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Older drivers and rapid deceleration events: Salisbury Eye Evaluation Driving Study

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ABSTRACT

Drivers who rapidly change speed while driving may be more at risk for a crash. We sought to determine the relationship of demographic, vision, and cognitive variables with episodes of rapid decelerations during five days of normal driving in a cohort of older drivers. In the Salisbury Eye Evaluation Driving Study, 1425 older drivers aged 67–87 were recruited from the Maryland Motor Vehicle Administration's rolls for licensees in Salisbury, Maryland. Participants had several measures of vision tested: visual acuity, contrast sensitivity, visual fields, and the attentional visual field. Participants were also tested for various domains of cognitive function including executive function, attention, psychomotor speed, and visual search. A custom created driving monitoring system (DMS) was used to capture rapid deceleration events (RDEs), defined as at least 350 milli-g deceleration, during a five day period of monitoring. The rate of RDE per mile driven was modeled using a negative binomial regression model with an offset of the logarithm of the number of miles driven. We found that 30% of older drivers had one or more RDE during a five day period, and of those, about 1/3 had four or more. The rate of RDE per mile driven was highest for those drivers driving <59 miles during the 5-day period of monitoring. However, older drivers with RDE's were more likely to have better scores in cognitive tests of psychomotor speed and visual search, and have faster brake reaction time. Further, greater average speed and maximum speed per driving segment was protective against RDE events. In conclusion, contrary to our hypothesis, older drivers who perform rapid decelerations tend to be more "fit", with better measures of vision and cognition compared to those who do not have events of rapid deceleration.

1. Introduction

Drivers who make rapid decelerations during the course of driving may put strain on drivers behind them, and appear to be more at risk of crash involvement. Simulator studies have shown that sudden stops are particularly predictive of rear end collisions, especially if the leading car is a sport utility vehicle or other higher and wider passenger car (Harb et al., 2007). Driving simulator experiments in right turn lanes show that higher deceleration rates were associated with higher rear-end crash history (Yan et al., 2008).

There are few data on characteristics of drivers who make rapid decelerations. Younger subjects (ages 20–29 years) have been shown to have a shorter deceleration distance and time, compared to older drivers, and tend to drive faster (Porter and Whitton, 2002). Moreover, rear end crashes tend to occur more commonly in younger age groups and among males (Yan and Radwan, 2006).

Crashes which involve older drivers are more likely to involve multiple vehicles and occur at intersections than crashes involving younger drivers (Mayhew et al., 2006). Deceleration patterns have been investigated not only as an indicator of a 'near crash' (Dingus et al., 2006) but also as a measure of appropriate speed management (Baldwin et al., 2004). Age-related decline in physical, cognitive and sensory function, including vision, has been proposed as the reason for poor driving performance and increased crash involvement amongst older drivers (Ball et al., 1993; Stutts et al., 1998; Staplin et al., 2003; Rubin et al., 2007; Horswill et al., 2010;

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Meuleners et al., 2011). In addition it has also been proposed that older drivers lose their driving skills when they start to drive less (Langford et al., 2006). 'The low mileage bias' may explain part of the increased crash risk or compound the effects of decline in function. The larger number of older people who rely on driving for transport, the aging of the population in western countries and increased risk of crash involvement and vulnerability to injury (Lyman et al., 2002; Meuleners et al., 2006; Hanrahan et al., 2009) make older driver safety a growing public health concern. We had an opportunity to evaluate visual and cognitive risk factors among older drivers and their association with rapid deceleration driving events, using a unique driving monitoring system (DMS) that recorded real time driving behavior over a five-day period.

2. Materials and methods

2.1. Population

The Salisbury Eye Evaluation Driving Study participants were recruited by postal invitation through the Maryland Department of Motor Vehicle Administration. The licensees had to be resident in zip codes which encompass the greater Salisbury metropolitan area and aged 67–87 years as of March 1, 2006. The recruitment process has been described in detail elsewhere (West et al., 2009), in brief of 8380 registered licensees, 4503 (54%) returned postcards. Of that group, 6.0% were no longer driving, 1.6% were decreased, and 2.3% were no longer living in the eligible area. Of the remainder, 42% agreed to participate and 83% of them completed the baseline clinic exam and driving assessment ($n = 1425$).

2.2. Study design

Participants had yearly visits, however this analysis is based on the cross sectional data from the baseline visit during which full clinical testing and driver monitoring was completed. A trained interviewer administered a questionnaire that collected data on medical conditions which may affect driving such as arthritis and stroke. We created a pain score that was the simple sum of positive answers to queries about pain in the feet, legs, knees, hips, or current medication use for arthritis; the score ranged from 0 to 5. The depression score was based on the geriatric depression scale (Yesavage et al., 1982), and ranged from 0 to 30 with higher scores indicating more symptoms of depression.

The time taken to brake in response to a visual stimulus was measured using an apparatus described previously (Zhang et al., 2007). The brake reaction time (BRT) was the total time in milliseconds taken for the participant to remove their foot from the accelerator and depress the brake pedal using the average for five test sequences presented at random time intervals.

Each participant underwent a series of vision tests that included visual acuity, contrast sensitivity, and visual field. Presenting binocular visual acuity was tested, with the participant's usual distance vision spectacles, using ETDRS charts and forced choice protocols (Ferris et al., 1982). Results were coded as number of letters correctly identified and scored as LogMAR acuity. Contrast sensitivity was tested for each eye separately using the Pelli Robson contrast sensitivity chart. Results were coded as number of letters correctly identified (Elliott et al., 1990). The visual field was tested using the Humphrey Field Analyzer II, Full Field 81 Point test, with a quantify-defects test strategy. Number of points missing on a 96 point bilateral visual field was recorded (Nelson-Quigg et al., 2000).

The participants also underwent a test of attentional visual fields. The attentional visual field was assessed using a custom-written program that comprised a computer, keyboard, touch-screen monitor, and mouse, and is described in detail elsewhere (Hassan et al., 2008). For a response to be correct, two numbers in the central and peripheral targets had to be correctly identified as well as the location of the peripheral target. The data are recorded as the widest angle out to 20° for which the participant had correct responses, in the vertical (0° and 180° meridians) and horizontal (90° and 270° meridians).

Each participant also underwent a series of tests that measure specific aspects of cognition. We specifically hypothesized a relationship with the cognitive domains of psychomotor speed and visual search, attention, and executive function; the specific test used was the trail making test (TMT) Parts A and B. This test measures visuomotor and perceptual scanning skills, as well as flexibility to shift sets under time pressure. In TMT Part A, the time for participants to connect the smallest numbered circle, to the next higher number circles on a sheet with random distribution of numbered circles, 1 through 25. TMT Part B requires a subject to consecutively connect circles while alternating between numbers (1–13) and letters (A–L), as quickly as possible. The number of seconds to complete Parts A and Part B are scored, with a maximum of 300 s allowed for Part A and a maximum of 480 s allowed for Part B. We also measured auditory divided attention, using the brief test of attention (BTA) (Schretlen et al., 1996). The participant listens to a number of series of letters and numbers and has to correctly count the number of letters heard. Visuo-motor integration was assessed using the Beery–Buktenica Developmental test of visual motor integration (Kulp and Sortor, 2003). In this test, a series of 24 figures of increasing complexity was copied and scored for accuracy by trained observers. The motor free vision integration test is part of the AAA Road Wise assessment and assesses visuo-spatial integration independent of motor skills. The test requires participants to complete an image that is partially drawn by selecting which combination of lines successfully finishes the image. The participant does not have to draw the lines but select from multiple choices. The number of errors was recorded. Planning and problem solving aspects of executive function were assessed using the "Tower of Hanoi" test. The goal is to move successively larger discs from the first to third peg, making sure that at no time a larger disc was on top of a smaller disc. The number of moves required was recorded for this test.

2.3. Driving monitoring system (DMS)

To measure the driving outcomes of interest, each participant's car was outfitted with a DMS created for this project. The system has been described in detail previously (Baldwin et al., 2004) and we summarize it here. Each DMS unit utilized five sensors, which were monitored and recorded by a custom-developed computer system. Data harvesting, time tagging, and storage were accomplished using a data acquisition software package specially created for the purpose. The sensor suite consisted of a high dynamic range color camera, a monochrome camera with infrared LED illuminators, a GPS receiver, a magnetic compass, and a two-axis accelerator. The color camera was oriented such that it captured images of the road in front of the vehicle, while the monochrome camera was positioned so as to capture images of the driver. Both video streams were recorded at a resolution of 352×240 pixels and at a rate of 30 frames per second. The GPS receiver provided location and velocity data at a rate of 1 Hz and the magnetic compass provided heading information at a rate of approximately 8 Hz. Finally, the accelerometers provided lateral and axial accelerations at a rate of 10 Hz.

The GPS receiver, road camera, and driver camera were located in the upper portion of the windshield, on the passenger side of the vehicle. The DMS unit was located behind the passenger seat. After a DMS unit was installed in a participant's vehicle, an installation procedure was observed for aligning both of the cameras and for