horizontal head movement in rats.
Methods: The spatiotemporal properties of peripheral and central otolith neurons were examined in young (7 – 21 days) and adult Sprague-Dawley rats decerebrated under halothane anesthesia. All animals were subjected to constant velocity off-vertical axis rotations (OVAR), which sequentially activate all the utricular hair cells per 360º revolution. Extracellular recordings were performed in the superior Scarpa's ganglion or the lateral / descending vestibular nuclei.
Results: During OVAR, 80-90% of peripheral otolith neurons in each age group tested showed one-dimensional response sensitivity while the remaining displayed two-dimensional response sensitivity. In contrast, 60-70% of central otolith neurons in P7 rats exhibited two-dimensional response sensitivity while only 20% in adults showed such a pattern. In the beginning of second postnatal week, the best vectors of both peripheral and central otolith neurons pointed predominantly along the interaural direction. From P14 onwards, however, the best response vectors of peripheral and central otolith neurons pointed in all directions along the plane of rotation. This finding indicates that the neonate's ability to code horizontal head orientations with respect to gravity is more restricted than the older rats. For both peripheral and central otolith neurons, the response gain also increased as the rats matured. Peripheral neurons in each age group tested and central otolith neurons in adults showed a variety of response dynamics with velocity: progressive lag, stable lead and stable lag. Among cen-

tral otolith neurons in young rats, however, stable lead response was rarely observed.
Conclusion: Our results suggest that during the first few postnatal weeks, peripheral and central otolith neurons in rats gradually achieved the gravity-dependent spatial coding capacity of the adult. [Supported by HK RGC]

P153
Postnatal Development of Glutamate Receptors in Otolith Neurons of the Rat Dorsomedial Cell Column
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Background: The inferior olive is known to receive inputs from the vestibular nuclei and project onto discrete zones within the cerebellum, which in turn controls vestibular-related sensory motor coordination. Relatively little attention, however, has been directed to assess how gravity-related spatial information of the adult pattern emerges in inferior olivary neurons. Besides, whether or not glutamate is a mediator of otolith-related inferior olivary neurons remains unexplored.
Objectives: Our goal is to chart the time course by which 3-D spatial reference of gravity information is encoded in the dorsomedial cell column (DMCC), a subnucleus of the inferior olive, during postnatal development. We also aim to examine the expression profile of ionotropic glutamate receptor subunits in these developing neurons.
Methods: Combined immuno- and hybridization histochemistry experiments were performed in conscious Sprague-Dawley rats (P6 to adult) that were subjected to sinusoidal linear acceleration along the vertical or horizontal plane. These were selected to activate specific subset(s) of receptors on the utricular and saccular maculae respectively. Neuronal activation within the DMCC was denoted by the expression of Fos protein and *c-fos* mRNA. The co-expression of glutamate receptor subunits and Fos protein in DMCC were also studied.
Results: Otolithic origin was confirmed in control animals, viz. labyrinthectomized rats subjected to linear acceleration and normal rats that remained stationary. Only a few sporadically scattered Fos-immunoreactive (ir) brainstem neurons were observed in the controls. In P6-8 test rats, no Fos-labeled neurons were found in the DMCC. DMCC neurons with c-fos expression in response to vertical stimulation were observed from P9 onwards while those to horizontal interaural stimulation were observed from P11 onwards. The number of these functionally activated evident in the DMCC of all age groups with horizontal stimulation along the antero-posterior axis. This finding indicates that otolith-related DMCC neurons only process information about head movements in the coronal plane. These Fos-labeled neurons were also studied for co-localization with NMDA or AMPA receptor subunits. In each age group studied, about 95-98% of Fos-labeled neurons responsive to horizontal interaural stimulation or vertical stimulation co-expressed NMDA (NR1, NR2A, NR2B) or AMPA (GluR2/3) receptor subunits. While the granule density of both NR2A and NR2B mRNAs decreased from P6 onwards, that of NR1 mRNA increased with age, peaked at P11 and reached the adult level by P21.
Conclusion: These findings suggest that in the postnatal period studied, dynamic changes in expression of glutamate receptor subunits contribute to the maturation of otolith-related DMCC neurons in the coding of head movements in the coronal plane. [Supported by HK RGC]

P154
Characteristics of the Vestibulo-Ocular Reflex in Young Figure Skaters
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Background: Figure skating involves an intense stimulation of the vestibular system (high linear and angular accelerations that can reach 1000°/s). Following spins, skaters can balance well and they feel no dizziness or motion sickness at all. Examination of dancers and skaters suggest that they use perceptual strategy or sensorimotor learning. According to the literature, these strategy and learning lead to decreased postrotatory vestibulo-ocular response [1,2] with few contrary views (Collins [3] found a vigorous postrotatory nystagmus). The population practicing figure skating in competition is a young population (about10-18 years old) undergoing up to 18 weekly trainings. However, at this age the vestibular system is in maturation. So, the vestibular system of these children is facing to 2 phenomena: i) maturation and ii) strong and repetitive stimulations.
Objectives: The aim of this study was to evaluate the vestibulo-ocular function of young figure skaters.
Methods: Eye movements were recorded by video-oculography in darkness in 12 figure skaters (age 13.8 ± 2.5 years; min=11yrs; max=18yrs). In a first part of the experiment, the canal-ocular response was evaluated by submitting the subject to an earth vertical axis rotation (EVAR) with clockwise and counterclockwise velocity steps of 60°/s delivered in a random order. The second part was a sinusoidal rotation test in total darkness (± 60°/s, 0.02 Hz). Quantified EVAR response parameters were the gain and the time constant. Sinusoidal rotation response parameter was the gain.
Results: EVAR: The mean gain of the vestibulo-ocular reflex (VOR) was 0.49 ± 0.16, the mean time constant was 10.5 ± 2 s. There was no difference in VOR gain and time constant between per and post-rotatory responses. The VOR gain in children until 11 years old is near 1 [4] and slightly decreases with age. The values obtained in young figure skaters are under what is expected at this age range.
Sinusoidal rotation test: The mean VOR gain was 0.41 ± 0.14. This value of VOR gain is low for children of these ages and is below the VOR gain value obtained in adults:

VOR gain in young adults at this stimulation frequency is near 0.5 [5].

Conclusion: The young figures skaters present low vestibulo-ocular responses. These results are in accordance with an habituation of the vestibular system in response to strong and repetitive stimulations. As vestibular maturation is still in progress at this age, complex interaction between habituation and maturation might occur. A comparison with a sex and age matched control group is in progress.

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P155

2 Cases of Oculocutaneous Albinism with Congenital Nystagmus

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Background: Albinism is autosomal recessive heritable disease. Findings in Albinism are not only hypopigmentation of skin but also ophthalmologic problems such as nystagmus and decreased visual acuity etc.

Objectives: We, authors have experienced two cases of "oculocutaneous albinism" that show different types in nystagmus.

Methods: Case 1: A woman of 77 years old paid a visit to our clinic due to dizziness suddenly broken out from 4 days ago after having severe URI one week before visiting the clinic. Case 2: As 37 years old woman visited our clinic for operation for thyroid malignant tumor recently found, she didn't make a complaint about dizziness and she could rather keep the posture balance well in everyday life.

Results: In case 1 ENG, spontaneous nystagmus(SN) was pendular so it was hard to discriminate its direction as the general, however according to mechanical analysis, it was left sided nystagmus whose size was 22-27°deg/sec. The direction of nystagmus was not changed by external light stimulation. As well, when she stared towards left, the size of nystagmus got lessened and its frequency got increased and during gaze, constant strong nystagmus was observed. Saccadic test appeared as the same shape as microwave saccadic jerk, however, generally, it was atypical ocular motility. As for pursuit test, it appeared cogwheel catch-up saccade due to pendular nystagmus, however it chased objects correctly. Optokinetic nystagmus test(OKN) showed regular pendular nystagmus regardless of visual field stimulation direction and optokinetic after nystagmus(OKAN) was not observed. In case 2 ENG, horizontal SN of 8°deg/sec whose fast phase facing right side was observed. And when gazing left side, horizontal nystagmus of the same direction with that of dark field spontaneous nystagmus was increased as 17°deg/sec and its frequency was increased as over double and it lasted during gaze. Whereas, when gazing right side, its direction was reversed and its frequency was the same and its size turned to nystagmus of 10°deg/sec. In saccadic test, it showed distinct corrective saccadic nystagmus. In pursuit test, right sided nystagmus of unlike direction with spontaneous direction in dark field already found was observed in both right pursuit and left pursuit clearly.

And anther characteristic is that in low cycle ocular pursuit test, she chased objects correctly, however in rather high cycle pursuit test, it showed atypical ocular motility. In test, OKN, she showed the same result with that of normal individual, however in OKAN, peculiarly OKAN whose direction was reversed appeared for 15sec and it had unusual finding that it passed over the neutral point for 5sec and then turned to left nystagmus.

Conclusion: Recently, authors have examined the characteristics of albinism patients who appeared pendular nystagmus and jerky nystagmus respectively through ENG. Although neutral point or null point is not identified through physical examination, it can be assumed through ENG.

P157

Identification of a Novel Cochlin Isoform in the Perilymph: Insights to Cochlin Function and the Pathogenesis of DFNA9 (Hereditary Hearing Loss and Vestibular Disorder)

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Background: The COCH gene mutated in DFNA9, an autosomal dominant hereditary hearing loss and vertigo with Meniere's disease like symptom, encodes Cochlin[1,2]. Previously, we reported three bovine cochlin isoforms, p63s, p44s and p40s in vivo [3]. Structure analysis of Cochlin isoforms showed that the mutations influence only the full-length isoform of Cochlin (p63s), and not the processed Cochlin isoforms (p44s and p40s), which do not contain the LCCL domain [3]. What happens to the LCCL domain once it is cleaved from full-length Cochlin was an open issue.

Objectives: We further characterized the expression and structure of Cochlin isoforms.

Methods: We have generated isoform-specific antibodies that recognize three distinct domains. Human and bovine inner ear proteins, as well as perilymph proteins were analyzed by one and two dimensional gel electrophoresis and western blot analysis.

Results: We have detected human and bovine Cochlin isoforms in the inner ear tissue. And we have identified a novel shortened 16kDa Cochlin isoform in the perilymph that is not present in the inner ear tissue. We designated this isoform Cochlin-tomoprotein (CTP) [4].
Conclusion: Recently, two groups analyzed the Cochlin isoform in COCH gene transfected cell lines and culture media [5,6]. The isoform formation pattern in their study is very different form what we have found in vivo. Moreover, they did not detect the N-terminal fragment containing the LCCL domain (i.e. CTP) in either the cell extracts or in the culture media. This indicates that proper enzymatic cleavage and processing of Cochlin may only occur in the unique extracellular environment of the inner ear. Elucidating the whole picture of formation and processing of the Cochlin isoforms, including the novel Cochlin isoform CTP identified here, might provide mechanistic clues to how mutations in the COCH gene damage the inner ear function of DFNA9 patients.
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P158

Progressive Vestibular Deterioration Precedes Hearing Deterioration in the P51S Coch Mutation (DFNA9). An Analysis of 74 Mutation Carriers

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Background: DFNA9 is a progressive autosomal dominant vestibulocochlear disorder caused by mutations in the COCH gene. The P51S mutation is a founder mutation in the Netherlands and Belgium
Objectives: to analyze cochleovestibular impairment features in P51S COCH mutation carriers (N=22) in a new, large Dutch family and to compare the results to those obtained in previously identified similar mutation carriers (N=5). Finally, an in-depth analysis was performed to all collective data obtained from such mutation carriers, with special emphasis on comparing age-related features between progressive hearing and vestibular impairment.
Methods: pure tone thresholds, phoneme recognition scores and vestibular responses were obtained in 74 P51S COCH gene mutation carriers.
Results: pure tone thresholds, phoneme recognition scores and vestibular responses of the mutation carriers in the new family were essentially similar to those previously established in all other mutation carriers. Hearing started to deteriorate in all mutation carriers from 43 years of age onwards, whereas deterioration of vestibular function started from age 34. Vestibular impairment started earlier, progressed more rapidly and, eventually, was more complete than hearing impairment in P51S COCH mutation carriers.
Conclusion: vestibular function in P51S COCH mutation carriers deteriorates earlier and more severely compared to auditory function.

P159

Modeling of the Interaction between Two Subjects Maintaining a Constant Distance During Locomotion: A Mathematical Approach with Van der Pol Oscillators

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Background: At each time humans have to coordinate their movements and trajectories to others. Some inter-subjects movement coordination has already been studied by Schmidt (Schmidt et al., 1990): two sitting subjects had to coordinate their leg movement. Similar experiment was performed by Kelso and colleagues (Haken et al., 1985; Kelso et al., 1981), but the interaction consisted for a single subject in a rhythmical inter-manual task. This last experiment led to a mathematical model of the interaction as a nonlinear system of two coupled Van der Pol oscillators.
Methods: In our study we are interesting in the interaction between two subjects during locomotion. The task for the couples of subjects was to maintain a constant distance between them during displacements along a rectangular track (8m x 2m). They were placed face to face and separated from each other of 2 meters. One subject was the leader and the other the follower: he had to follow the

leader so as to minimize the variations of distance. The recording of the displacements was achieved using markers placed on the body of the subjects and with a Vicon system (Vicon 8 - Oxford Metrics Ltd.).

Results: We analyzed the oscillations in the displacements of the subjects along the longitudinal axis. In order to describe the coordinated behavior of the subjects (Ducourant et al., 2004), we therefore designed a model using a nonlinear system of two Van der Pol oscillators coupled in velocity. The preliminary results we have obtained from this model show a good prediction of the measured data.

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Gentamycin in the Middle Ear for Unilateral Vestibular Ablation in Guinea Pigs

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Background: Ménière disease in severe cases is difficult to be treated. The elimination of the affected ear is used nowadays to reduce the nausea, vomiting and vertigo. The application of gentamycin to the middle ear is at the moment one of the methods to produce vestibular ablation on the side that received the aminoglycoside ototoxic.

Objectives: The objective of this research is to determine the singular dosage that applied in the middle ear causes the most severe unilateral lesion of vestibular hair cells and the least severe lesion of cochlear hair cells.

Methods: Four groups of guinea pigs were used and received different dosages of gentamycin: 01, 05, 10, 25 mg to quantify the lesions of hair cells of the inner ear. The animals were sacrificed 14 days after the application of the drug. The inner ear structures were prepared for analyses by scanning electron microscopy.

Results: The studied structures showed lesions in the hair cells of all the ears that received the larger dosages of the drug. The lesions were dosage dependent (05, 10 and 25 mg). The only group that received 01 mg of gentamycin showed vestibular lesions without cochlear lesions.

Conclusion: There was a larger sensibility to the drug in the vestibular hair cells than cochlear hair cells. Only the animals that received the smallest dosage of gentamycin (01 mg) presented selective vestibular lesions without cochlear lesions.

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Vestibular Evoked Myogenic Potentials Throughout Meniere Attack

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Background: It is our premise that violent vertiginous attack in Meniere's disease is caused by rupture in the saccular membrane, because next to the cochlea, saccule is the second most part for the development of endolymphatic hydrops.

Objectives: The aim of this study was to apply vestibular evoked myogenic potential (VEMP) test to those with unilateral definite Meniere's disease throughout vertiginous attacks, in order to investigate the role of saccule in Meniere attack.

Methods: From January 2001 to December 2003, consecutive 12 patients with unilateral definite Meniere's disease having vertiginous attack were admitted to our ward. Each patient underwent videonystagmography (VNG) for recording spontaneous nystagmus and vestibular evoked myogenic potential (VEMP) test, using 95dB tone burst stimulation.

Results: At the very beginning of Meniere attack, spontaneous nystagmus beat toward the lesion side in 5 patients (42 %), and healthy side in 7 patients (58%). Twenty-four hours later, 6 patients had no spontaneous nystagmus, while the remaining 6 patients (50%) showed spontaneous nystagmus beating toward the healthy side. Nevertheless, all

patients had their spontaneous nystagmus subsided, 48 hours later. VEMP test was performed within 24 hours of Meniere attack, which revealed normal VEMPs in 4 ears, and abnormal VEMPs in 8 ears (67%), including absent VEMPs 6, delayed VEMPs 1, and depressed VEMPs 1. Of 8 patients with abnormal VEMPs, resolution and return to normal VEMPs were disclosed in 4 patients, while the other 4 patients remained absent VEMPs, 48 hours later.
Conclusion: Rupture of saccular membrane precipitates most Meniere attacks, manifested as abnormal VEMPs and contralateral paralytic nystagmus with a longer lasting period. After the attack is over, spontaneous nystagmus vanishes. Abnormal VEMPs may or may not recover to normal VEMPs depending on the individual saccular pathology.

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Structural and Ultrastructural Changes in Semicircular Canal Cristae After Intratympanic Gentamicin Treatment in the Chinchilla

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Background: Intratympanic gentamicin treatment is frequently used to treat intractable vertigo due to Ménière's disease. While commonly referred to as "chemical labyrinthectomy", intratympanic gentamicin does not silence the spontaneous firing of vestibular afferents (Hirvonen et. al., 2002).
Objectives: We hypothesized that at least some vestibular hair cells and their synaptic specializations must be preserved in order to provide the synaptic input necessary to maintain firing in the vestibular afferents.
Methods: Adult chinchillas received a single, unilateral intratympanic gentamicin injection (26.7 mg/ml, 30 min exposure); the contralateral ears served as controls. Animals were sacrificed and fixed 14-28 d later. Semicircular canal cristae were sectioned for light and electron microscopy.
Results: Cristae treated with intratympanic gentamicin had 44% reduction (p=0.007) in mean number of vestibular hair cell nuclei seen per transverse section compared to control cristae, including loss of all Type I hair cells. There was a 21% reduction (p=0.009) in the calculated height of the neuroepithelium. Remaining type II hair cells were contacted by bouton afferent endings. There was no significant change in the number of afferent boutons in contact with hair cells per section (p=0.5) or in the ratio of afferent boutons to type II hair cell nuclei per section (p=0.7). Bouton efferent endings were observed, with no significant quantitative change following intratympanic gentamicin. Ribbon synapses were also observed. The number of ribbons seen per section was reduced by 45% (p=0.007), but the ratio of ribbon synapses to hair cells did not change after intratympanic gentamicin treatment (p=1.0).
Conclusion: A single intratympanic gentamicin treatment does not create a complete labyrinthectomy. Rather, some hair cells and their synaptic specializations are preserved, which may provide the synaptic input to maintain spontaneous firing of vestibular nerve afferents. Preservation of spontaneous firing after intratympanic gentamicin may decrease the adaptive burden for the central vestibular nuclei in comparison to surgical labyrinthectomy. Supported by NIDCD R03 DC005700, K23 DC00196-01, R01 DC02390, T32 DC00027, grants from the Finnish Medical Foundation and Finnish Academy.
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Dolls' Eyes Response to Head Tilt in Meniere's Disease

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Background: The most notable histopathological feature of Meniere's disease (MD) is, by definition as the endolymphatic hydrops (EH). Despite initially the EH involves the whole inner ear system, there are few reports of otolith dysfunction due to the EH in MD patients.
Objectives: To detect the EH in the otolith organs, we investigated the otolithic nature based on dolls' eyes response to head tilt (dolls' eye) in MD patients.
Methods: Dolls' eye was investigated in 6 normal subjects, ranging in age from 22 to 44 year-old and 16 MD patients in age from 16 to 67 year-old, visiting our clinic.
The Dolls' eyes maneuver in head tilt (DM) was applied in all subjects. All subjects were instructed to sit on the couch in the upright position, to fixate examiner's nose, during the test. The head was smoothly tilted from the upright position to the right shoulder about 10-15 degrees firstly and after that, the head recovered to the upright, passively. To the opposite side tilt was done in the same way. All tests were performed in the light. Subjects were asked not to blink during the test as few as possible. Either right or left eye movements were monitored, by using a modified Frenzel glasses with an infrared camera, and each side of the glasses was able to open the eye cover to stare at the examiner's nose. Recorded eye movements (6 normal subjects and 6 out of 16 patients) were analyzed using custom made software running on the public domain NIH Image Program that is widely used in the world. And we asked how they feel whilst the DM.
Results: The smooth dolls' eye was observed in 6 normal subjects. Patients showed quite strange eye movements. They were mainly torsional nystagmus to the tilted side, similar to normal pattern but something different, sort of limitation eye movements, which the eye went to the opposite to the tilted side a bit and almost stood still, as such.

MD patients all declared that it was difficult to stare at examiner's nose despite the instruction, since they all felt strange eye movements and/or sick.

Conclusion: We could not realize which the vestibular organs actually play a main role of these strange eye movements in MD patients. It is reported that some of MD patients showed abnormal ocular torsion (AOT) in the upright position that can be contributed otolith dysfunction because of the EH. AOT may drive an incomplete response to the DM and produce strange eye movements. According to this, in cases of MD, the DM can be useful to detect strange eye movements non-invasively. Therefore, we emphasize that the DM may be able to detect the EH in MD patients.

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Vestibular Function at the End of Intratympanic Gentamicin

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Background: The protocol we have used here for the treatment of patients with Ménière's disease involves the clinical and bedside examination of three important signs of vestibular function: spontaneous nystagmus, the head-thrust test and post headshake nystagmus. While these are sometimes subtle findings, they are usually easy for the experienced clinician to recognize. In order to better understand this protocol of intratympanic gentamicin administration, we thought it necessary to determine the degree of change in vestibular function, in terms of gain and phase of the VOR, when the treatment was considered to have terminated.

Objectives: The aim of this study was to analyze the effects of intratympanic gentamicin injections on vestibular function in patients with unilateral Meniere's Disease (MD) that is refractory to medical treatment. In such patients, the results of Bedside examination of vestibular function were compared to those from laboratory tests

Methods: 33 Patients with unilateral Meniere's Disease (according to AAO-HNS guidelines 1995) that had been unresponsive to medical therapy for at least one year. Intratympanic gentamicin injections (27 mg/ml) were performed at weekly intervals until symptoms or signs of vestibular hypofunction developed in the treated ear. Vestibular function was evaluated in two different rotatory chair tests. The parameters that were specifically considered were the time constant of the vestibulo-ocular reflex (VOR) after impulse rotation with a peak chair velocity of 100ºs-1, and the phase, gain and symmetry of the VOR after the sinusoidal harmonic acceleration (SHA) test with a peak chair velocity of 50ºs-1.

Results: After treatment, both the time constant of the VOR after rotation towards the treated side and the gain in the SHA test were significantly reduced. These reductions were in accordance with the number of additional signs observed upon bedside examination at the end of the treatment.

Conclusion: The changes observed in the VOR correlate well with the results of bedside examination of vestibular function, which in turn reflects the damage induced by intratympanic gentamicin injection. The degree of change in VOR function at the end of the treatment indicate that the courses of weekly injections can be considered a subablative protocol.

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A Longitudinal Study of Quality of Life (QoL) in People with Meniere's Disease

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Background: This study aimed to determine what factors influence the adjustment of people diagnosed with Ménière's disease to life with their illness and what aspects of QoL change in this process. In addition, this study aimed to determine what effects the self-help group (SHG), to which the participants belonged, had on the adjustment process and to determine whether the process of comparing with other people within the SHG was influencing adjustment.

Objectives: To assess factors influencing adjustment to Ménière's disease over time, and to determine which aspects of QoL change and which factors predict this change in QoL.

Methods: The design was longitudinal. At baseline and 10 month follow-up 301 people with Ménière's disease who were members of a SHG completed questionnaires assessing 3 aspects of QoL (functional QoL, measured by the SF-36; goal-oriented QoL, measured by the GOQoL; the perception of positive change since the onset of Ménière's disease, measured by the Posttraumatic Growth Inventory). Baseline predictors comprised SHG comparisons (measured by the Identification/Contrast scale and SHG items), psychological factors (self-esteem, measured by Rosenberg's scale; perceived control, measured by the IPQ-R; optimism, measured by the LOT; demographic factors), and disease severity (tinnitus, fullness of the ear, hearing, and vertigo). Statistical analyses included partial correlations and hierarchical regression analysis.

Results: Results showed length of membership of the SHG ($p < .05$), perception of movement towards goals ($p < .05$), optimism ($p < .005$), perceived control (($p < .05$), self-esteem ($p < .00$), and social support ($p < .05$) positively predicted change in QoL over time. Comparisons within the SHG negatively influenced QoL over time ($p < .000$).

Aspects of QoL that showed a positive changeover time were the goal-oriented aspects($p < .000$).

Conclusion: These results showed the SHG to have an overall positive effect on QoL showing the SHG to assist in the adjustment of people with Ménière's disease to life with the illness; this was probably due to the support and information provided by the SHG. Those with social support, an optimistic attitude, a perception of control over their illness, and who experienced high self-esteem, and who perceived themselves as moving towards their goals at baseline showed better QoL at follow-up. Some comparisons, those with persons who were better-off and which were interpreted negatively, lead to worse QoL, showing that comparisons were influencing adjustment. Positive adjustment was evident by the change in the perception of moving towards goals, which was present by follow-up, this may be promoted by high self-esteem. The results of this study show the important role of the SHG, comparisons with others, the perception of goals, social support, perceived control, an optimistic attitude, and self-esteem in the positive adjustment to Ménière's disease.

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A Principal Components Analysis of a Meniere's Disease Data Set

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Background: Meniere's disease is characterized by repeated vertigo attacks, hearing loss and tinnitus. It is a diagnosis of exclusion and often difficult even for an experienced physician.

Objectives: We aimed to portray the clinical picture in Meniere's disease by conducting the principal components analysis (PCA) to 313 Meniere's disease cases.

Methods: PCA is a multivariate statistical method that forms new variables (principal components) that are linear combinations of the original variables. Preferably the original variables should have high correlations (loading) with a small number of principal components, and ideally few of the first principal components account for most of the information (variance) of the data. The loading can be used to interpret the new variables, because they indicate how influential the original variables are in forming the new variables. Variable sets A) all variables, B) specific questions, which ONE presents when a general question has been answered, C) general questions and specific vertigo related questions, and D) general questions, were used to study the data on different perspectives. An experienced otoneurologist examined the components and commented their medical relevance.

Results: Principal components with eigenvalues greater than one were retained, and only loadings 0.5 or above were considered. PCA with sets A, B, C and D produced 37, 33, 17 and 14 components, which accounted for 78%, 74%, 70% and 72% of variance, respectively. Many of the principal components were self-evident. However, focusing on the vertiginous symptoms produced a new component which suggests that subjects with Tumarkin type drop attacks and gait difficulties outside the vertigo were more susceptible for position or pressure change, visually and exercise induced vertigo.

Conclusion: The clinical picture of Meniere's disease could be reproduced in components created with PCA. New finding was the link between the gait difficulties outside the vertigo attacks and Tumarkin attacks with several provocative factors for the vertigo.

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Noise-Induced Hearing Loss and Meniere's Disease: A Medico-Legal Application for Electrocochleography (EcochG)

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Background: In NIHL a large threshold difference between ears is problematic if there is not an obvious acoustic trauma cause. MRI scanning now unequivocally excludes retrocochlear pathology. Where the greater loss is due to Meniere's disease the patient may or may not reveal a history of vertigo attacks. EcochG with clicks and tone bursts now has a high sensitivity for implying the presence of endolymphatic hydrops and a diagnosis of Meniere's disease without all the classic symptoms being present at one time.

Objectives: To ascertain the cause of the greater loss of hearing in one ear in 8 patients claiming compensation for NIHL. MRI of 8th nerves was normal. Questioned about the possibility of Meniere's disease 4 admitted having vertigo, and 4 denied a vertigo history.

Methods: Bilateral transtympanic EcochG was performed with 90dB clicks and 0.5, l, 2, 4 kHz tone bursts. The click SP/AP ratio and SP (microvolt) for tone bursts were measured and graded on the Gibson "normals" as an indicator of the presence or absence of endolymphatic hydrops.

Results: In 7 the EcochG was "normal" in the better hearing ear and in all 8 "abnormal" (hydrops) in the ear with the unexplained greater loss. Later enquires determined that 3 patients had concealed a history of vertigo attacks. The EcochG clarified the diagnosis, with a successful NIHL compensation claim in 4, and in 4 it invalidated the claim.

Conclusion: EcochG confirmed Meniere's disease in the worst hearing ear in 8 patients claiming for NIHL compensation. It provided a more precise diagnosis of both disorders and allowed a more objective judgment of their claim. In NIHL compensation cases some patients may conceal a history of vertigo attacks

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Retrospective Study on Long-Term Prognosis of Cases Mostly Conservatively Treated in Meniere's Disease

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Background: Guide lines for the diagnosis, definition, symptom such as recurrent vertigo attacks, fluctuated hearing impairment, tinnitus and fullness in the ear in Meniere's disease had been published by AAO-HNS in 1972 1985 and 1995. It was informed by the reported that clinical observation for 2 years should be needed to evaluate the efficacy of treatments. However, the patients suffering from vertiginous spells and increasing the grade of hearing impairment against recommended medical treatment were experienced for longer time course than several years. This study was designed to investigate retrospectively the long-term prognosis of vertigo and hearing impairment in Meniere's disease.

Objectives: The results of mostly conservative treatment against vertigo and hearing impairment were evaluated in 39 patients of typical cases on the basis of AAO-HNS'S 1995 Guideline for Meniere's disease.

Methods: Total number of vertigo attacks and the worst mean value of 4 frequency hearing levels were examined during 6 months after the four periods, which were the first visiting to our hospital, 2 years, 10 years and 20 years later.

Results: The mean values obtained from the worst mean of 4 frequencies hearing levels for 6 months since the first visiting day, 2 yrs, 10 yrs and 20 yrs later were 43 dB, 46 dB, 55 dB and 76 dB, respectively. Stage classification for 6 months since the first visiting showed the stage 1st (less than 25 dB), stage 2nd (26-40 dB), stage 3rd (41-70 dB) and stage 4th (more than 71 dB) were 24%, 16%, 50%, and 10 %, respectively. In the time course of 2 yrs the rate of the stage 1st decreased to 16%. The rate of the stage 4th increased from 10% to 27% 10 yrs later and to 67% 20 yrs later. The mean worst hearing levels showed 14% of improved hearing (improved more than 10 dB) and 35% of worsened hearing (worsened more than 10 dB) after 2 yrs later. The rate of improved hearing decreased to 9% and one of the worsened hearings increased to 50% 10 yrs later. Comparison of the rate of vertigo attacks for 6 months between since the first visiting day and 2 yrs later revealed 63% of class A (complete controlled) and 83% of class A plus B (improved). They also did 60% of class A and 80% of class A plus B 10 yrs later. Vertigo attack completely disappeared in all four cases 20 yrs later.

Conclusion: It was assumed to be important to prevent progressive irreversible hearing loss that adequate therapy for Meniere's disease within 2 years since the patient's first visiting day or within 4 years since the first attack of vertigo in this disease.

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Patients of Meniere's Disease Possess Singular Behavioral Characteristics

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Background: The cause of Meniere's disease is still unknown. Since Meniere's disease is one of typical psychosomatic diseases, its cause should lie in environmental or/and psychogenic stress of daily patient's life.

Objectives: To find the cause of Meniere's disease in patients' life, a questionnaire-based study was conducted in a patient group and control groups.

Methods: The questionnaire included items related to lifestyle (n=8), behavior (n=24), stress and stressors (n=22), means of relaxation (n=11), and physical symptoms (n=5). Subjects were patients of idiopathic endolymphatic hydrops (n=209) with vertigo (Meniere's disease) and without vertigo, workers in a company (n=3,410), and a local population (n=639). Answers of pair-, triple- or multiple-choice were statistically examined by X2 test between the patient group and control groups.

Results: The patients, compared to the control groups, had fewer holidays ($P < 0.0001$) and a stronger propensity ($P < 0.005$) to immerse themselves in whatever they do, to be a perfectionist, to worry before doing something, to swallow their disgust, to strive to meet superiors' expectations. They also had fewer opportunities to enjoy sports and pleasant chats, and were more nervous about personal relations. However, environmental stresses were fewer and weaker in the patient group than in control groups.

Conclusion: The present results suggest that the cause of Meniere's disease is lack of reward, i.e., insufficient gratitude from others against patient's efforts. A poor prognosis may result from behavioral patterns that are hard to change. Correction of unhealthy behaviors of daily life in the early stage of the disease may be the most important to prevent worsening of the disease.

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Caloric and Quantitative Head Thrust Test in Ménière's Disease

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Background: The quantitative head thrust test (HTT) provides objective measurement of semicircular canal function. Caloric tests have traditionally been used to characterize horizontal canal function in vestibular disorders, including Ménière's disease.
Objectives: The objective was to compare the findings on both caloric and HTT in subjects with unilateral Ménière's disease.
Methods: Subjects were candidates for gentamicin treatment due to vertigo attacks not controlled by medical therapy (N = 38; 25 males, 13 females; 30-70 years old, mean age = 52.9 years). Duration of symptoms was 1-30 years (median 5.3 years). We recorded angular vestibulo-ocular reflexes (aVOR) with search coils in a magnetic frame in response to passive HTT. A caloric response asymmetry > 20% was considered to be unilateral weakness. GA in passive HTT > 5.8% (the 99% confidence interval in normals) was considered significant.
Results: Twenty patients (52.6%) showed abnormal results in either test. A pathologic caloric UW was present in 16 patients (42.1%). In passive HTT, 12 patients (31.6%) showed pathologic GA. Eight patients (21.1%) showed abnormal results on both tests. A significant correlation was found between caloric unilateral weakness and GA in HTT ($r = 0.54$; $p < 0.05$). HTT gain asymmetries in subjects with unilateral Ménière's disease were smaller than those published for vestibular neuritis. Only two subjects with Ménière's disease had 100% caloric weakness, and none had > 30% asymmetry on HTT.
Conclusion: These findings suggest substantially preserved canal function in subjects having active vertigo attacks in Ménière's disease. The HTT may be less sensitive to canal dysfunction than traditional caloric testing in Ménière's disease. However, the two tests probe different frequencies of endolymph movement, and the disorder may differentially affect low frequency sensitivity of the canals. In addition, endolymph velocity in HTT may exceed that in caloric testing, so that the HTT overcomes the weakness in canal sensitivity to yield a relatively normal aVOR in many cases.

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Long-Term Results with Cryosurgery to the Fenestration of the Semicircular Canal for Ménière's Disease

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Methods: Twenty patients with Ménière's disease were treated with cryosurgery to fenestration of lateral semicircular canal through the modified Wolfson's method of surgical technique, and all the patients were followed up from 4 to 7 years. The long-term results were observed and analyzed.
Results: According to AAO-HNS (1985) criteria of results of treatment, class-A was found in 3 patients, class-B in 9,class-C and class-D in 4 respectively. No patients had class-E or F. The effective rate was 80.0%. No complications occurred in all the patients. We discussed and analyzed the mechanisms of the operation, the long-term results and short-term results.
Conclusion: It is concluded that this operation suits those patients with Ménière's disease who failed in systematic drug treatment and are with surgical indication. Cryosurgery has the advantages of good long-term results in both controlling vertigo and preserving hearing as well as safety.

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The Role of the Activation of JNK in Neomycin-Induced Vestibular Sensory Hair Cell Death

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Background: c-Jun N-terminal kinase (JNK) is a member of the mitogen-activated protein kinase family. In many kinds of cells, JNK is phosphorylated following exposure to stress. This activation of JNK results in apoptotic cell death. Inhibition of the JNK signaling pathway can prevent cochlear hair cell death [1,2]. However, little is known about the role of JNK in vestibular sensory cells.
Objectives: To investigate the role of JNK in vestibular hair cell death induced by aminoglycoside exposure.
Methods: Cultured utricles of CBA/CaJ mice were used. In this study, the reagent (CEP-11004) was used as the inhibitor of JNK signaling pathway. Cultured utricles were divided to three groups (Control group, Neomycin group, Cultured utricles of CBA/CaJ mice were used. In this study, the reagent CEP-11004 was used as an inhibitor of JNK signaling. Cultured utricles were divided to three groups (Control group, Neomycin group, Neomycin + CEP-11004 group). In the Neomycin group, utricles were cultured with neomycin (1 mM) to induce hair cell death. In Neomycin + CEP-11004 group, utricles were cultured with neomycin and CEP-11004 (0.1 - 1.0 M). To evaluate the activation of JNK, immunohistochemistry using antibodies directed against phosphorylated JNK and phosphorylated c-Jun were used. To examine hair cell death, we counted the hair cells that were labeled with antibodies against calmodulin and calbindin. In addition, we used in situ substrate detection of activated caspase-9.
Results: Many hair cells with phosphorylated JNK and c-Jun were detected in the utricles of the Neomycin group, though very few positive cells were seen in the Control group. CEP-11004 inhibited the phosphorylation of both JNK and c-Jun in Neomycin + CEP-11004 group 12 h after exposure to neomycin. The survival rate of hair cells was about 76.1% 24 h after exposure of neomycin (1 mM). The survival rate of hair cells in Neomycin + CEP-11004 group was significantly more than that in Neomycin group (92.3%). These data show that inhibition of JNK protects vestibular hair cells against neomycin-induced death. In

addition, the inhibition of JNK inhibited the activation of caspase-9 in hair cells.
Conclusion: These results show that JNK plays an important role in neomycin-induced vestibular hair cell death and caspase-9 activation.
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P173
Binding Properties of Betahistine for Recombinant Human Histamine H3 Receptors
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Background: The histamine H3 receptor (H3R) was initially characterized as an autoreceptor regulating histamine release in brain [1]. Its recent cloning in the human [2] and rat [3] confirmed that it is a Gi/o protein-coupled receptor. Betahistine behaves as a H3R antagonist with micromolar potency at rat H3 autoreceptors [4]. However, some antagonists are less potent at the human than at the rat H3R, an observation explained by their interaction with two amino acids located in the third transmembrane domain of the receptor and different in the two species [5].
Objectives: The aim of the present study was to compare the affinity of betahistine at recombinant human and rat H3Rs by using the binding of [^{125}I]iodoproxyfan, a selective H3R radioligand [6].
Methods: cDNAs encoding for the rat (rH3R) and human (hH3R) H3-receptors were stably transfected in CHO-K1 or HEK-293 cells. Membrane suspensions of CHO(rH3R or hH3R) and HEK(hH3R) cells were prepared. Aliquots were incubated for 60 min at 25°C with 20 pM [^{125}I]-iodoproxyfan alone or together with betahistine at increasing concentrations. For determination of IC50 values of betahistine, each inhibition curve was analyzed with an iterative least-squares method. The K_i values of betahistine were calculated from its IC50 values by using the relationship: K_i=IC50/(1+(S/K_D) where S represents the concentration and K_D the apparent dissociation constant (82 ± 3 pM and 85 ± 4 pM at human and rat H3Rs, respectively) of [^{125}I]-iodoproxyfan.
Results: [^{125}I]Iodoproxyfan binding to membranes of HEK(hH3R) and CHO(hH3R) cells was inhibited by betahistine with IC50 values of 2.7 ± 0.3 μM and 3.3 ± 0.4 μM, leading to K_i values of betahistine for the human H3R of 2.0 ± 0.2 μM and 2.5 ± 0.3 μM, respectively. The inhibition of specific binding to membranes of CHO(rH3R) cells led to a K_i value of betahistine for the rat H3R of 1.4 ± 0.1 μM.
Conclusion: Whereas some antagonists display lower potencies at the human receptor, the present findings show that betahistine is equipotent at human and rat H3 receptors, with a K_i value of ~2 μM. The potency of betahistine at the human receptor is also in the same range as that displayed by the drug at native H3 autoreceptors modulating histamine release in the rat brain [4] and might therefore account for the beneficial therapeutic effects of the compound.
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Treatment of Episodic Ataxia Type 2 with the Potassium Channel Blocker 4-Aminopyridine
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Background: Episodic ataxia type 2 (EA2) is clinically characterized by recurrent, hour-to-day-long attacks of ataxia, which are provoked by stress or exercise, and by central ocular motor and vestibular dysfunction, mainly downbeat nystagmus (DBN), during the attack-free intervals. Genetically, EA2 is an autosomal dominant hereditary disorder caused by mutations of the calcium channel gene CACNA1A, which encodes the CaV2.1 subunit of the P/Q-type calcium channel that is mainly expressed in the Purkinje cells. Functional changes of the P/Q-type calcium channel mutations lead to a reduced calcium current, which is assumed to reduce the inhibitory effect of the Purkinje cells in EA2, resulting in a diminished release of GABA and a disinhibition of deep cerebellar nuclei and thus ataxia and DBN
Objectives: Recent findings that aminopyridines (as potassium channel blockers) improve DBN, most likely by increasing the inhibitory influence of the Purkinje cells, prompted us to evaluate the effects of 4-aminopyridine (4-AP) on the occurrence of attacks in three patients with EA2.
Methods: Three patients (two males, ages 18 to 51 years) were diagnosed to have EA2. Mutations in the CACNA1A gene confirmed the diagnosis in two. All patients were given 5 mg of 4-AP tid.
Results: This dosage of 4-AP completely prevented attacks of ataxia in two patients (who no longer responded to acetazolamide, and markedly reduced them in the third. The attacks recurred after treatment was stopped; subsequent treatment, however, again alleviated the symptoms (mean follow-up time: 6 months). The agent was well tolerated by all patients.
Conclusion: 4-AP prevents or reduces attacks in EA2 by apparently increasing the release of GABA in the Purkinje cells. The following mechanisms of 4-AP are relevant: it increases the excitability of Purkinje cells, prolongs the duration of action potentials, and increases the release of neurotransmitters by blocking several potassium currents, e.g., the A-current and the delayed-rectifier

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Human Gaze Saccades' Preview Control of the VOR

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Background: During gaze movements the degree to which eye velocities are reduced, and the amplitude and timing of the reacceleration of the eyes, depends upon the concurrent head movement (Zangemeister and Stark 1981). In our earlier paper on gaze latency (Zangemeister & Stark 1982) we found flexible differences of eye versus head latencies during gaze shifts of variant initial conditions such as amplitude and prediction. We postulated then that head and eye motor commands are separately generated on the higher level of the cerebello-cortical loop. This was confirmed by Sparks et al. 2002, who showed that the desired gaze signal is parsed in eye and head pathways upstream of the excitatory burst neurons, i.e. in the cerebello-cortical loop.
Objectives: To show the effect of differential head eye latencies on the intrasaccadic VOR gain.
Methods: We studied dynamic characteristics of predictive and random saccadic eye-head movements in normal subjects (10) and in another set transcranial magnetic stimulation (TMS) over the cerebellum in normal subjects (10). Paradigms varied target sequences in amplitude, direction, frequency. We used infrared high resolution technique for eye movement recording and an ultrasound device for head movement recordings. TMS was done using a monophasic stimulus of 1.5 Tesla maximum.
Results: Latency. Highly predictable target steps resulted in earlier onset of the head movement and an increase of the intrasaccadic head contribution to the overall gaze displacement. Dynamics. Differences of the level of VOR suppression were significant when gaze amplitudes exceeded 60°. Consequently, an effective speed-up of large gaze saccades was found with increased target predictability. This was mirrored when we applied TMS at 5–25 ms after the position change of the 60° target, and 50– 5 ms before the start of eye movement: Mean peak velocity of synkinetic saccades increased up to 600°/s, compared to 350–400°/s without the use of TMS. Time optimal gaze movements [>50°], we found anticipatory slow eye movements (ASEM) with prediction in 43 %, with random targets in 11%, and in cerebellar patients highly reduced (3%) for both conditions. Head-Eye-Synkinesis. With application of TMS shortly after the target display, the number of eye movements that preceded head movements was significantly increased ($p < 0.001$), and the delay between eye and head movements was reduced or reversed ($p < 0.001$), compared with gaze movements without the use of TMS.
Conclusion: We conclude that eye-head coordination during human gaze saccades underlies high level cortico-cerebellar preview control mechanisms: A parametric modulation of the intrasaccadic VOR maintains gaze accuracy that is based on an intact cerebellum and contribution of the more flexible head motor system, depending on gaze amplitude and prediction.
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P176

Convergence Reduces Ocular Counterroll (OCR) During Static Roll-Tilt

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Background: During maintained roll-tilts around the naso-occipital axis, both eyes roll or tort in the opposite direction to roll-tilt, a phenomenon known as ocular counterroll (OCR). While the magnitude of OCR is primarily determined by vestibular input the direction of gaze also plays a major role.
Objectives: The aim of this study was to measure the effect of vergence on OCR.
Methods: Binocular videooculography was used to measure 3D eye position during maintained whole body static roll-tilt in darkness and also in a fully lit room, while subjects fixated first on a distant (at 130cm) and then a near (at 30cm) head-fixed target aligned with the subject's midline. Six subjects were tested.
Results: For both directions of roll-tilt we found that while converging on the near target, human subjects displayed a significant reduction in OCR i.e. the interaction between OCR and vergence was NOT simple addition or subtraction of the torsion induced by vergence with the torsion induced by roll-tilt. It has been suggested that such a reduction in OCR is due to the altered geometry of the eyes during roll-tilt conflicting with stereopsis, with vergence acting to reduce the conflict facing the stereoscopic mechanism by reducing torsion. The vergence-induced reduction in OCR existed in human observers even when stereopsis was absent (with one eye covered), so that neither stereoscopic disparity nor the subjective sensation of stereopsis is the direct cause of the OCR reduction. To remove the possibility that the OCR reduction may be associated with the changed horizontal position of the eye in the orbit during symmetric convergence, we measured the OCR reduction when the distant and near targets were aligned directly in front of one eye. We found the magnitude of OCR in this asymmetric convergence case was also reduced for near viewing by about the same amount as in the symmetric vergence condition, confirming that the convergence command rather than horizontal position of the eye underlies the OCR reduction. Increasing convergence from 130 cm to 30 cm reduced OCR gain by around 35% on average. That reduction was equal in both eyes. The same reduction in OCR was found when the asymmetric vergence condition was conducted on 2 subjects in a fully lit room, further confirming that it is vergence and not actual retinal disparities that cause the reduction in OCR.
Conclusion: These results demonstrate the important role vergence plays in determining ocular counterroll during roll-tilt and support the contention that vergence acts to

reduce the conflict facing a stereopsis-generating mechanism.

P177

Advantage of a Test on Smooth Pursuit Eye Movement Using Oscillatory Optokinetic Stimuli

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Background: Eye Tracking Test (ETT) is one of the equilibrium function tests and has been frequently examined with optokinetic pattern test in both clinical and basic research. In general, ETT using a spot target is considered to estimate the combination of smooth pursuit eye movement (SPEM) and saccadic eye movement (Saccade). In other words, the assistance of Saccade is indispensable for SPEM on pursuing a spot target besides extremely slow pursuit velocity. In this sense ETT depends upon the function of not only SPEM but also Saccade. Using sinusoidal random dots pattern oscillation in healthy subjects, we reported that we could evaluate the affection of SPEM alone independent of Saccade function in pursuit eye movement.
Objectives: The purpose of this experiment is to clarify the differences between only Saccade disturbance and both SPEM and Saccade disturbance in dizzy patients, using sinusoidal spot target oscillation (i.e. conventional ETT) and oscillatory optokinetic stimuli.
Methods: Nine dizzy patients whom we diagnosed as central nervous disorders and Meniere disease participated in the test as subjects. We used a white hemisphere dome screen (made by First Medical Co.) of 50 cm a radius and projected a red laser spot or white random dots pattern (dots density: 220/100 cm2). A patient with the head fixed at a chin rest sat just 50cm far from the hemisphere dome in complete darkness. Six sinusoidal oscillations with frequencies ranging from 0.2 to 0.8 Hz and peak velocities ranging from 19 to 75 deg/sec were employed. Patient's horizontal eye movements were recorded by 2D-VOG(SMI) for 30 sec in each test. Gain and phase between eye and oscillatory target from spot and random dots pattern stimuli were computed by use of Fast Fourier Transformation (FFT) after calculating with the program to obtain the cumulative smooth eye movement curve.
Results: In the patients of Meniere, the velocity gain on both ETT and oscillatory optokinetic stimuli test had a similar tendency with frequency increased. In the patients of lacunar infarction the results of gain-frequency relation seemed like the result in Meniere. However, in early period of spino-cerebellar disease (SCD), the obvious differences between the gain-frequency relation of ETT and that of oscillatory optokinetic stimuli test were observed.
Conclusion: We consider that the SPEM for a small oscillatory target seems to depend on Saccade function that assists the SPEM to keep the moving target at the fovea. From the above results, in incipient period of some cerebellar lesion, there is a possibility that the SPEM function is preserved and Saccade is alone impaired even if low gain in ETT. ETT impairment can be classified into two criteria, the disorders of only Saccade and both SPEM and Saccade, when we examine both conventional ETT and oscillatory optokinetic stimuli test and compare each gain in dizzy patients.

P178

Far and Near Target Dynamic Visual Acuity: Bilateral Vestibular Deficit Patients

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Background: Head rotational and linear transducers (semicircular canals and otoliths, respectively) differentially contribute to gaze stability and visual acuity at different visual target distances. Patients with absent or impaired canal and/or otolith function often report oscillopsia and decreased visual acuity during active and passive whole body movements, such as walking and riding in a car. A locomotion paradigm that functionally characterizes this loss of gaze control could be clinically useful in providing insight regarding relative otolith and canal contributions to dynamic visual acuity.
Objectives: The purpose of this study was to quantify the changes in visual acuity in a population of vestibular deficient patients during gait using the method of Peters and Bloomberg (in review). This technique indirectly assesses canal and otolith contribution to gaze stability.
Methods: Six bilateral vestibular loss (BVL) subjects (25-79 years of age), and 4 sex and age-matched normal volunteers participated in this study. Subjects were tested once and then retested five months later. Their scores were averaged. To measure changes in visual acuity, subjects initially performed a visual acuity test while standing quietly. Subjects then walked (shoes on, arms free) on a motorized treadmill at 1.12 m/s while viewing visual targets at either 4 meters (FAR) or 0.5 meters (NEAR). By comparing the results of static (standing) and dynamic (walking) visual acuity thresholds, the visual acuity decrement associated with an inability to compensate (maintain ocular globe stability) for motion of the head and body can be determined.
Results: When compared to the FAR condition, the NEAR condition showed significantly larger decrements ($t=5.5$, 8 degrees of freedom, $p=0.00056$) in dynamic visual acuity for both controls and BVL patients. A comparison between the subject groups indicates that BVL patients have larger decrements in visual acuity in the FAR condition ($t=4.9$, 7 degrees of freedom, $p=0.002$), but statistical significance was not reached in the NEAR condition ($t=2.18$, 7 degrees of freedom, $p=0.066$).

Table:

Mean decrements in visual acuity (logMAR) in controls and BVL patients		
	Near	Far
Controls	0.153	-0.02
BVL patients	0.313	0.0148

Conclusion: 1) Significant changes were observed in NEAR versus FAR target visual acuity in both controls and BVL patients. 2) Significant changes were observed when comparing controls to BVL patients in the FAR condition. The observed changes in controls versus BVL patients may be explained by the affect of altered vestibular contributions to gaze stability (absent or reduced linear VOR). Future studies will include independent measures of the LVOR in controls and BVL subjects.

P179

Novel Interpretation of Optokinetic Afternystagmus

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Background: Optokinetic nystagmus (OKN), which is elicited by a moving visual scene across the field of vision, can be used at the bedside to demonstrate focal parieto-occipital disease and to evaluate factitious blindness. Optokinetic afternystagmus (OKAN) is noted immediately after the removal of the visual stimulus. OKAN is often a normal finding and lasts only 10-40 milliseconds. Due to usual methods of OKN generation and analysis, OKAN is often not measured.
Objectives: Interpretation of the unique patterns of OKAN that we observed in our vestibular laboratory.
Methods: Our laboratory uses a rotating drum stimulus that produces a complex pattern of dots on a curved wall. The stimulus is presented initially with dots moving to the right for 30-45 seconds, followed by a stimulus-free period of 30-45 seconds in order to observe OKAN. This is then repeated in the leftward direction. Eye movement data is captured with infrared videonystagmography and analyzed using commercial vestibular laboratory software.
Results: Upon review of the vestibular tests from September 2000 to March 2002, the common patterns of OKAN included: unilaterally positive, bilaterally positive (symmetric, asymmetric) and no OKAN bilaterally (time constant < 0.5 sec). Unilateral vestibular losses at times manifested an OKAN prolongation contralateral to the side of loss. The symmetric, bilaterally positive OKAN group often had a history of headache, with or without migrainous features, per clinical review. Normal vestibular testing, except for unilaterally prolonged OKAN, was quite infrequent. More commonly, a unilaterally prolonged OKAN was seen along with brief nystagmus in the same direction in other portions of positional testing. A bias of the VOR to the same direction of the OKN and/or a borderline caloric paresis (approx. 24-26%) may be seen. The clinical picture of these patients often suggested vestibular neuronitis. An asymmetric, bilaterally prolonged OKAN, when combined with the clinical picture often suggested a peripheral vestibular disturbance provoking, or unmasking, a central phenomenon such a migraine.
Conclusion: OKAN analysis may provide insight into the further understanding of patients with vestibular disorders.
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P180

Effects of Glycine Receptor Antagonist upon Pontine Omnipause Neurons during Saccadic Eye Movements

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Background: Omnipause neurons (OPNs) are a pivotal component of the brainstem saccade generator. They discharge tonically at a high rate during intersaccadic intervals and pause during saccades in all directions. Their tonic discharge exerts a powerful inhibitory action on premotor burst neurons. A pause in OPN activity removes this inhibition and allows the burst neurons to fire in response to an excitatory inputs from the upper structures such as the superior colliculus. Our previous study with intracellular recordings demonstrated that the saccade-related pause of OPN firing is caused by inhibitory postsynaptic potentials (Yoshida et al. 1999). The study further suggested that this inhibition consists of two components that may serve as latch and trigger: the inhibition with a temporal profile closely paralleling that of eye velocity and the short pulse-like inhibition occurring at the onset of the pause.
Objectives: In the present study, we have investigated the transmitters that mediate the saccade-related inhibition of OPNs. Since OPNs are known to receive numerous contacts from glycinergic and GABAergic afferents (Horn et al. 1994), we studied the effects of strychnine, a glycine receptor antagonist, and bicuculline, a GABA receptor antagonist, on the firing pattern of OPNs.
Methods: Extracellular recordings were made from single OPNs using three-barrel micropipettes in alert cats. OPNs were identified by their characteristic discharge pattern described above. Strychnine or bicuculline was applied

iontophoretically by passing currents through the two barrels containing the drug and NaCl solutions.
Results: Application of strychnine decreased the ratio of pause duration to saccade duration. The time of pause onset relative to saccadic onset was slightly delayed, and the resumption of the tonic firing relative to saccade end was markedly advanced. Such decreases of pause duration were found regardless of the direction of saccadic eye movements. Application of bicuculline had no significant effect on the duration and timing of the pause, but increased the firing rate during intersaccadic intervals.
Conclusion: The results indicate that saccade-related pause of OPN firing is mainly caused by glycinergic inhibition. GABAergic inputs, on the other hand, may contribute to the regulation of the activity of OPNs during fixations.

P181
Effects of Bilateral Canal Plugging on The Discharge Of Brainstem Neurons during Eye and Head Gaze Shifts: Where Is the Vestibular Signal in Gaze Control?
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Background: t is thought that vestibular signals contribute to the control of head unrestrained gaze movements. It is not known precisely how that contribution is implemented, or to what degree vestibular signals influence the relationship between neural discharge and observed eye, head or gaze movement.
Methods: To address these issues, we have recorded the activity of brainstem neurons during head unrestrained gaze shifts with, and without, intact semi-circular canal input.
Results: Bilateral canal plugging produces variable, hypermetric, gaze shifts that become accurate after a few days. Gaze shifts following canal plugging contain a post-saccadic eye counter rotation to stabilize gaze, but are not accomplished by a single gaze saccade. Rather, they are comprised of a very hypometric eye saccade and a prolonged slide of gaze toward the target during initial eye counter-rotation. Therefore, vestibular information seems critical for the generation of accurate single gaze saccades, but not for accurate gaze shifts per se. Burst tonic, burst and omnipause neurons change their discharge following canal plugging. Burst tonic neurons in the abducens nucleus fail to discharge to the end of gaze movements. Such neurons display linear number of spikes re size relationships with eye movement. Omnipause neurons pause for gaze shifts, but resume discharge before saccade end. OPN stimulation interrupts saccades and produces eye counter-rotation during canal plugged gaze shifts, but disrupts gaze accuracy. Burst neurons display linear number of spike versus eye amplitude relationships following canal plugging. The burst discharge profile matches the velocity profile of the eye saccade before and after canal plugging, but multiple velocity/discharge frequency peaks characteristic of normal gaze shifts are not seen in canal plugged gaze shifts.
Conclusions: These observations suggest that vestibular input is critical for accurate gaze shifts driven by the saccade burst generator. Furthermore, relationships between premotor neuron discharge and gaze, eye and head movement are influenced by active VOR during gaze shifts in intact animals. Finally, this data suggests the convergence of vestibular signals on the saccade burst generator above and below premotor neurons.

P182
The Relationship Between Tinnitus Pitch and Audiometric Pattern
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Background: The relationship between tinnitus pitch and sensorineural hearing loss (SNHL) has been discussed but are still unclear. We reported that only slight permanent hearing losses by tone exposure may cause an increase in the spontaneous firing rate even in the absence of a detectable cortical reorganization of the tonotopic map, which might correlate to the occurrence of tinnitus in noise exposed subjects with only minor permanent hearing loss.
Objectives: Tinnitus pitches of patients whose pure tone audiograms were classified by the audiometric pattern were examined to clarify the relationship between tinnitus pitch and audiometric pattern of SNHL and normal hearing, that between tinnitus pitch and small dip within normal hearing and that between tinnitus pitch and the cause of 4kHz dip hearing loss.
Methods: 114 tinnitus patients with SNHL and normal hearing classified into the following 4 types by the audiometric pattern obtained from pure tone octave audiometry from 125 to 8kHz were selected: 1. steep downslope with SNHL, 2. downslope with SNHL, 3. normal hearing, 4. 4kHz dip with SNHL. In normal hearing type, hearing loss with 5dB or more at a given frequency than that of the adjacent frequencies was defined as small dip. Tinnitus pitch was measured by pitch matching method from 125 to 8kHz with pure tone octave audiometry. The relationship between tinnitus pitch and type of SNHL and normal hearing, that between tinnitus pitch and small dip within normal hearing and that between tinnitus pitch and the cause of 4kHz dip hearing loss were analyzed.
Results: Tinnitus pitches in both downslope types with SNHL were mainly located at 8kHz and were spread broader in downslope type than in steep downslope type. Tinnitus pitches with normal hearing type were mainly at 8kHz but were spread from low to high frequencies compared with those in both downslope types with SNHL. Tinnitus pitches with small dip and normal hearing were located at small dip frequencies, the adjacent frequencies of small dip and 8kHz. And tinnitus pitches with 4kHz dip type mainly were at 4kHz in noise injury and 8kHz in idiopathic SNHL.
Conclusion: The broader SNHL grew the broader tinnitus pitch diffused, which might suggest the tight correlation

between tinnitus and hearing loss. Tinnitus pitches with 4kHz dip in noise injury tended to be close at 4kHz compared with those in idiopathic SNHL, which would imply the tight relationship between tinnitus and localized hearing loss. And the fact that tinnitus pitches with normal hearing type were mainly located at 8kHz and those with small dip within normal hearing were located at small dip frequencies, the adjacent frequencies of small dip and 8kHz makes us reconfirm the importance of measurement of hearing levels at more than 8kHz. Moreover it is speculated that small localized hearing loss could be the cause of tinnitus and some changes or damages might be spread to the adjacent frequencies of small dip hearing loss even within normal hearing.

P183

Elevated Intracellular Cyclic AMP - A Neurochemical Correlate of Tinnitus

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Background: Hearing loss is an inevitable sequelae of noise induced as well as ototoxic cochlear damage. Such deafness is often accompanied by tinnitus. It was suggested that increased spontaneous neural activity (SA) might be the underlying mechanism for tinnitus. Neurochemical consequences of cochlear ablation (CA) have also been widely explored. A significant synaptic plasticity has been reported following cochlear insults. Yet a direct relationship of increased SA with plastic neurochemical alterations remains to be recognized. In central auditory neurons, the signals emerging after CA are transduced by a range of mechanisms including extracellular signal-regulated kinase (ERK) pathway. One of the functional roles of this pathway is to enhance the inhibition of phosphodisterase E 4 (PDE4), thereby elevating intracellular cAMP concentrations ($[cAMP]_i$). It is possible that increased $[cAMP]_i$ could be one of the causes of increased SA, which is a possible physiological correlate of tinnitus.
Objectives: We sought to determine if increasing $[cAMP]_i$ affects SA, and if so what possible mechanisms may be involved and the possible physiological/pathological ramifications. In particular, we investigated if such elevations in SA could mimic the neural code for acoustic sounds, including pure-tones.
Methods: Neural responses evoked by ipsilateral, best-frequency pure tone were collected on extracellular single unit recordings. SA was obtained in the absence of the pure-tone. The neural activity was recorded during control and after pressure application of 50 μM forskolin (an agent that systematically increases $[cAMP]_i$). The recordings were performed in the superior olivary complex (SOC) of the auditory brainstem, and the recording sites were later confirmed by histology.
Results: Forskolin specifically increases tone-evoked responses and SA of the SOC neurons in dose-dependent manner. Interestingly, the increased SA following application of 50 μM forskolin mimics the neural rate that is normally generated by tonal stimuli. The increased tone-evoked and spontaneous SOC neural excitability in response to forskolin is possibly via PKA dependent and/or independent mechanisms. Based on experiments involving sequential applications of ZD7288 (100μM) (a selective blocker of hyperpolarization activated inward cationic conductance, Ih) and forskolin, it is proposed that effect of forskolin on tone-evoked and spontaneous SOC neural excitability may be predominantly due to increased activation of Ih - a PKA independent mechanism.
Conclusion: These results provide for the first time, direct evidence that systematic increase in the $[cAMP]_i$ by application of forskolin elevates the SA of auditory brainstem neurons, which may mimic the neural code for pure-tone sounds. Here we suggest, increased levels of $[cAMP]_i$ that could follow cochlear insults, may be a mechanism of increased SA and therefore could be a "neurochemical correlate" of tinnitus.

P184

Hyperacusis Treatment with a Combination of Low Level Laser Light, Anti-Oxidant Control and Pulsed Electromagnetic Field - A Clinical Pilot Study

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Background: People with hyperacusis can experience discomfort at 40 to 50 decibels or lower. The disorder may be frequency-specific. Among hyperacusis patients 86 % suffer from tinnitus. In such cases it is the hyperacusis that is often considered as the more severe of the two problems. Tolerance levels for sound of pure tone are less than 90 dB.
Objectives: No great changes are expected in hyperacusis during six weeks. The literature claims that hyperacusis represents disturbances of central auditory processing without peripheral pathology. This would be questioned if local therapy on peripheral inner ear cells would be successful. The combination of the three therapies was expected to cause treatment results in six weeks. TRT is a treatment procedure more likely taking years instead of months to accomplish.
Methods: The study on hyperacusis treatment was carried out with a combination of Low Level Laser, Anti-oxidants and Pulsed Electromagnetic Field in a clinical trial where all patients suffering from hyperacusis underwent with no selections or limitations the combined therapy 12 times during six weeks. No treated patients were excluded. Therapy was bilateral. Hyperacusis was evaluated both subjectively and by audiometry. Audiometry: Levels of discomfort, hearing thresholds and tinnitus levels were measured. Low Level Laser Therapy: 50 J of 904 nm of pulsed laser light over a round area of 50 cm2 over the TMJ. 60-450 J of 808 nm continuous light via meatus. 60 J of 650 nm continuous light via meatus. Pulsed Electromagnetic Field Therapy: Every treatment session started with the Bemer

3000 bed for 8 minutes using program "6". Intensive-applicator was used for 16 minutes, twice. Program "P3" was used and the applicator was in a contact mode with the mastoid bone. Every treatment session lasted 40 minutes. Anti-oxidant Therapy - pharmacological drugs: Anti-oxidants: Ginkgo biloba, E-vitamins, multi vitamins, beta-carotene etc. Reactive Oxygen Metabolites (dROMs) were measured with Callegari CR2000.

Results: Subjective assessment among the 39 patients treated showed that 35 were much improved, 1 felt very little improvement and 3 felt no differences at all. Measurement by audiometry of 24 treated ears resulted in an average improvement of: 0-5 dB: 8 %; 5-10 dB: 17 %; 10-15 dB: 50 %; 15-20 dB: 17 %; 20-25 dB: 8 %. An average improvement of 10 dB or more was measured among 75 % of the ears; the total average was 10.83 dB.

Conclusion: The combined therapy seems to be a beneficial treatment for hyperacusis. Tinnitus symptoms were lessened and eliminated. Hearing thresholds were improved. Distortion was improved.

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P185

Combined Tinnitus Therapy

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Background: It is well known that tinnitus as a symptom is difficult to treat and there are lots of modalities used for treatment, each only with partial effect. Guidelines for including each patient into appropriate treatment group are still missing.

Objectives: We compared effects of each method of treatment: pharmacotherapy (vasoactive drugs, local anesthetics, corticosteroids), rehabilitation, soft laser, combination of methods. The aim of the study is to define inclusive/exclusive criteria for each treatment method or combination of methods.

Methods: The study was performed on the comparison of the effects on VAS: vasoactive drugs and local anesthetics both with/without rehabilitation or soft laser therapy. We have chosen VAS (visual analogue scale) as the main evaluation method of tinnitus treatment because of the main aim of our performance - improvement in quality of life.

Results: Most effective is combination of methods. In acute tinnitus treatment were the most effective combinations with Pentoxiphyllin. In chronic tinnitus treatment were the most effective combinations with corticosteroids.

Conclusion: According to results is worth to treat both chronic and acute tinnitus.

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G Induced Vestibular Dysfunction and Countermeasure Against It in Guinea Pigs—Behavior and Ultrastructure Observation

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Background: High magnitude of g force (high g) is frequently encountered in aerospace flights. However, although a few data have been reported, its effects on vestibular system (especially of otolith organs) have not been well known. It was conceivable that high g would cause vestibular dysfunction (G induced vestibular dysfunction, G-VD) because of the higher density of otoconia. If so, its relationship to some aerospace problems such as spatial disorientation (SD), space adaptation syndrome (SAS), etc. would need to be well understood, and a countermeasure against it is needed.

Objectives: To test the following hypothesis: (1) G-VD is another rarely occurred but possible G threat in aerospace activities apart from G-LOC. (2) As a widespread phenomenon in humans and animals and an effective measure to increase their tolerance to adverse factors, preconditioning is also exit in vestibular system, that is by pre-exposure to a low hypergravity environment could mitigate G-VD.

Methods: We studied 112 guinea pigs in four groups: 28 of them were exposed to 10G along the interaural axis (10G group) for five min; 28 were preconditioned 8 days in 2G environment before exposed to the 10G (preconditioned group); 28 were exposed to 2G environment for 8 days, but without 10G exposure; the last 28 guinea pigs that were kept in 1g environment all the time formed a control group. Their postural behavior and ultrastructure of the utricle macule were observed.

Results: The incidence of BA (behavior abnormalities) in 10G group (79%) is significantly high than that in preconditioning group (50%). The ultrastructure study of the utricle macule showed that in 10G group, disappearance and regeneration of otoconia occurred after 10G exposure. In preconditioning group, emergence of flaws and porosis of otoconia were observed 0.5h and 24h later respectively after 10G exposure. By using TEM, secretion of the global substance from hair cells, plasmolysis and cell nucleus pyknosis were observed in 10G group, while in preconditioning group, only a few cells showed cell nucleus pyknosis.

Conclusion: High G exposure of 10G for five minutes could cause vestibular dysfunction in guinea pigs, and preconditioning of pre-exposure to 2G environment could alleviate it. The possibility of this kind G-VD in humans during their aerospace activities can't be excluded by now, their relationship to some SD mishaps and SAS needs to be studied.

P187

A Model for Transient and Reversible Blockage of Vestibular Input Using TTX by Osmotic Pump in Guinea Pigs

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Background: On the earth we always feel gravitation. However, in a space life, we lose bilateral vestibular input, we can adapt ourselves to circumstances.
Objectives: To investigate the mechanisms of vestibular compensation in the loss of bilateral vestibular function, animal model for transient and reversible blockage of vestibular input using tetrodotoxin (TTX) by osmotic pump was developed.
Methods: Animals were examined vestibulo-ocular reflex (VOR) and vestibulo-colic reflex (VCR) sequentially after intracochlear administration of 5ug TTX by osmotic pump bilaterally for 1 week. After 1week infusion of TTX, VOR and VCR were recorded until 168 hours later. After all VOR and VCR recording were finished, inner ear specimens were examined under light microscope.
Results: VOR of TTX treated animals was come to no response around 12 to 24 hours after TTX administration had started. But 120 hours after TTX administration stopped, VOR recovered almost same level as that of pretreatment. On the other hand, VCR of TTX treated animals was come to no response neither around 24 hours after TTX administration had started, but about 24 hours earlier than that of VOR, VCR recovered almost same level as that of pretreatment around 96 hours after TTX administration stopped. Microscopic findings of inner ear specimen showed almost no damage in hair cells of crista ampullaris or macula.
Conclusion: These data indicate that transient blockage with bilateral intracochlear administration of TTX may be useful for studying the central vestibular response to recurrent or episodic vestibular disruption in the intact vestibular system.

P188

Vestibulo-Ocular Reflex Dynamics Following Unilateral Labyrinthectomy: High Frequency, Acceleration, and Velocity Rotations

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Background: The vestibulo-ocular reflex (VOR) effectively stabilizes gaze over the wide range of head movements that occur during natural head movements. Moreover, the VOR operates with an impressively short latency of 5-7 msec consistent with the physical constraints of the underlying neural circuitry. Nevertheless, the VOR only lags head movements by ~20 degrees at 15 Hz, indicating that central pathways compensate for this fixed latency. Following unilateral labyrinthectomy, the VOR demonstrates remarkable compensation, but response asymmetries become more significant as the frequency, acceleration, and/or velocity of head movement increases.
Objectives: Here we have further probed the VOR response dynamics following unilateral labyrinthectomy by exploring the reflex response across the range of frequencies, accelerations, and velocities encountered during daily activities. The effects of frequency, acceleration, and velocity were dissociated by keeping two of the three parameters in a constant range. The time course of compensation was addressed by characterizing responses to these stimuli at different times during the compensation process from day 1 (acute stage) to day 40 (fully compensated) post lesion.
Methods: Head and eye movements were measured using search coil technique in macaque monkeys, before and after labyrinthectomy. Stimuli included: 1) sinusoids of 0.5-15 Hz (velocities of 20-80 deg/s and accelerations of 60-10,000 deg/s^2), 2) transient head perturbations with accelerations of up to 12,000 deg/s^2 (velocities of 30-120 deg/s), and 3) ramped velocities up to 500 deg/s (accelerations of 1000-3000 deg/s^2).
Results: 1) Gains for contralesional sinusoidal rotations recovered to normal values by 4 days. In contrast, VOR gain decreased with increasing frequency for ipsilesional rotations reaching a value of ~0.3 at 15Hz. Contralesional response phase also recovered to normal values, whereas ipsilesional responses lagged by ~30 deg at 15Hz. 2) Similarly, gain in response to ipsilesional perturbations decreased as acceleration increased - reaching ~0.3 for the highest values. 3) Finally, gain decreased as a function of increasing ipsilesional head velocity, but remained relatively constant at ~0.35 for velocities from 250-500 deg/s; a non-linearity resulting from a soft saturation in the eye velocity was clear for head velocity greater than 50 deg/s.
Conclusion: Following unilateral labyrinthectomy, VOR response non-linearities were increasingly apparent as head velocity or frequency and acceleration increased. The gain of ipsilesional response was reduced to a minimum of ~0.3 for the frequencies, accelerations, and velocities tested. Thus the intact side was unable to restore 70% of the response during the compensated stage for these more challenging stimuli. In summary, this study confirms the necessity of using a wider range of frequencies and velocities for exploring response asymmetries in clinical practice where patients with a spectrum of vestibular deficits are encountered.

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Changes in Simple and Complex Spike Firing of Cerebellar Purkinje Cells After Vestibular Deafferentation

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Background: 'Vestibular compensation' (the behavioural recovery that follows unilateral vestibular deafferentation)

is an attractive model of neuronal and synaptic plasticity in the adult CNS. Recent studies have revealed several cellular mechanisms that may help restore resting activity in brainstem vestibular nucleus neurons after deafferentation. These include a rapid down-regulation of inhibitory GABA-A, GABA-B and glycine receptors in the deafferented cells, and an up-regulation of their intrinsic membrane excitability. In addition, a gradual activity-dependent re-organization of synaptic connectivity also takes place within the vestibular reflex pathways (Dieringer 2003).
The cerebellum, in particular the flocculus, is required for early behavioural compensation after unilateral labyrinthectomy (UL), but its precise role is unknown (Kitahara 1998). Johnston et al (2002) showed that inhibition of LTD in the ipsilesional flocculus prevented the up-regulation of intrinsic excitability of the deafferented vestibular neurons – i.e. this post-lesional change in intrinsic properties of brainstem neurons is dependent upon cerebellar cortical plasticity.
Objectives: To characterize the effects of unilateral vestibular deafferentation on firing rates of cerebellar flocculus neurons.
Methods: The effects of UL on the firing rates of simple and complex spikes in Purkinje cells in the ipsi- and contralesional flocculus of urethane-anaesthetized Sprague-Dawley rats were determined using in vivo electrophysiological recording techniques.
Results: We observed a significant decrease in simple spike firing of ipsilesional P-cells acutely post-UL, and no change in simple spike firing of contra-lesional P-cells. Surprisingly, complex spike firing rates were unchanged in both ipsi- and contra-lesional P-cells.
Conclusion: Our results demonstrate a marked imbalance in simple spike activity of ipsi- and contra-lesional flocculus P-cells after UL, which may be subsequently corrected by cortical plasticity through mechanisms like LTD. This interaction between flocculus P-cells and brainstem vestibular neurons offers new experimental opportunities to investigate cellular mechanisms of cerebellum-dependent motor plasticity.
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Extracellular Recordings from Vestibular-Nerve Afferents in the Normal C57BL/6 Mouse

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Background: An understanding of the responses of vestibular nerve afferents to motion stimuli in mice is important for investigations of cellular and genetic mechanisms of the inner ear.
Objectives: These experiments sought to define the response dynamics of afferent nerve fibers innervating the semicircular canals and otolith organs in C57BL/6 mice.
Methods: Data were obtained from 50 adult mice weighing 25-50 g with ages ranging from 6 weeks to 2 months. Each animal was first anesthetized with ketamine/xylazine. Animals were maintained with a core body temperature of 32-33° C. The vestibular nerve was exposed in the posterior cranial fossa. Extracellular recordings were made with glass micropipettes from 172 afferents.
The animal was placed on a superstructure attached to a position servomotor. Rotations were delivered with the center of rotation aligned with the center of the mouse's head or offset 50 cm from the center of the head in order to elicit angular and linear accelerations, respectively. Maximum sensitivity vectors were obtained for each canal and otolith unit by tilting the animal -20°, 0° and 20° in the interaural and naso-occipital planes and rotating in each position at 0.75 Hz. Sinusoidal rotations were then delivered at frequencies ranging from 0.1 - 12 Hz (on-axis) or 0.5 - 10 Hz (offset 50 cm).
Results: The resting rates of regularly (CV* < 0.15, n = 82) and irregularly (CV* > 0.15, n = 90) discharging canal afferents were 37.9 ± 11.9 and 27.2 ± 16.0 sp/s, respectively. Vestibular time constants measured 3.7 ± 1.0 s for regular and 2.4 ± 0.7 s for irregular canal afferents. Sensitivity and phase for regularly discharging canal afferents measured 0.11 ± 0.03 (sp/s)/(°/s) with a phase lead of 5.5 ± 6.3° re head velocity at 0.75 Hz. Sensitivity increased by 20.0 ± 30.8% at 12 Hz with a corresponding phase lead of 35.2 ± 31.7°. Sensitivity of irregularly discharging canal afferents measured 0.14 ± 0.07 (sp/s)/(°/s) with a phase lead of 15.7 ± 9.1° at 0.75 Hz. Sensitivity increased by 120 ± 85% at 12 Hz with a phase lead of 51.8 ± 26.0°. Sensitivity and phase for regularly discharging otolith afferents measured 36.9 ± 19.5 sp/s/g and 1.2 ± 5.7° re head acceleration at 0.75 Hz. At 10 Hz, sensitivity declined to 26.0 ± 14.0 sp/s/g with a phase lag of 15.3 ± 31.5°. Irregularly discharging otolith afferents measured 44.2 ± 20.3 sp/s/g with a phase lead of 19.4 ± 22.0° re head acceleration at 0.75 Hz. At 10 Hz, sensitivity was 37.5 ± 13.3 sp/s/g with a phase lead of 15.0 ± 2.2°.
Conclusion: The sensitivity and phase of mouse canal and otolith afferents were well fit by a transfer function made up of two components: a mechanical model based on fluid dynamic equations and a first order lead term associated with either pre- or post- synaptic transduction. The lead term increased as the irregularity of firing rate increased. The maximum sensitivity vectors of the canals were orthogonal.

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Patterns of Recovery in Locomotor Function Following Long-Duration Spaceflight

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Background: Following their return to Earth, astronauts experience disturbances in their ability to walk and maintain postural stability. We have previously shown that astronauts returning from spaceflight show disturbances in locomotor control manifested by changes in various subsystems including head-trunk coordination, dynamic visual acuity, lower limb muscle activation patterning and kinematics (Glasauer, et al., 1995; Bloomberg, et al., 1997; McDonald, et al., 1996; 1997; Layne, et al., 1997; 1998, 2001; Newman, et al., 1997; Bloomberg and Mulavara, 2003). Despite having characterized these mechanistic changes, little is known about the relationship between the recovery rate of these individual sub-systems and postflight recovery in functional mobility relevant to the astronaut population.
Objectives: The goal of this study was to investigate the linkage between recovery in head movement control and alterations in a practical and multifaceted test of postural and locomotor control.
Methods: Six cosmo/astronauts were tested before and after long-duration missions (6 months) on the International Space Station. Subjects performed two tests of locomotor function. 1) The Integrated Treadmill Locomotion Test (ITLT) called for subjects to walk on a motorized treadmill at 6.4 km/h while identifying optotypes (Landolt Cs) displayed on a laptop computer placed 4 m from the subject's eyes. Head and trunk kinematic data were collected with a video-based motion analysis system (Motion Analysis Corp., Santa Rosa, CA). 2) The Functional Mobility Test (FMT) required subjects to walk at a preferred pace through an obstacle course set up on a base of 10 cm thick medium density foam. The dependent measures were time to complete the course and the number of obstacles touched.
Results: Compensatory pitch head movements were measured during the ITLT and the power in this signal was summed in the frequency range of 1.5-2.5 Hz reflecting the contributions of reflexive head stabilization mechanisms. (Keshner and Peterson, 1995). Subjects showed a reduction in power in this frequency range during postflight locomotion reflecting a change in the dynamics of head movement control. Data obtained from the FMT showed significant increases in time to complete the course during postflight testing. A comparison of the recovery rates in head movement control and FMT performance showed two recovery patterns: i) a concordant recovery trend between head movement control and FMT performance indicating a restitution pattern of recovery and ii) head movement recovery that lagged recovery in FMT performance suggesting that improvement in locomotor function was attained through a pattern of substitution.
Conclusion: These data suggest that recovery of postflight locomotor function may occur through adaptive mechanisms that lead to either restitution or substitution of function. Understanding the modes of postflight readaptation has implications for countermeasure development and astronaut postflight rehabilitation.

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Deficits and Recovery of Torsional Optokinetic Nystagmus in Humans After Unilateral Vestibular Neurotomy

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Background: Torsional optokinetic nystagmus (tOKN) is evoked by motion of a large visual field around the visual axis. Contribution of tonic vestibular inputs in the optokinetic system has been evidenced in healthy subjects by changes in horizontal, vertical and torsional optokinetic nystagmus for gravitoinertial forces changes and/or vestibular stimulations. After unilateral loss of vestibular inputs, the dynamic properties of horizontal optokinetic nystagmus were strongly impaired. However, the effects of unilateral vestibular dysfunction on the tOKN responses remain unknown.
Objectives: The aim of this study was to analyze changes in tOKN after complete unilateral loss of vestibular inputs in humans and its subsequent recovery.
Methods: To answer these questions, we investigated the tOKN dynamic properties (torsional slow phase eye velocity) and symmetry (directional preponderance) of 17 Ménière's patients who underwent a curative unilateral vestibular neurotomy (UVN). To determine the recovery time-course of the functional deficits, we examined patients one day before UVN, and one week, one month and three months postoperatively. Optokinetic stimulations were performed clockwise and counterclockwise with velocities ranging from 5°/s to 120°/s. Dynamic torsional eye movements and static ocular cyclotorsion were recorded using a videonystagmography system. Patients' performances were compared with those of 10 healthy subjects tested at the same time intervals.
Results: Torsional OKN properties were drastically affected by unilateral vestibular loss. Evidence of impaired tOKN is that slow phase eye velocity was significantly increased for ipsilesional stimulations compared to preoperative and control data. Conversely, tOKN velocity was strongly reduced for contralesional stimulations. Torsional slow phases were indeed absent or very weak for this direction of stimulation. These results point to a marked tOKN asymmetry with ipsilesional directional preponderance of eye movements. Three months following UVN, tOKN asymmetry remained uncompensated. In addition, tOKN

asymmetry was associated with static ocular cyclotorsion of both eyes towards the operated side. Again, recovery of static cyclotorsion was not achieved three months after UVN. Finally, patients' preoperative status did not differ from that of healthy subjects.
Conclusion: These results confirm the role of vestibular cues for stabilizing gaze during optokinetic stimulations around the line of sight. In addition, they suggest either that tOKN requires periods longer than 3 months to regain normal values after UVN, or that tOKN asymmetry could be part of permanent asymmetrical functions of unilateral vestibular loss.

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Role of the Neurotrophins in Vestibular Compensation in the Adult Cat
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Background: Behavioral recovery from vestibular dysfunction induced by unilateral vestibular neurectomy (UVN), known as vestibular compensation, is attributed to functional and structural reorganization of neural networks in the central vestibular system. Although neurotrophins (NTs) have been studied in a wide variety of circumstances involving neuronal plasticity, and they have been studied extensively in the peripheral vestibular system, there are comparatively few data on NTs expression and function in the central vestibular system.
Objectives: To assess the possible contribution of NTs to this recovery process, we investigated in a first step the expression of two NTs, the nerve growth factor (NGF) and the brain-derived neurotrophic factor (BDNF) together with their high affinity receptors tyrosine kinase (Trk) A and B in the vestibular nuclei complex (VNC) and related structures such as the inferior olive (IO) in control and UVN cats. A second step was aimed at identifying the plasticity mechanisms by which the NTs could favor the vestibular recovery process. To visualize the NTs signaling pathways that promote neuronal excitability and survival, we investigated the interaction of two immediate early genes (Fos, Zif 268) with the NTs. To establish a link between NTs expression and neurotransmitter plasticity, we investigated the coexpression of NTs with Choline Acetyltransferase (ChAT) in the vestibular neurons of control and UVN cats.
Methods: Fos, Zif 268, BDNF, NGF, TrkA, TRkB, and ChAT immunoreactivity (ir) was analyzed at 2h, 1, 3, 7, 15 and 30 days after UVN. Data from these subgroups of cats were quantified in light microscopy by means of an image analyzing system and compared to those recorded in control animals.
Results: Results showed a high and differential expression of NTs and their receptors in both the VN and the IO neurons in control animals. UVN induced a bilateral upregulation of both the NTS and their TrK receptors protein expression in these structures, peaking 3 days after UVN and returning to control level at 30 days. A colocalization of NTs/ZIF 268 was observed mainly 3 days post UVN in the lateral VN while a coexpression of NTs/Fos was observed earlier (1 day) in the medial VN. ChAT-ir neurons were expressed mainly in the inferior VN with an upregulation observed bilaterally in this nucleus 3 days post UVN. A coexpression of ChAT/BDNF and ChAT/NGF was observed in the inferior VN as well.
Conclusion: We suggest that the increased Nts expression observed after UVN very likely induce cellular mechanisms mediating neuronal excitability and survival via IEGs signaling pathways. The NTs modulate ChAT neurotransmission, a process that could regulate the level of excitation or inhibition in the VN. Taken together, these results show that NTs are implicated in the general process of vestibular compensation.

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Adaptation of the Vestibulo-Ocular Reflex to Chronic Constant-Rate Stimulation of the Peripheral Vestibular Nerve Via a Prosthesis
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Background: Tone imbalance associated with complete unilateral loss is relatively common and can result in severely impaired mobility, blurred vision, vertigo and motion sickness. Presently, little can be done to improve these symptoms when they are chronically present.
Objectives: Our general objective was to investigate central adaptation to alterations in peripheral vestibular function. Such knowledge can help us improve clinical interventions for patients suffering unilateral vestibular loss or similar problems. Our specific objective was to investigate adaptation to peripheral electrical stimulation of ampullary nerves, which will also contribute to the development of vestibular implants.
Methods: Platinum wire electrodes (150 μm) were inserted near the nerve innervating the right horizontal semicircular canal in 4 guinea pigs. A head bolt was surgically attached to the skull and an electrical stimulation device was attached to this head bolt. The electrical stimulation device delivered current pulses to the vestibular nerve via the electrode at a constant rate of 250 Hz. The current pulses were charge-balanced and biphasic, with a pulse duration of 200 μs with a 200 μs delay between the two phases. The device was battery powered and portable, allowing the animal to move freely in its environment. The electrical stimulation was turned on for weeks 1, 3, 5, 7 and turned off for weeks 2, 4, 6, and 8. Then the stimulation was turned on in the morning of days 54, 56, 58, 62, and 64 and turned off in the morning of days 55, 57, 61, 63, and 65. When tested, the animals were restrained to be stationary in the dark. Eye movements were recorded using search coils and the frequency of fast phases was calculated.
Results: When the electric stimulation was first turned on, the first animal responded with a brisk nystagmus (ap-

proximately 300 beats/min). The response decayed back toward zero gradually, taking about 24 hours to reduce to less than 20 beats/min. When the stimulation was first turned off, the nystagmus (peak of approximately 200 beats/min) was in the opposite direction, demonstrating an after-effect typical of central adaptation. The nystagmus decayed gradually to less than 20 beats/min after about 24 hours, about the same time course as when the stimulation was first turned on. The responses decayed to near zero over a period of about 1 *day* in the first four weeks (weeks 1, 2, 3, and 4). For the later weeks (weeks 5, 6, 7, and 8), the responses decayed to near zero much more rapidly, over a period of just a few *minutes*. After about 10 off-to-on transitions, eye responses lasted just a few seconds. Qualitatively similar results were recorded for other animals.
Conclusion: Guinea pigs adapt to chronic constant-rate stimulation of an ampullary nerve. With repeated exposure to the same patterned electrical stimulation, the animals adapt more and more rapidly, eventually adapting so quickly that minimal responses were evident. Chronic patterned electrical-stimulation provides a new tool to investigate vestibular adaptation. Supported by NIH/NIDCD R01 DC03066

P195
Do Vestibular Lesions Interfere with Time Estimation?
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Background: We have found (Israël et al., in press) that short temporal interval estimation seems to be modified by the self-motion acceleration polarity as the subjects were decelerating their pressing rate in the decelerating motion trials, and were accelerating their rate in the accelerating motion trials. In microgravity, subjects performing a continuation task undershot the target inter-response intervals and the timing became more variable (Semjen et al., 1998). Does it mean that time perception depends upon the vestibular system and hence upon its integrity?
Objectives: We examined the influence of the vestibular system integrity on temporal intervals production. It was then necessary to extend our previous investigations with longer time intervals (8-15s).
Methods: Two experiments were executed. First, 13 blindfolded healthy volunteers participated. They were seated on a mobile robot and had to press a button at the beginning and at the end of the selected interval. After one trial without motion, rotations and translations were applied, followed by a last trial without motion. Second, 15 patients with vestibular disorders performed the same production task on a rotating chair. They were separated in 4 groups, based on the results of caloric stimulation: no lesion (nl), unilateral (ul) and bilateral (bl) lesions.
Results: All the subjects produced longer intervals during motion than without motion. For 8 and 15 seconds respectively, the produced intervals were: with No motion, healthy = 8.19 ± 1.28s and 15.52 ± 2.28s; nl = 6.35 ± 1.78s and 13.4 ± 2.32s; ul = 7.06 ± 1.27s and 14.13 ± 3.31s; bl = 6.15 ± 1.9s and 11.18 ± 2.32s. With motion: healthy = 9.48 ± 2s and 17.45 ± 3.67s, nl = 7.85 ± 1.1s and 15.5 ± 2.32s, ul = 7.86 ± 1.83s and 15.27 ± 4.16s, bl = 6.41 ± 1.46s and 12.06 ± 1.8s. Patients with bilateral disorders produced shorter time intervals than the no lesion and unilateral ones (nul): at 8 seconds, No motion, nul = 7.2 ± 1.44s, and with Motion 8.41 ± 1.46s; at 15 seconds, No motion, nul = 14.36 ± 2.42s, and with Motion 16.07 ± 3.38s. For healthy subjects, intervals produced in rotations did not significantly differ from translations.
Conclusion: Vestibular bilateral disorders seem to induce a biased time perception whereas unilateral lesion does not. Perhaps a correct time perception only needs one safe vestibular organ. Furthermore our subjects were long term patients. So what would be the effect of acute lesion on time perception? One patient (not included in this preliminary analysis) produced perfect time intervals, but did not perceive she had been rotating! Apparently it is not the vestibular input that would control time perception, but rather vestibular perception would do it?
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P196
Synaptic Ultrastructure and Plasticity in the Adult Rat and Mouse Utricular Macula and Mouse Crista Under Conditions of Normal and Hypergravity
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Background: The afferent innervation pattern of the utricular macula has been examined in previous studies (Fernández et al., 1990, 1995). Afferents were classified as one of three morphological types: calyx, dimorphic and bouton.
Objectives: Given the diversity of afferent innervation, we are interested in the regional pattern of normal synaptic innervation in the adult rat, to provide background data to interpret our hypergravity experiments. Synaptic ribbons provide innervation to the utricular macula by conveying head motion signals between hair cells and afferent terminals. Calyceal invaginations are hypothesized to play a role in synaptic transmission by facilitating vesicle recycling, and are only present between calyces and type I hair cells. Other studies have suggested a role for calyceal invaginations in ephaptic transmission between type I hair cells and calyx endings. (Goldberg, 1996). Previously, the synaptic ultrastructure of the chinchilla crista ampullaris was examined (Lysakowski and Goldberg, 1997). There were re-

gional variations in the distribution of both synaptic ribbons and calyceal invaginations, which were more numerous in the central zone. Type II hair cells possessed more afferent boutons peripherally than centrally.

Methods: The synaptic ultrastructure of the mouse utricular macula was studied in three samples, while the mouse crista has so far been studied in only one sample. The disector method was used to estimate the number of synaptic ribbons and calyceal invaginations as described previously in a study of the chinchilla crista ampullaris (Lysakowski & Goldberg, 1997). Hypergravity experiments under controlled conditions were done in rats to study synaptic plasticity. We used a variable linear force to prevent adaptation in the irregular afferents. Multiple samples were taken from each utricular macula. Each sample spanned the entire sensory epithelium and included material from all three regions: striola, juxtastriola, and medial and lateral extrastriola, or in the case of the crista, central, intermediate and peripheral.

Results: Results indicate that there are slightly lower numbers of synaptic ribbons per hair cell in the rat and that these numbers do not vary by region, but that calyceal invaginations are more numerous in the striola, as compared to the extrastriola, as in chinchilla. The mouse utricular results are based on 84.5 hair cell equivalents (52 in the invaginations data). The average number of synaptic ribbons was 10.5 ± 4.1 in type I hair cells and 12.9 ± 1 in type II hair cells. Some of the synaptic ribbons (20%) occur in clusters. A variety of shapes, ranging from spheroids to elongate and intermediate forms, was present also. The most widely expressed form of ribbons (45%) was spheroids. The average number of calyceal invaginations in type I hair cells was 30.4 ± 3.8, with 25.2 ± 9 invaginations in type IC hair cells and 28.9 ± 4.7 in type IS hair cells. This number varied by region with more (52.6 ± 19.2) invaginations per type I hair cell in striola and fewer (30.6 ± 3.6) in extrastriola.

Conclusion: In the mouse crista, our preliminary results, based on 12 hair cell equivalents from one sample, indicate that central type I hair cells have fewer ribbons than peripheral type I hair cells, and type II hair cells in both regions are more numerous. There are also large numbers of calyceal invaginations in type I hair cells.

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P197

Massive Expression of Voltage-Gated Na^+ Channels During Synapse Uncoupling in Adult Rat Utricle Hair Cells

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Background: In a recent study (Chabbert et al. 2003) we provided evidence that during postnatal period, the rat utricle hair cells transiently express voltage-gated sodium channels that underlie electrical activity and activity-dependent BDNF release. Such cellular processes disappear at the end of the first post-natal week, once synaptogenesis has been completed. The aim of the present study was to test whether such a developmental phenomenon could be re-activated in adult rats during synaptic uncoupling.

Methods: Selective and transient destruction of the terminal endings of the vestibular primary neurons was achieved using applications of 5 mM kainate into the middle ear.

Results: 24 hours after the excitotoxic injury, only retraction bulbus were visible below the sensory epithelia. During that synaptic uncoupling, massive expression of the voltage-gated sodium current (I_{Na}) occurred in the utricle hair cells, increasing I_{Na} by 600% and providing hair cells the capability to fire TTX-sensitive action potentials. Four days after the excitotoxic injury, the utricle hair cells were contacted by repaired postsynaptic dendrites and no morphological traces of the injury remained visible. Both the percentage of hair cells that express I_{Na} and the density of I_{Na} per hair cell recovered the values previously reported in intact adult hair cells. TTX-sensitive action potentials could not be evoked anymore.

Conclusions: These results indicate that the selective destruction of the synapse between the utricle hair cells and their cognate afferents induce the re-acquisition by the sensory cells of an excitability phase previously reported during synaptogenesis process.

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The Effect of a 12-Week Vestibular Rehabilitation Therapy Program on Computerized Dynamic Posturography in Parkinson's Disease Patients

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Background: Parkinson's disease (PD) is characterized by many motor symptoms including decreased postural stability. Postural control mechanisms at various levels have been shown to be dysfunctional in a PD population and this

may lead to increased risk of falling and subsequent musculoskeletal injury. Exercise therapy and balance training may be effective adjunctive therapies for improving postural instability in PD. Despite many studies finding a potential benefit of exercise therapy in PD populations, there remains a need to determine the type of exercise therapy that is the most beneficial. Vestibular rehabilitation therapy (VRT) is a specific balance therapy designed to challenge various mechanisms of postural stability. VRT has been shown to be effective as an adjunct rehabilitation program for improving postural stability in several patient populations and has been suggested for use in a PD population.

Objectives: To examine the effects of vestibular rehabilitation therapy (VRT) on quantitative and clinical measures of postural stability in Parkinson s disease (PD) patients.

Methods: 13 subjects (mean age 64 ± 12 SD; 4 females and 9 males) with idiopathic PD (Modified Hoehn-Yahr stage 2-3 ON stage medication) completed a cohort repeated measures clinical trial. Subjects completed a 12-week, 3-times/week physiotherapist supervised VRT program. The VRT program consisted of exercises designed to induce vestibular habituation and challenge postural stability reflexes. The equilibrium composite score from the Equitest protocol of computerized dynamic posturography (CDP) (NeuroCom international) was the primary outcome. Motor control and Adaptation tests of CDP and clinical measures postural stability; functional reach test (FRT), Berg balance scale (BBS), Activities-specific balance confidence scale (ABC), and subjective impressions questionnaire (SIQ) were secondary measures.

Results: A statistically significant improvement in the equilibrium composite score (Mean, ± SD) 61±17 to 68 ±13 (p-value 0.04) was detected. FRT distance increased (cm, Mean ± SD) from 22.5± 13 to 32.0 ± 9. No detectable change in BBS occurred (Mean ± SD) 51 ±5 to 52 ±6. Motor control results showed little change in backward translation muscle latency response time (Mean ± SD) 135±15 to 134 ± 12. Force production from dorsiflexion perturbation increased from (Mean, ± SD) 58 ± 46 to 71 ± 40. An increase in ABC scale (Mean, ± SD) 71 ± 19 to 83 ±17 was detected. 85% of subjects reported improved subjective impression of feeling of physical well-being, and 92% reported improved balance on the SIQL. Greatest changes in postural stability outcome measures occurred in subjects with Hoehn and Yahr classification of 2.5 and 3.0.

Conclusion: A VRT program designed for PD patients appears to be beneficial for improving postural stability. The FRT may be helpful as a clinical measure of postural stability, while the BBS may not be sensitive to determine such changes in a PD population. A VRT program may be especially beneficial for PD population with greater postural stability impairment.

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A Randomized Controlled Trial of the Effectiveness of Bibliotherapy-Based Vestibular Rehabilitation for Members of the Meniere's Society

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Background: A trial of vestibular rehabilitation (VR) for people with dizziness of mixed aetiology in primary care has shown that patients can successfully undertake self-treatment with minimal guidance from a nurse [1]. Consequently, this treatment might be suitable for delivery by "bibliotherapy" (i.e. self-treatment guided by a booklet. This study sought to determine whether VR delivered by bibliotherapy could enhance well-being in members of the Ménière's Society UK, who have episodic vertigo with a profile similar to Ménière's disease (although diagnosis has not always been confirmed by a specialist). VR cannot play any curative role in Ménière's disease, but has been recommended for people whose symptoms have stabilized for at least six weeks, as a means of relieving dizziness due to incomplete compensation. Alternatively, since stress may aggravate symptoms of dizziness in Ménière's disease, bibliotherapy using a stress reduction (SR) booklet might also reduce symptoms or relieve psychosocial effects of the disease.

Objectives: The aim of this study was to carry out a randomized controlled trial of whether members of the Ménière's Society UK would benefit from being sent self-help booklets providing guidance in VR or SR.

Methods: 329 volunteers recruited from the UK Ménière's Society were randomized to receive the VR booklet, SR booklet, or no booklet. Assessment was by previously validated self-report questionnaires at baseline and three months after they had been sent the booklet, using the Vertigo Symptom Scale (short form), the Dizziness Handicap Inventory, the Hospital Anxiety and Depression Scale, the Positive Well-being Scale, the Patient Enablement Instrument, and a single item assessing whether they felt worse or better than at baseline.

Results: 38% of the VR group, 34.3% of the SR group but only 19% of controls reported feeling better at follow-up than at baseline (p=.004); odds ratios for improvement relative to controls were 2.6 for VR and 2.3 for SR Both booklet groups had significantly higher enablement scores than the controls (p<.001) and lower levels of anxiety (p=.01). The groups did not differ in terms of symptoms, handicap or well-being. Post hoc analyses showed that the SR booklet reduced depression relative to controls (p=.02) and the VR booklet decreased physical handicap scores relative to controls (p=.04).

Conclusion: Members of the Ménière's Society derived subjective benefit from receiving booklets advising how to relieve their symptoms by means of vestibular rehabilitation or stress reduction. Although their level of symptoms was not changed by therapy, they felt less anxious and more able to cope. A six month follow-up is now being carried out, together with analyses to determine predictors of benefit, including psychological characteristics at baseline and levels of adherence.

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P200

Full-Body Gaze Control Mechanisms Elicited During Locomotion: Effects of VOR Adaptation

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Background: Control of locomotion requires precise interaction among several sensorimotor subsystems. During locomotion the performer must satisfy two performance criteria: maintain stable forward translation and stabilize gaze (McDonald, et al., 1997). Precise coordination demands integration of multiple sensorimotor subsystems for fulfilling both criteria. To test the general hypothesis that the whole body can serve as an integrated gaze stabilization system, we previously investigated how the multiple, interdependent full-body sensorimotor subsystems respond to changes in gaze stabilization task constraints during locomotion (Mulavara and Bloomberg, 2003). The results suggest that the full body contributes to gaze stabilization during locomotion, and that its different functional elements respond to changes in visual task constraints.

Objectives: The goal of this study was to determine how the multiple, interdependent, full- body sensorimotor subsystems aiding gaze stabilization during locomotion are functionally coordinated after the vestibulo-ocular reflex (VOR) gain has been altered.

Methods: We investigated the potential of adaptive remodeling of the full-body gaze control system following exposure to visual-vestibular conflict known to adaptively reduce the VOR. Subjects (n=14) walked (6.4 km/h) on the treadmill before and after they were exposed to 0.5X minifying lenses worn for 30 minutes during self-generated sinusoidal vertical head rotations performed while seated. We measured: temporal parameters of gait, full body sagittal plane segmental kinematics of the head, trunk, thigh, shank and foot, accelerations along the vertical axis at the head and the shank, and the vertical forces acting on the support surface.

Results: Following exposure to the 0.5X minifying lenses, there was a significant increase in the duration of stance and stride times, alteration in the amplitude of head movement with respect to space and a significant increase in the amount of knee flexion during the initial stance phase of the gait cycle.

Conclusion: This study provides further evidence that the full body contributes to gaze stabilization during locomotion, and that different functional elements are responsive to changes in visual task constraints and are subject to adaptive alteration following exposure to visual-vestibular conflict.

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Cervicogenic Dizziness — Still an Entity to Consider?

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Background: Disturbed somatosensory signals from the cervical joints and muscles might be the cause of cervicogenic dizziness. A substantial theoretical background [1,2] supports the existence of the entity but there are no diagnostic tests. There is a relationship between neck pain, dizziness and impaired postural control / cervical position sense [3,4]Conservative treatment guided by musculoskeletal findings can relieve the complaints of patients with suspected cervicogenic dizziness [5,6].

Objectives: The aim was to study musculoskeletal findings in patients with suspected cervicogenic dizziness and to follow up the patient group after physical therapy intervention.

Methods: The study was prospective, descriptive and hypothesis generating. Twenty-two patients were included and 17 (15 women, 2 men) completed it. A structured history and otoneurological examination excluded possible extra-cervical causes. A physical examination made the base for treatment intervention and evaluation. Main functional evaluations were muscle balance, altered movement patterns and tenderness. Treatment was performed in a clinical decision way. Follow up was made directly after the treatment period and after 2 years.

Results: The intervention improved both dizziness and neck pain (Table). Two years later 11 patients were symptom free / improved of their dizziness and 7 patients of their neck pain. The most common musculoskeletal findings were imbalance, tender dorsal neck muscles and cervical range of motion equal to or larger than a normal population [7].**Table:**

Complaints on 5-point scale; mean (int quart range) and 100 mm VAS			
	Before intervention	After intervention	
Dizziness frequency	Daily (1)	Few times/month (2.5)	p=0.003
Dizziness intensity	Severe (0.5)	Moderate (1)	p=0.001
Neck pain frequency	Daily (1)	Several times/week (2.5)	p=0.002
Neck pain intensity	VAS 61 (SD 18.5)	VAS 42 (SD 20.5)	p=0.004

Conclusion: Patients with suspected cervicogenic dizziness have several features in common. Physical therapy relieves their dizziness and neck pain. Cervicogenic dizziness is a differential diagnosis to consider in oto-neurological clinical work and physical therapy is the primary treatment of choice.

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P202

Sensor-Assisted Vestibular Rehabilitation

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Background: Head movement exercises are essential for compensation following a unilateral vestibular loss.
Objectives: To develop and validate the use of a low cost device which allows therapists to monitor patient compliance and progress in vestibular rehabilitation.
Methods: Subjects attach a laser to the head and make movements toward LED targets. VORx1 exercises have been implemented.
Results: The technology will be demonstrated at the meeting.
Conclusion: This will allow for progression of exercise programs remotely, with semi-autonomous performance via the PDA (Palm Pilot) interface. Also provide a rich source of data on motor learning.

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Effects of Immersion in Virtual Reality on Postural Control

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Background: Recently, it was reported that simulator sickness developed when users were immersed in virtual reality (VR). One possible reason is that the visual scene in VR has time lag behind the head movement.
Objectives: In the present study, we examined motion sickness symptoms and postural sway using two different conditions of VR: one is a twofold visual-vestibular conflict (VVC) and the other is a VVC with additional time lags.
Methods: We first created the VR world in CAVE to induce a twofold VVC for angular head movement. Subjects were nine healthy volunteers and were exposed to 20 min of immersion in the VR. Subjective symptoms were evaluated according to Graybiel's score of motion sickness, and objective posture control was measured using posturography. We next created the VR world in HMD to induce a VVC with additional time lags behind the head movement. Subjects were 23 healthy volunteers and were immersed in VR with additional time lags up to 0.8 sec. Graybiel's score and posturography were also measured.
Results: Under the twofold VVC condition in CAVE, the score of motion sickness gradually increased during immersion in VR. The body sway area with eyes opened and closed was not changed during VVC, but significantly increased immediately after immersion in VR. After immersion in VR with additional time lags up to 0.8 sec in HMD, neither the score of motion sickness nor the body sway path with eyes opened and closed was changed. However, after immersion in VR with additional time lags, Romberg rate of body sway path with eyes closed divided by that with eyes opened was significantly decreased in comparison with that before immersion in VR
Conclusion: Under the twofold VVC condition in CAVE, motion sickness built up during VVC, and postural instability occurred immediately after immersion in VR. These findings indicated that in addition to VR sickness, ataxia is another side effect of VR immersion, suggesting that postural instability after VR immersion is hazardous for VR users. The VVC with additional time lags in HMD did not induce motion sickness and postural instability. However, Romberg rate of body sway path was significantly decreased after immersion in VR. Since Romberg rate is an index of visual dependency on posture control, these findings indicated that the immersion in VR decreased the visual dependency on posture control. It is suggested that the adaptation to VVC in VR immersion increased the contribution of vestibular and somatosensory inputs to posture control by ignoring the conflicting delayed visual input in the VR world. VR may be a promising treatment for visual vertigo in vestibular patients with unsuccessful compensation by its ability for vestibular and somatosensory reweighing for posture control. In conclusion, VR may be useful tool for research of motion sickness and for the treatment of patients with vertigo.

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How Can Optokinetic Stimulation Improve Chronic Vertigo?

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Background: Optokinetic stimulation (OKS) is frequently used in vestibular rehabilitation in France.
Objectives: We will try to determine the physiological mechanism by which OKS promotes vestibular compensation, in particular if OKS modifies the functioning of the Optokinetic Nystagmus (OKN) pathway itself.
Methods: The study was carried out on 70 chronic vertigo patients (P), with peripheral vestibular pathology (Menière disease (n=26), vestibular neuritis (n=30) and BPPV (n=14) of whom 27 followed rehabilitation (PR); and on a control group of 32 healthy subjects (HS).
The subject stood in a dark room, wearing a video nystagmography helmet (Ulmer system), and submitted to wide field horizontal optokinetic stimulus, at a constant speed (10, 20 or 30°/s according to the subject's tolerance). The patient had to look attentively at the points ("look" condition) during 1 minute then the patient was asked to look passively at the dots, for 2 minutes ("stare" condition). We calculated the mean OKN gain for each stimulation (CW and CCW), and each condition.
Results: The "gain" in look condition is regular and stable, close to 1 for HS as well as for P and each aetiology, with no statistical difference. In "stare" condition the gain is significantly lower ($p<0.0001$) than in look condition for HS and P, and also for each aetiology. But "stare" OKN gain is much lower ($p<0.0001$) in group HS than in group P (respectively 0.41 ± 0.14; and 0.65 ± 0.15). After rehabilitation, the OKN "stare" gain drops and becomes, for all groups as for HS. Sensations were classified during "stare" condition into four levels (level –1: visual dependence, i.e. patient disturbed; level 0: no instability and no self-motion illusion; level 1: background seems to move in opposite direction to the dots; level 2: vection, i.e. the subject himself feels as if he is moving in opposite direction to the points. HS tolerate OKN stimulation and most of them (67%) are at level 0, although the majority of patients are at level -1 (66%). After rehabilitation, the distribution of sensations becomes close to that of group HS except for vection (level 2), which becomes more frequent in patients than in HS.
Conclusion: We have found a new pattern of OKN gain that separates chronic vestibular pathologies from HS. This new pattern was the same for each aetiology. It disappears with repeated OKN stimulation. We suggest that inhibition of stare OKN in chronic vertigo patients is explained by the persistence of a strategy adopted during acute vertigo: an overuse of cortical OKN system in order to reduce retinal slip produced by spontaneous nystagmus. This avoidance of retinal slip could also prevent adaptive change in altered VOR gain since it is known that the vestibular cerebellum requires for compensation, a signal error of VOR to compensate. This avoidance of retinal slip could also prevent adaptive change in altered VOR gain since it is known that a signal error of retinal slip is required by the vestibular cerebellum for compensation.

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Change in Velocity - A Useful Outcome Measure in Vestibular Rehabilitation? A Preliminary Study

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Background: Walking is suggested as gold standard for assessing balance and functional performance in patients with vestibular deficits. Gait velocity is reduced in the vestibular deficient patient compared to the healthy. For functional purposes it is important to obtain adequate velocity depending on the task and environmental requirements. Increase in velocity following therapy may thus reflect improvement in gait functions and balance. Tests registering gait velocity seem to be lacking in the clinic for this group of patients.
Objectives: To explore velocity as an outcome measure in the treatment of patients with vestibular disorders.
Methods: Six patients (5 women, mean age: 54.8ys ±4.8) with vestibular deficiencies due to peripheral (n=5) and central vestibular disorders (n=1) were examined before and after a program of vestibular rehabilitation (VR). The peripheral diagnostic category was vestibular neuritis (n=4), the central diagnosis was of the cervicogenic type (n=1) while the last diagnostic category was mixed peripheral and central: perilymphatic fistula and post-concussion syndrome (n=1). All the patients had long-lasting complaints of dizziness and imbalance (>8 months), symptoms being more pronounced during locomotion. Vestibular asymmetry was established by calorics in 5 of the patients. Gait parameters were collected using GAITRite, an electronic walkway commercially available and connected to a computer. The patients walked across the mat following standardized procedures. The same procedure (slow, preferred and fast walks) was used before and after intervention, a total of four registrations of each velocity were collected per test day. The rehabilitation program comprised exercises commonly used in VR, and was organized as group training (10 weeks). No attention was paid to exercises that could be expected to increase gait velocity.
Results: For the group as a whole there was a significant increase in preferred gait speed from 1.2 m/sec to 1.4 m/sec ($p=0.04$). An increase in speed was also observed in the slow (from 0.71 to 0.86 m/sec) and fast velocities (1.8 to 1.9 m/sec), but the changes were not significant.
Conclusion: Results indicate that it is possible to influence gait velocity by a program of VR and thus discriminate between pre-and post-therapy scores. To our knowledge, there is no clinical test available using velocity as outcome variable. The Dynamic Gait Index (DGI), a scale commonly used in patients with vestibular disorders has a 4-point ordinal assessment scale. The DGI lacks rules for

scoring, and a possible ceiling effect is questioned. Outcome variables based on ratio scales, like gait velocity, may be more reliable. Development and validation of a timed gait test to be used in the clinic is in progress.

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Vestibular Rehabilitation Outcome of Patients with Unilateral Vestibular Deficits: Results from Turkey

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Background: Patients with vestibular disorders frequently report vertigo, imbalance and gait problems. In the 1940s, pioneering authors Cawthorne and Cooksey suggested a treatment for vertigo that was a radical departure from the traditional medical management that many physicians still use today.
Objectives: The main purpose of this prospective study was to assess the efficacy of vestibular rehabilitation program for patients with unilateral peripheral vestibular deficits.
Methods: Patients who had unilateral peripheral vestibulopathy are assessed during pre- and post-rehabilitation periods in terms of functional, physical and emotional conditions using Dizziness Handicap Inventory. All patients were treated as their own control group.
Results: Forty-seven patients (31 women and 16 men) with a mean age ± standard deviation (SD) of 51.25 ± 12.9 years (min:26-max:76) were included in the study. All the mean values of Dizziness Handicap Inventory scale scores and subscores increased significantly after vestibular rehabilitation (p=0.000).
Conclusion: The Cawthorne - Cooksey program is effective for treating unilateral peripheral vestibular pathologies. Improvement affects both control of body balance and performance of activities of daily living.
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P208

Balance Prosthesis: Postural Control and Head Shaking

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Background: A Vibrotactile Balance Prosthesis using somatosensory substitution has been tested in a variety of experimental conditions and has been shown to help decrease sway under adverse conditions.
Objectives: Our experimental design involved multitasking: horizontal head shaking, with auditory stimulation via a metronome.
Methods: Seven patients were placed on the Posturography Platform and asked to stand quietly during the Sensory Organization Test (SOT) Condition 5 (sway referenced, eyes closed) while wearing the Balance Prosthesis. All subjects had failed SOT Condition 5, were well compensated, and had either a vestibular neuronectomy or suffered from incomplete bilateral vestibular loss. All of them had participated in vestibular rehabilitation, are active individuals, and are well compensated. During experimentation, subjects were tested during two opposite activities known to alter the Posturography response: A) head shaking horizontally side to side to the beats of a metronome and B) keeping the head still. We then had the prosthesis turned on or off, as those two head-shaking/head still conditions were repeated. Prior to data collection, patients were familiarized with the use of the prosthesis using SOT conditions 2 and 5. Two patients were unable to stand up while shaking their heads, and for those patients, the Posturography gain was decreased. After training, twelve 20-second trials of each of the four conditions, totaling 48 trials were run, with two short periods of rest.
Results: Analysis of the results showed that subjects swayed the most during the head shaking trials with the Balance Prosthesis turned off, and that sway was decreased when the Balance Prosthesis was turned on. The least amount of sway was obtained when the head was still and the prosthesis turned on.
Conclusion: The current Balance Prosthesis is able to improve the patient's balance under further destabilizing circumstances, which are similar to events encountered during normal activities.
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P209

Vestibular Rehabilitation: Results with 250 Patients

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Background: Vestibular rehabilitation is indicated when medication, liberatory maneuvers or natural exercises of daily life are not enough to completely cure or completely compensate vestibular diseases.
Objectives: The aim of this study is to situate which factors prevent natural vestibular compensation in order to build specific program for each.
Methods: 250 patients underwent vestibular rehabilitation between 1998 and 2003.
For all patients we assessed: results of otoneurological exploration, pathologies of other systems of balance that could interfere with vestibular compensation. We tried to find out if visual dependence had appeared or had increased since the start of vestibular disease, to evaluate psychosocial context of disease. We also performed a battery of tests to analyze the balance and sensations of the patient, when the subject is standing still with or without foam in darkness, or when he is submitted to optokinetic stimulation. Then the subject is seated on a rotating chair and is turned slowly for few seconds, right or left. This exercise is executed with eyes open, with or without fixation (retinal slip), and eyes closed (isolated vestibular stimulation). The aim was to discover which stimulation provokes symptoms that the patient feels in daily life.
Results: Meniere disease (20%), unilateral canal paresis (19%) unsteadiness (12%) are the most frequent aetiologies of all patients (group P). Two sub-groups are distinguished; group A with patients who underwent only 1–4 sessions (36.8%) and group B who underwent more than 4 sessions (63.2%). Mean numbers of sessions in group B is 10. In group A, the patients with neuroma or bilateral vestibular areflexia are the most frequent aetiologies. Patients in this group stopped early the rehabilitation because they feel cured (35%), non motivated (19%), satisfied (7%). In group B, abnormalities in otoneurologic examination is found in 31% of cases. Main symptoms of patients were unsteadiness (75%), vertigo (28%), isolated visual dependence, depression (38%). On foam, 63% of patients were disturbed and foam triggered the main symptom of 32% of patients. On rotating chair, 42% were disturbed at least once and 8% were disturbed only in one condition. Global results of rehabilitation: improvement in 41%; satisfaction in 52%; and failure in 7% (mainly bilateral areflexia and pseudo neuritis).
Conclusion: Exercises could identify the mechanism of non-compensation: persistence of overuse of podal input or visual input or vestibular input. So we think that patients had adopted a rigid strategy during acute vertigo and were keeping this strategy even when crisis is over. We can often find an origin of this persistent rigid strategy in patients' history with other disease and psychological context. Vestibular rehabilitation could fit each patient.

P210

Correcting Ocular Torsion in Basicranium Asymmetries

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Background: Unilateral ocular torsion (OT) is widely described as a consequence of CNS and/or vestibular disorders but is also specific of basicranium asymmetries (BCA). BCA involves anatomical asymmetry of the orbits and labyrinths.
Objective: To measure OT with an easy, reproducible and fast exam, to provide optical correction for the torsions.
Methods: We examined 320 patients, who all had visual acuity measures according to the ETDRS as well as a binocular vision study. Fundus images of both eyes were taken using the HRA (Heidelberg retinal angiograph) while the patient was wearing a special helmet to verify the 0° head position, with IR and RF filters. On the red free images, the position of the fovea was measured in degrees using the AOB angle, O being the center of the papilla, OA the horizontal line drawn from O, OB the line from O to the foveola. OCT was performed in all patients to crosscheck the location of fixation point as well as to evaluate the anatomical normality of the eye. Follow up after prismation was obtained.
Results: Ocular torsion was present with a mean angle of 6.2° (± 3.8°) in 90% of patients, and 82% of patients show a left torsion. Significant basicranium asymmetries are present in 72% of cases. Refractive errors are common (74% of study subjects) and astigmatism is present in 41% of patients, and 54% have an oculomotor deficit, mostly K syndromes (41%). Subjective pain evaluation was improved before and after prismation as well as cessation of migraines: in 77% of cases patients were able to stop pain medications.
Conclusion: Ocular torsion seems to be very common in the population that presents cervical pain and migraines, because of the associated head tilt in roll. Prevalence of left torsion can possibly be explained by developmental factors. Prismation can correct the tilt of the head based on oculocephalogyrus reflex, by exciting a refixation saccade. Prismation seems to be an effective therapy that can possibly help in reducing the need for analgesics and correcting posture problems in adults as in children.

P211

Macular Gravity Receptor Influence on the Intrinsic Circadian Period and Light Sensitivity of the Mammalian Pacemaker

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Background: Recently, it has been reported that the vestibular macular gravity receptors (i.e., organs utriculus and sacculus) can influence the regulation of the circadian timing system (CTS), suggesting that the vestibular system and CTS may be linked [1]. The present study was designed to evaluate the influence of the macular gravity receptors on: 1) the intrinsic period of the circadian pacemaker and; 2) the period-lengthening response to increasing light intensity, i.e., "Aschoff's Rule".

Objectives: Here, we tested the hypothesis that mice lacking functional macular gravity receptors would demonstrate a significantly different intrinsic circadian period in constant lighting conditions (dark and light) as well as an altered period response to changes in light intensity as compared to mice with intact macular receptors.

Methods: Our model, the head tilt mouse (het/het abbreviated het) lacks otoconia, the inertial elements of the macular organs, and thus gravity reception; however, canal and auditory function are normal. Twelve male, adult het mice (het/het) and 12 male, adult heterozygote normal littermates (het/+), termed WT mice here (Mus musculus), were housed individually and circadian rhythms in body temperature (Tb) and activity (ACT) were recorded via biotelemetry in: 24-hour light-dark cycles (LD); constant darkness (DD, 0 micromoles s-1 m-2); and constant light (LL, 0.5 micromoles s-1 m-2). The data were analyzed for circadian period.

Results: We found that, in DD, het mice (n=12) demonstrated a significantly longer circadian period of Tb (23.97±0.04 vs. 23.65±0.08 hours; $p<0.001$) and ACT (23.95±0.06 vs. 23.67±0.10 hours; $p<0.001$) rhythms compared to WT mice. In addition, the het mice demonstrated a significantly attenuated (0.56±0.14 vs. 1.02±0.14 hours; $p<0.001$) period-lengthening response to increased ambient illumination (LL) compared to WT mice.

Conclusion: The results of the present study provide the first evidence for a vestibular influence on the mammalian circadian pacemaker. As the intrinsic period of the circadian pacemaker is a determinant of the phase angle of entrainment and the limits of entrainment, an abnormal period has been suggested as an etiology for many disorders [2]. For example, changes in the period of the circadian pacemaker have been both implicated in and exhibit a high co-morbidity with aging, circadian sleep-wake and mental health disorders. Results from the present study suggest the possibility that vestibular dysfunction may be a contributing etiology to the pathophysiology of a subset of circadian and circadian sleep-wake disorders.

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Aging Effects on Vestibulo-Ocular Responses in C57BL/6 Mice: Comparison with Alteration in Auditory Function

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Background: The mechanisms involved in age-related changes in auditory and vestibular function have been investigated using animal and human subjects. Various animal models have been reported for the study of age-related changes in hearing, especially aging-induced sensorineural hearing loss (presbycusis). In contrast to auditory function, an animal model for the study of age-related vestibular dysfunction has not been established, although age-related changes in vestibular function have been investigated in humans.

Objectives: In this study, we evaluated age-related changes in vestibulo-ocular responses in C57BL/6 mice that have long been considered as a model of presbycusis.

Methods: We observed the alteration in horizontal vestibulo-ocular reflex (VOR) responses of C57BL/6 mice during aging and compared with the alteration in auditory brain stem responses (ABRs). In parallel to functional assessments, morphological changes in the auditory and vestibular peripherals were examined to elucidate the relationship between age-related degeneration in the peripheral sensory organs and functional loss.

Results: The gain of VOR increased depending on ages until 12 weeks and then exhibited moderate dysfunction due to aging over 24 weeks. On the other hand, no alteration in thresholds of ABRs was observed from 3 weeks to 12 weeks; however, ABR thresholds significantly elevated from 24 weeks. Histological analysis demonstrated degeneration of auditory peripherals that was closely related with functional loss due to aging. Vestibular peripherals also exhibited age-related degeneration similarly to auditory, although age-related dysfunction was not apparent. Age-related changes in vestibular function of C57BL/6 mice demonstrated different time course from those in auditory function. In addition, morphological degeneration of the peripheral systems was closely associated with auditory function, but not with vestibular function.

Conclusion: These findings suggest that the central system may play a key role in age-related changes in vestibular function.

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Determining Age-Related Changes in Vestibular Function Using Clinical Measures

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Background: Our research team is investigating the causal factors related to the decline in balance that has been demonstrated across the 40 to 60 age period [1,2].
Objectives: Clinical measures were used to investigate changes in gaze stability and balance with age.
Methods: Three hundred and twenty (320) independently ambulant women were recruited through the electoral roll to represent healthy women aged 20 and 80 years. Postural stability was measured using force-plates (velocity of sway) while the modified CTSIB [3] was undertaken and while the subject maintained stability during a series of head movements: gentle head shaking with eyes focused on a marker; moving head and eyes in tandem to set markers and gentle head shaking with eyes closed. Gaze stability was determined by using the Dynamic Visual Acuity Test [4] as well as by observational ratings of focal gaze during passive head movement and following the Halmagyi Impulse Test [5] using both normal vision and 20-diopter lens.
Results: Analysis of data for the mCTSIB tasks showed that foam conditions with eyes closed were most demonstrative of change with a significant decline in stability by the 50's and further loss in stability by the 70's. With eyes open, the decline in stability was evident from the 60's. All subjects were able to manage the firm conditions (eyes open and closed) with the head stationary without a significant decline in stability. When head movement was introduced, particularly when rotated while gaze was fixated on an object, postural stability was significantly reduced between the 40's and 60's and between the 50's and 70's and from the 60's with the other head movements. The Dynamic Visual Acuity Test demonstrated that healthy women were able to maintain gaze stability until the 60's and then a significant decline in gaze stability emerged. When normal vision was available, the capacity to maintain gaze stability during passive head movements and with head impulse to midline showed no significant difference across age cohorts until the 60's. Use of the 20-diopter lens caused a significant decline from the 40's.
Conclusion: The results show that test conditions implicating vestibular function are indicative of early changes in postural and gaze stability with age. Clinical measures of gaze stability together with balance measures could be used as part of a screening protocol to identify people with deficits and assist with appropriate referral.
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Balance Training and Visual Rehabilitation in AMD Patients

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Background: With aging, efficiency of sensory and motor functions decreases, possibly resulting in falls (Lord, 1996). In addition to central visual loss, 2/3 of Age-Related Macular Degeneration (AMD) patients present ENT deficits (Diard, 1998). AMD pathology is the main cause of low vision in developed countries, and affects 20% of the >70 yrs old population. In order to regain abilities in daily life tasks, we used perceptual learning procedures. The patients spontaneously develop preferred retinal loci (PRL) in an attempt to catch straight ahead visual information. The shift between PRLs results to the loss of spatial references. The rehabilitation program consists, initially, in the choice and the development of a systematic trained retinal locus (TRL) during fixation, saccades and pursuits.
Objectives: In line with studies on cortical plasticity and the role of feedback processes, we showed that the use of visuomotor training improves the stabilization of TRL. We investigate the effects of multi-sensory training on postural stability and sensory organization in elderly adult controls and in AMD patients. The impact on stabilization of an eccentric retinal fixation is measured. We expect to foster the use of the visuo-vestibulo-proprioceptive loop and so, to shorten the number of rehabilitation sessions.
Methods: We compared the results of a group of more than 12 patients (central scotoma, 1.7<VA>0.5 LogMAR), with those of a group of healthy age-match subjects (60-90 yrs). On a postural platform (Multitest®), 1) we measured the initial balance status, 2) we trained balance, stressing sensori-motor coordination by selectively inhibiting or luring either visual, vestibular or somesthetic information, because producing a conflict between two systems reinforces of the other system, 3) we measured the resulting balance status. In conditions 1) and 3), we assessed the amount and distance of mis-pointing during a random presentation of targets on a computer touch-screen in relation to the shift of PRL / TRL.
Results: Preliminary results indicate that training balance accelerates sensory reorganization and, for AMD patients,

improves visual information integration used in stabilization of eccentric fixation and accuracy in visuomotor tasks.
Conclusion: These results suggest that sensory and motor processes interfere with visual processing in cross-modal balance training.
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Influence of the Age on the Static Posturographic Results in Healthy People
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Background: Static posturography allows knowing a lot of balance parameters on each one of the studied conditions: opened and closed eyes Romberg without foam (OER and CER) and with foam (FOR and FCR). The influence of the age on the results of the posturography parameters is a controversial subject.
Objectives: To know the influence of the age on the parameters of the posturography.
Methods: Patients: 64 volunteers with normal vestibular function (mean age: 53,4 years) (range: 10-82).
Methods: static posturography (NedSVE/IBV) using a thirteen centimeters foam. Statistics: Pearson correlation coefficient and multiple regression analysis of the sway amplitude on FOR and FCR.
Results: (*: significance with p<0,05; **: significance with p<0,01). 1) Age-sway amplitude on OER: r:0,007 (NS); CER: r:0,059 (NS); FOR: r:0,592**; FCR: r:0,612**. 2) Age-sway velocity on OER: r:0,155 (NS); CER: r:0,120 (NS); FOR: r:0,487**; FCR: r:0,335**. 3) Multiple regression analysis: there is a linear relation between age and sway amplitude on FCR and FOR (Age = 27,29 + 0,01FCRsa + 0,06FORsa)
Conclusion: 1. Sway amplitude on foam conditions is the better parameter to know the postural control deterioration age-related. 2. Sway amplitude on the different posturographic conditions is bigger in according with the patient is older, so the person losses progressively the capacity to maintain the gravity center when the visual and/or somatosensory systems are distorted.
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Effects of Aging on Head and Trunk Movements During Walk
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Background: Recently, accidental falls in the elderly has become a social issue. Pathological mechanisms of aging related to the stability during walk should be clarified; therefore some universal, simplified technique to evaluate the stability during walk should be developed.
Objectives: The aim of the current experiments is to investigate head and trunk movements during walk in healthy adults to see the effects of aging on the kinematics of walking.
Methods: 10 healthy adults each in 20's, 50's, 60's, and 70's were examined. Infrared reflexive markers were placed at the top, and at both lateral side of the head, the neck, and at the waist. Subjects walked straight along the hallway for five seconds' periods. They walked five times with eyes open, and five times with a blindfold with their comfortable speed. The movements of each marker were recorded with two infrared CCD cameras, and processed using a three-dimensional motion analysis system, MacReflex® of QUALISYS. Walking velocity, head rotation in the roll plane (head roll), and trunk rotation in the roll plane (trunk roll) were estimated.
Results: Subject in 70's walked slower than those in 50's or 60's. Head roll was significantly smaller in the subject in 70's than those in 50's. No difference was seen in trunk roll among age groups. There found two types of relation between head and trunk roll. One was that head rolled to the opposite direction to trunk (negative relation), and the other to the same direction (positive relation). The number of the subject who showed negative and positive relation were 8 and 2 in 20's, 4 and 3 in 50's, 5 and 3 in 60's, and 6 and 2 in 70's respectively with eyes open. With a blindfold the number of the subject were 5 and 1 in 20's, 2 and 4 in 50's, 2 and 2 in 60's, 4 and 3 in 70's, respectively.
Conclusion: I. Effects of aging upon head and trunk movements during walk
In most subjects in 20's head and trunk rolled to the opposite direction, whereas the number of the subjects increased in those 50 years and above in whom head and trunk rolled to the same direction. The head roll must have physiological significance of maintaining the stability by reducing the sway of center of gravity. The control of head position during walk might be declined, and as the result the head might tend to move passively according to the trunk sway in a higher proportion of older subjects. These findings

suggest that there might be a latent decrease in the vestibular function in those subjects. II. The influence of vision The relation of head and trunk motion did not so much change between the two visual conditions in most subjects in 20's. On the contrary in the subjects aged 50 years and above, positive relations were more frequently observed with a blindfold. This suggests that in the subjects in 20's spatial orientation depends highly on vestibular inputs but not much on visual inputs, while in the subjects aged 50 years and above, it depends more on visual inputs.

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Age-Related Changes in Three Dimensional Vestibulo-Ocular Reflex

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Background: Age leads to histological changes in anatomic structures involved in vestibulo-ocular reflex (VOR) [1], which may lead to a decline in VOR gain. Alternatively, if the central compensatory mechanisms remain intact, the function of VOR may remain relatively stable in spite of peripheral anatomical deterioration. Most studies indicate decreased gain with increasing age [2]. Vestibular loss can be best demonstrated by the head-impulse test, which uses high accelerations [3].
Objectives: We tested how age affects three-dimensional rotational VOR response characteristics to transient rotational testing at high acceleration.
Methods: We studied two age separate groups of healthy human subjects (9 young, 25 to 35y; 8 elderly, 61 to 81y). Performance of VOR was tested by unpredictable manually delivered head rotations in three orthogonal planes (torsional, vertical, horizontal) with angular accelerations up to 13000 °/s^2. 3-D eye and head position was recorded using dual search coils. Eye and head velocity at 40 ms from onset of the head impulse were analyzed to determine instantaneous VOR gain [4].
Results: VOR gains changed significantly with age as revealed by ANOVA [$F(1,15=9.9$; $p=0.0066$] with elderly subjects showing lower VOR gains (young 0.78±0.02 SE; elderly 0.67±0.02 SE). The decay tended to be highest in the torsional plane. Independent of age, vertical and horizontal gains were significantly higher [$F(2,30)=45.0$; $p<0.0001$] than torsional gain.
Conclusion: Head impulse testing disclosed age-related deterioration in VOR gains in all planes of stimulation. If the decay of peripheral anatomical structures [1] involved in the VOR would be the only factor for age-related gain decrease, a similar change in torsional and vertical gain would be expected, since vertical and torsional VOR share the same peripheral sensors and pathways. Different decays in these planes suggest a plane-specific compensatory involvement of central vestibular structures, e.g., the cerebellum.

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