

Supplementary Material

Listener Detection of Objectively Validated Acoustic Features of Speech in Huntington's Disease

Supplementary Table 1. Perceptual characteristics of speech in premanifest and early stages of HD compared with healthy controls on sustained vowel and reading tasks.

Perceptual speech measures	Group	Frequency and Degree of severity (N, %)			
		Unremarkable	Sub-clinical	Mild	Moderate
Pitch					
Abnormal pitch	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	11 (68.8%)	5 (31.3%)	0 (0.0%)	0 (0.0%)
	Control-B	13 (92.9%)	1 (7.1%)	0 (0.0%)	0 (0.0%)
	EarlyHD	10 (71.4%)	4 (28.6%)	0 (0.0%)	0 (0.0%)
Pitch breaks	Control-A	15 (93.8%)	1 (6.3%)	0 (0.0%)	0 (0.0%)
	PreHD	14 (87.5%)	2 (12.5%)	0 (0.0%)	0 (0.0%)
	Control-B	13 (92.9%)	1 (7.1%)	0 (0.0%)	0 (0.0%)
	EarlyHD	11 (78.6%)	2 (14.3%)	1 (7.1%)	0 (0.0%)
Voice tremor	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	14 (87.5%)	2 (12.5%)	0 (0.0%)	0 (0.0%)
	Control-B	12 (85.7%)	2 (14.3%)	0 (0.0%)	0 (0.0%)
	EarlyHD	10 (71.4%)	4 (28.6%)	0 (0.0%)	0 (0.0%)
Loudness					
Increased loudness	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	12 (85.7%)	2 (14.3%)	0 (0.0%)	0 (0.0%)
Reduced loudness	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	11 (68.8%)	5 (31.3%)	0 (0.0%)	0 (0.0%)
	Control-B	12 (85.7%)	2 (14.3%)	0 (0.0%)	0 (0.0%)
	EarlyHD	10 (71.4%)	4 (28.6%)	0 (0.0%)	0 (0.0%)
Monoloudness	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	10 (62.5%)	5 (31.3%)	1 (6.3%)	0 (0.0%)
	Control-B	11 (78.6%)	3 (21.4%)	0 (0.0%)	0 (0.0%)
	EarlyHD	6 (42.9%)	6 (42.9%)	2 (14.3%)	0 (0.0%)
Loudness decay	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	15 (93.8%)	1 (6.3%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	10 (71.4%)	3 (21.4%)	1 (7.1%)	0 (0.0%)
Voice quality					
Harsh voice	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	12 (75.0%)	4 (25.0%)	0 (0.0%)	0 (0.0%)
	Control-B	9 (64.3%)	3 (21.4%)	2 (14.3%)	0 (0.0%)
	EarlyHD	3 (21.4%)	8 (57.1%)	3 (21.4%)	0 (0.0%)
Hoarse voice	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

	PreHD	13 (81.3%)	3 (18.8%)	0 (0.0%)	0 (0.0%)
	Control-B	10 (71.4%)	4 (28.6%)	0 (0.0%)	0 (0.0%)
Breathy voice	EarlyHD	5 (35.7%)	8 (57.1%)	1 (7.1%)	0 (0.0%)
	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	11 (68.8%)	5 (31.3%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strained voice	EarlyHD	3 (21.4%)	9 (64.3%)	2 (14.3%)	0 (0.0%)
	Control-A	15 (93.8%)	1 (6.3%)	0 (0.0%)	0 (0.0%)
	PreHD	7 (43.8%)	8 (50.0%)	1 (6.3%)	0 (0.0%)
	Control-B	10 (71.4%)	3 (21.4%)	1 (7.1%)	0 (0.0%)
	EarlyHD	3 (21.4%)	7 (50.0%)	4 (28.6%)	0 (0.0%)
Resonance					
Hypernasality	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	11 (68.8%)	5 (31.3%)	0 (0.0%)	0 (0.0%)
	Control-B	11 (78.6%)	3 (21.4%)	0 (0.0%)	0 (0.0%)
	EarlyHD	7 (50.0%)	4 (28.6%)	3 (21.4%)	0 (0.0%)
Hyponasality	Control-A	15 (93.8%)	1 (6.3%)	0 (0.0%)	0 (0.0%)
	PreHD	13 (81.3%)	3 (18.8%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	11 (78.6%)	2 (14.3%)	1 (7.1%)	0 (0.0%)
Prosody					
Abnormal speech rate	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	8 (50.0%)	8 (50.0%)	0 (0.0%)	0 (0.0%)
	Control-B	13 (92.9%)	1 (7.1%)	0 (0.0%)	0 (0.0%)
	EarlyHD	5 (35.7%)	8 (57.1%)	1 (7.1%)	0 (0.0%)
Short phrases	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	13 (81.3%)	3 (18.8%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	8 (57.1%)	5 (35.7%)	1 (7.1%)	0 (0.0%)
Prolonged interval	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	13 (81.3%)	2 (12.5%)	1 (6.3%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	9 (64.3%)	4 (28.6%)	1 (7.1%)	0 (0.0%)
Short rushes of speech	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	15 (93.8%)	1 (6.3%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	9 (64.3%)	2 (14.3%)	3 (21.4%)	0 (0.0%)
Excess and equal stress	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	7 (50.0%)	4 (28.6%)	3 (21.4%)	0 (0.0%)
Articulation					
Imprecise consonants	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	11 (68.8%)	4 (25.0%)	1 (6.3%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	3 (21.4%)	9 (64.3%)	2 (14.3%)	0 (0.0%)

Prolonged phonemes	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	13 (81.3%)	3 (18.8%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	8 (57.1%)	3 (21.4%)	3 (21.4%)	0 (0.0%)
Articulatory breakdowns	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	14 (87.5%)	2 (12.5%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	8 (57.1%)	3 (21.4%)	3 (21.4%)	0 (0.0%)
Distorted vowels	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	14 (87.5%)	2 (12.5%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	8 (57.1%)	5 (35.7%)	1 (7.1%)	0 (0.0%)
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Intelligibility					
	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	15 (93.8%)	1 (6.3%)	0 (0.0%)	0 (0.0%)
	Control-B	14 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	EarlyHD	11 (78.6%)	2 (14.3%)	1 (7.1%)	0 (0.0%)
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Naturalness					
	Control-A	16 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	PreHD	9 (56.3%)	5 (31.3%)	2 (12.5%)	0 (0.0%)
	Control-B	12 (85.7%)	1 (7.1%)	1 (7.1%)	0 (0.0%)
	EarlyHD	1 (7.1%)	6 (42.9%)	7 (50.0%)	0 (0.0%)

Control-A = Healthy individuals who have been age- and sex-matched to participants in PreHD group

Control B = Healthy individuals who have been age- and sex-matched to participants in EarlyHD group

Supplementary Table 2. Correlation between perceptual and acoustic speech-timing measures.

Spearman's rho (<i>p</i>)	Perceptual features			
	Speech rate	Short phrases	Variable rate	Prolonged intervals
Acoustic measures				
Pause (mean)	-0.28 (0.03)*	0.28 (0.03)*	0.44 (0.001***)	0.39 (0.002**)
Pause (SD)	-0.25 (0.06)	0.23 (0.08)	0.39 (0.002**)	0.32 (0.013*)
%Silence	-0.21 (0.10)	0.07 (0.59)	0.30 (0.02*)	0.19 (0.16)
Speech rate	0.21 (0.10)	-0.07 (0.59)	-0.30 (0.02*)	-0.19 (0.16)

Strength of Spearman's correlation (r_s): $r_s < 0.40$ weak, $0.40 \leq r_s < 0.60$ moderate, $0.60 \leq r_s$ strong

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Supplementary Table 3. Group performance [Mean (SD)] and correlations between SDMT and speech-timing outcome (significant results in **bold**).

	EarlyHD		PreHD	
	Mean (SD)	Pearson correlation (<i>r</i>, sig.)	Mean (SD)	Pearson correlation (<i>r</i>, sig.)
Cognitive measures				
SDMT (total)	32.82 (9.65)		58.67 (11.63)	
Speech-timing acoustic measures				
Reading – Speech rate	3.01 (0.68)	0.51* ↑	3.88 (0.67)	0.77** ↑
Reading – Silence percentage	24.77 (6.06)	– 0.19	20.16 (4.54)	0.03
Monologue – Silence percentage	29.63 (10.07)	– 0.60* ↓	21.65 (8.21)	– 0.36

Note: The identification of a group difference was based on a one-way analysis of variance (two-tailed). Correlations between speech task performance and SDMT performance are highlighted in bold and annotated according to the strength and direction of the relationship.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ at $\alpha < 0.05$ level

Strength of Pearson correlation: $r < 0.29$ = weak, $0.30 < r < 0.49$ = medium, $0.50 < r < 1.00$ = strong

↑ positive correlation, ↓ negative correlation