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Movement-in-depth, cognitive impairment, and crash risk

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Abstract. In this study, 243 cognitively intact and cognitively impaired older participants' movement-in-depth (looming) abilities were assessed using a portable device that we had previously developed in our laboratory [4]. Results indicated normative relationships between looming ability and age, looming ability and driving violation records, and age and driving violation records. Findings also confirmed the validity and reliability of the measurements taken with the device. In conclusion, this device may be useful for identifying drivers at risk for rear-end collisions, developing effective training interventions, and creating fair and valid driver licensing tests.

Keywords: Movement-in-depth, rear-end-collisions, older drivers, loom, cognitive impairment

1. Introduction

According to the United States National Highway Traffic Safety Administration (NHTSA), in 2008 an estimated 1.75 million rear-end collisions resulted in more than 464,000 injuries, 1,900 fatalities, and 1,284,000 cases of property damage [3]. One reason for these crashes may be that some people are less able to detect when they are closing in on another vehicle, an ability known as movement-in-depth or looming. This research evaluated and field-tested a portable device that assesses movement-in-depth ability in cognitively impaired and cognitively intact older adults and investigated the relationship between looming ability, age, cognitive status and driving violation records.

2. Method

2.1 Participants

The loom thresholds of 243 older participants' were assessed. Participants were recruited from community-dwelling elderly and also through referrals from a local memory disorder clinic.

2.2 Procedure

The loom task took about 15 minutes of experimental time. This permitted three sessions, each of which involved 25 determinations at six different velocity growth rates (0.00 degrees per second; 0.0156 deg/s; 0.0312 deg/s; 0.0468 deg/s; 0.0624 deg/s; and 0.0780 deg/s).

The past history of driving crashes was accessed by having subjects respond to a questionnaire that was constructed to summarize information that currently appears in individual Florida Traffic Crash Reports throughout the State and also included questions from the Owsley Driving Habits Questionnaire [1] with the focus on rear-end collisions. Participants also completed a Static Visual Acuity assessment and a driving history questionnaire. Participants were also administered the Mini-Mental Status Exam (MMSE) in order to assess cognitive status where a score of 26 or below identified individuals with cognitive impairment. In addition, participants were administered a series of cognitive tests that predicted whether or not they were likely to fail an on-the-road test, and were then administered the road test. Participants in this study were also administered the Useful Field of View (UFOV) test [2].

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3. Results

3.1. Repeated Measures Analysis of growth rate by age group

A repeated measures analysis of variance was conducted on the data. The within subject factors were the 6 growth rates and the between subjects factors were age group (1 = 74 years and younger, 2 = 75-84 years, 3 = above 85). The analysis indicated a significant overall effect for the model. The analysis further indicated a significant overall effect for growth rate ($F(5, 990) = 17.11$, $p < .005$) and a significant effect for age group ($F(2, 198) = 3.06$, p = 0.049). Post hoc analyses using Tukey HSD did not indicate significant differences between the specific age groups.

3.2. Repeated Measures Analysis of growth rate by cognitive status

A repeated measures analysis of variance was conducted on the data. The within subject factors were the 6 growth rates and the between subjects factors were cognitive status group and gender. The analysis indicated a significant overall effect for the model. The analysis further indicated a significant overall effect for growth rate ($F(5, 1060)=22.57$, $p < .005$) and a significant interaction effect for growth rate and cognitive status group ($F(5, 1060) = 6.81$, $p < .005$).

3.3. Correlations of Growth Rates with UFOV, age, and cognitive status

3.3.1. The UFOV overall score was positively correlated with age (r = .197, p = .001) and negatively correlated with cognitive status (r = -0.514, p = .000).

3.3.2. The UFOV overall score was negatively correlated with the percentage of correctly identified loom events at the 0.000, 0.0624, and 0.078 deg/s growth rates.

3.3.3. The UFOV overall score was positively correlated with the percentage of correctly identified loom events at the .0156 deg/s growth rate. The UFOV processing speed score was uncorrelated with all of the other variables.

3.3.4. Both UFOV divided attention and switching attention scores were positively correlated with age and cognitive status.

3.3.5. UFOV divided attention and switching attention scores were negatively correlated with the percentage of correctly identified loom events at the 0.000, 0.0624, and 0.078 deg/s growth rates.

3.3.6. UFOV divided attention and switching attention scores were positively correlated with the percentage of correctly identified loom events at the 0.0156 deg/s growth rate.

3.4. Correlation of Loom Score with visual and cognitive measure

3.4.1. The loom score was negatively correlated with MMSE score (r = -.194, p = .004). Individuals with higher loom scores (i.e. poorer loom performance) had poorer MMSE scores.

3.4.2. The loom score was negatively correlated with the road sign recognition score (r = -.314, p = .000). Individuals with higher loom scores (i.e. poorer loom performance) had poorer road sign recognition scores.

3.4.3. The derived loom score was negatively correlated with depth perception score (r = -.219, p = .002). Individuals with higher loom scores (i.e. poorer loom performance) had poorer depth perception.

3.4.4. The loom score was positively correlated with the UFOV category score (r = .322, p = .000). Individuals with poorer loom performance had higher crash risk scores.

3.4.5. The derived loom score was negatively correlated with the UFOV sub-scales of divided and switching attention (r = .257, p = .000; r = .246, p = .001, respectively). Individuals with poorer loom performance had poorer divided and switching attention performance.

3.5. Correlation of loom score and other measures with driving record violations

3.5.1. Loom score was positively correlated with the number of crashes an individual had been involved in (r = .147, p = .023). The poorer the loom performance (higher loom score indicates poorer performance), the higher the number of crashes.

3.5.2. Loom score was positively correlated with the number of improper backing violations committed by an individual (r = .131, p = .038). The poorer the loom performance, the higher the number of improper backing violations.

3.5.3. Loom score was positively correlated with the total number of violations that an individual had committed (r = .153, p = .019). The poorer the loom performance, the more overall violations committed.

3.5.4. MMSE score was positively correlated with the number of speeding violations an individual had (r = .124, p = .026). The higher MMSE score (i.e. the higher the cognitive performance), the higher the number of speeding violations.

3.5.5. MMSE score was negatively correlated with the number of "incapable of operating a motor vehicle" violations (r = -.112, p = .039). The poorer the cognitive performance, the higher the number of these violations.

3.5.6. MMSE was also negatively correlated with the number of "improper backing" violations (r = -.130, p = .02). The poorer the cognitive performance, the higher the number of these violations.

4. Discussion

Results from the study indicated significant age differences among individuals above 60 years of age. Those in the old-old category performed significantly worse than those in the young-old and middle-old categories. Additional analysis of Loom performance by cognitive impairment revealed that although cognitively intact older adults perform less well than middle-aged and young- old adults, their pattern of performance is comparable. A correlational analysis of the loom data with the UFOV test scores revealed various significant relationships. The analyses investigating the relationships between the loom score and other visual and cognitive measures also revealed a number of expected significant findings. And, analyses of the loom score and driving violations indicated that the loom score was also positively correlated with several driving record violations and with the total number of violations committed by an individual.

In conclusion, the execution of this research has allowed us to field-test a device that can assess movement-in-depth ability in adults of different ages, and, as such, were able to identify its predictive validity with real-world criteria. This device will be useful for identifying drivers at risk for rear-end collisions and for the development of effective training interventions and fair and valid driver licensing tests as well.

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