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Predictors of older drivers' involvement in rapid deceleration events

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ABSTRACT

Rapid deceleration occurs when substantial force slows the speed of a vehicle. Rapid deceleration events (RDEs) have been proposed as a surrogate safety measure. As there is concern about crash involvement of older drivers and the effect of age-related declining visual and cognitive function on driving performance, we examined the relationship between RDEs and older driver's vision, cognitive function and driving confidence, using naturalistic driving measures. Participants aged 75 to 94 years had their vehicle instrumented for 12 months. To minimise the chance of identifying false positives, accelerometer data was processed to identify RDEs with a substantial deceleration of >750 milli-g (7.35 m/s^2). We examined the incidence of RDEs amongst older drivers, and how this behaviour is affected by differences in age; sex; visual function, cognitive function; driving confidence; and declines over the 12 months. Almost two-thirds (64%) of participants were involved in at least one RDE, and 22% of these participants experienced a meaningful decline in contrast sensitivity during the 12 months. We conducted regression modelling to examine associations between RDEs and predictive measures adjusted for (i) duration of monitoring and (ii) distance driven. We found the rate of RDEs per distance increased with age; although, this did not remain in the multivariate model. In the multivariate model, we found older drivers who experienced a decline in contrast sensitivity over the 12 months and those with lower baseline driving confidence were at increased risk of involvement in RDEs adjusted for distance driven. In other studies, contrast sensitivity has been associated with increased crash involvement for older drivers. These findings lend support for the use of RDEs as a surrogate safety measure, and demonstrate an association between a surrogate safety measure and a decline in contrast sensitivity of older drivers.

1. Introduction

In Australia, over the five years 2008–2012, fatal crashes involving operators aged 65 years and older have increased by 8% (from 218 in 2008 to 233 in 2012), while all fatal crashes decreased by 12% (from 1219 in 2008 to 1068 in 2012) (Bureau of Infrastructure Transport and Regional Economics, 2014). This may be partially due to increases in the numbers of older drivers on the road (Bureau of Infrastructure Transport and Regional Economics, 2014). Older drivers are also at increased risk of injury due to fragility (Kent et al., 2005; Meuleners et al., 2006). Nevertheless, a Queensland study found drivers aged 80 years and older were most likely to be at fault in crashes, regardless of the crash severity (Rakotonirainy et al., 2012). Moreover, there are concerns about crash risk for older drivers with poor or declining visual, cognitive and physical function (Anstey et al., 2012; Wong et al., 2012).

While there is a need to investigate the safety of older driver behaviour, using crashes as a measure of safety is impractical, as large sample sizes and/or long follow up periods are required to provide adequate statistical power for such studies. In naturalistic

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driving studies, near crashes have been defined by a rapid evasive driving manoeuvre (Owens et al., 2015; Wang et al., 2015; Yan et al., 2016). Some researchers have used braking responses as an alternative measure of driving performance, with indices such as deceleration time, deceleration distance, time to collision and brake reaction time (Dingus et al., 1997; Kiefer et al., 2006; Kusano et al., 2015; Markkula et al., 2016; Montgomery et al., 2014; Wege et al., 2013). These driving studies relied on vehicles fitted with equipment to monitor the roadway and vehicles ahead, or driver responses to headway or forward collision warning systems. Researchers involved in the 100 Car Study developed algorithms to detect crashes and near crashes from naturalistic driving based on a combination of these measures and confirmed near crashes by review of video footage (Dingus et al., 2006; Klauer et al., 2009). Klauer et al. (2009) found drivers involved in crashes and near crashes decelerated at >300 milli-g more frequently than drivers who were rarely or had not been recorded as involved in a crash or near crash, and argues this behaviour may have contributed to increased crash and near crash involvement. More recently, the Strategic Highway Research Program 2 (SHRP2) has defined near crashes based on rapid steering, braking or acceleration and confirmed this with review of video footage (Owens et al., 2015). Wang et al. (2015) used maximum deceleration (with a longitudinal trigger threshold of 1.5 m/s^2), average deceleration and percentage reduction in vehicle kinetic energy to define near crashes, and used maximum deceleration to define the risk level of the events with greater deceleration classified as higher risk. This study confirmed findings with review of video footage and found nearly all near crashes involved heavy braking.

Several studies have employed rapid deceleration events (RDEs) as a surrogate safety measure indicative of near crashes (Dingus et al., 2006; Keay et al., 2013b; Klauer et al., 2009; Simons-Morton et al., 2009). Af Wahlberg found acceleration/deceleration behaviour of bus drivers was a more accurate predictor of crash involvement than various measures of speeding (af Wahlberg, 2006), and this behaviour correlated with crashes for which the driver was responsible (af Wahlberg, 2008). Similarly, review of video footage from a teenage driver study found almost all RDEs were due to driver misjudgements (Simons-Morton et al., 2009). Abrupt deceleration has also been associated with stress among bus drivers (Nakai and Ogawa, 2014), and drivers who report frequent mobile phone use while driving (Zhao et al., 2013).

Some research has used other driving errors as surrogate safety measures to assess the relationship between older driver's safety on the road and decreased function. For example, the Salisbury Eye Evaluation and Driving Study found lane change errors and failure to stop at red lights were associated with deficits in visual attention (Munro et al., 2010; West et al., 2010).

Given the relatively new use of RDEs as a surrogate safety measure, there is little research examining the relationship between rapid deceleration; ageing; and declines in visual and cognitive function. We are only aware of one previous study investigating older drivers involvement in rapid deceleration (Keay et al., 2013b). Counter-intuitively, Keay et al. (2013b) using data from the Salisbury Eye Evaluation and Driving Study, found drivers aged 67–87 years involved in RDEs during 1 week of monitoring had better vision and cognition compared to those not involved. However, those with lower mileage were more likely to be involved in RDEs per distance driven. Although not based on RDEs, some studies have found drivers aged over 30 years brake earlier, thereby decelerating quicker than younger drivers (Kusano et al., 2015; Montgomery et al., 2014; Porter and Whitton, 2002). With long term naturalistic driving studies such as Candrive II (Marshall et al., 2013a,b) and SHRP2 (Owens et al., 2015) being conducted, it is anticipated there will be more research emerging in this area. The Candrive/Ozcandrive study involves deploying in-vehicle monitoring continuously over 5 years to record naturalistic driving of more than 1200 Canadian, Australian and New Zealand drivers aged 70 years and older, as well as conducting health and function assessments to examine a number of research questions about safety and exposure measures of these drivers (Koppel et al., 2013; Langford et al., 2013; Rapoport et al., 2013). This sample was chosen to be sufficiently large and over a long enough period of time to allow at-fault crashes to be a primary outcome (Marshall et al., 2013a). Our study examines rapid deceleration in a community-based sample of drivers aged 75 years and older, based on objective, naturalistic driving data collected over 12 months. The objectives of this study were to investigate (i) the incidence of RDEs for older drivers, and (ii) predictors of involvement in RDEs including age; sex; baseline measures of vision, cognitive function and driving confidence; and meaningful decreases in these measures over the 12 months.

2. Methods

2.1 Study design and participants

Volunteer participants joined a Randomised Controlled Trial (RCT) examining an educational safety program (Keay et al., 2013a). We analysed data from the control participants who did not receive the program (n = 190). Eligibility criteria included being aged 75 years or older; achieving two or fewer errors on the Short Portable Mental Status Questionnaire cognitive assessment (Pfeiffer, 1975); holding a valid driver's license; being the primary driver of his/her vehicle (driving at least 80% of the time); and residing in the outskirts of Sydney. Participants were recruited during July 2012 to October 2013, and in-vehicle data collection was completed in May 2014. Most of the participants' vehicles were successfully instrumented (96%, 182/190). The University of Sydney Human Ethics Committee approved the study (Protocol: 14235), and written consent was provided by all participants.

Based on the average rate of 1 to 5 RDEs per participant over 12 months, a sample size of 182 provides 80% power to detect a difference of 13 to 28% in the rate of RDEs per participant per 12 months for a comparison of a binary covariate (Mathews, 2010).

Participants undertook a series of assessments at baseline and 12 months, conducted by trained staff in the participant's home. Participant vehicles were instrumented using a C4D Data Recorder with a GPS receiver and tri-axial accelerometer. The small data recorder box was installed in a position not visible to the driver or passengers, such as under the seat or dash board, and the GPS antenna was unobtrusive. GPS data used to calculate driving exposure was recorded every second and determined location through navigational satellites. Acceleration data was recorded at a higher frequency of 32 Hz and used to identify RDEs in the direction of travel.

2.2 Outcome measure

The accelerometers were installed into participant's vehicle aligned with the direction of travel and level to flat ground. The accelerometer output was reviewed at installation when the vehicle was stationary and an offset for the accelerometer data calculated. The data was scrutinised during the study period to determine if the offset had changed. The method used to treat the data to resolve these issues, along with the criteria for validity of RDE data are described in detail in a complimentary Data in Brief paper. As part of processing the accelerometer data to identify RDEs, a Butterworth filter was applied to smooth the data (Meredith et al., 2013). A RDE was defined as having one data point (approximately a 32nd of a second) at or above the deceleration threshold of 750 milli-g (7.35 m/s^2). To minimise the chance of identifying false positives, RDEs that were likely to be related to a single incident were counted as a single event, defined as occurring within 3 s of the previous event dropping below 500 milli-g deceleration