Accident Analysis and Prevention 82 (2015) 199–212

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Crash avoidance in response to challenging driving events: The roles of age, serialization, and driving simulator platform

Alexandre Bélanger, Sylvain Gagnon*, Arne Stinchcombe

School of Psychology, University of Ottawa, 550, rue Cumberland, Ottawa, Ontario K1N 6N5, Canada

ARTICLE INFO

Article history:
Received 14 May 2014
Received in revised form 20 April 2015
Accepted 26 April 2015
Available online 16 June 2015

Keywords:
Older drivers
Serialization
Challenging road event
Driving simulators

ABSTRACT

We examined the crash avoidance behaviors of older and middle-aged drivers in reaction to six simulated challenging road events using two different driving simulator platforms. Thirty-five healthy adults aged 21–36 years old ($M = 28.9 \pm 3.96$) and 35 healthy adults aged 65–83 years old ($M = 72.1 \pm 4.34$) were tested using a mid-level simulator, and 27 adults aged 21–38 years old ($M = 28.6 \pm 6.63$) and 27 healthy adults aged 65–83 years old ($M = 72.7 \pm 5.39$) were tested on a low-cost desktop simulator. Participants completed a set of six challenging events varying in terms of the maneuvers required, avoiding space given, directional avoidance cues, and time pressure. Results indicated that older drivers showed higher crash risk when events required multiple synchronized reactions. In situations that required simultaneous use of steering and braking, older adults tended to crash significantly more frequently. As for middle-aged drivers, their crashes were attributable to faster driving speed. The same age-related driving patterns were observed across simulator platforms. Our findings support the hypothesis that older adults tend to react serially while engaging in cognitively challenging road maneuvers.

1. Introduction

Older drivers are recognized as being safe and experienced drivers (Marshall et al., 2013). Yet crash studies have shown that approximately 10% of the older driver population is over represented when both crash occurrence and distance driven are considered (Eberhard, 2008; Lyman et al., 2002). Collision investigations have revealed that older drivers are significantly more involved in collisions involving multiple vehicles and are more often at fault during collisions (Langford et al., 2006). Considering the expected increase in the population of older drivers (Turcotte, 2012), a growing body of literature underlines the importance of reaching a better understanding of older drivers' characteristics in order to circumscribe the factors that potentially increase crash risk in this population (Eby and Molnar, 2009; Fildes 2008; Molnar et al., 2006).

Accident analyses have been instrumental in this regard and have shown that older drivers are more susceptible to crashing when simultaneously attending to several sources of information and performing multiple driving maneuvers, such as turning left at an intersection (Boufous et al., 2008; Mayhew et al., 2006; Skyving et al., 2009). Deficits in visual scanning of busy driving environments are targeted as the main contributing factor (Braitman et al., 2008; Horswill et al., 2008; Staplin and Lyles, 1991). Recent studies as well as current models of older driver behavior all underline the fact that driving competency is multi-factorial and that the multiple factors involved interact with one another (Anstey et al., 2005; Dickerson and Bédard, 2014; Kamenhoff, 2008; Michon, 1985; Wood et al., 2008). However, the precise cognitive and motor components as well as their interactions have yet to be fully revealed (Bédard et al., 2008; Fildes 2008; Leproust et al., 2008; Wheatley and Di Stefano, 2008). Although very informative, models have failed to generate indicators of driving safety. While cognitive assessment tools such as the UFOV® or the trail making test are associated with crash risk among older drivers, they fail to satisfactorily discriminate safe from unsafe drivers (Classen et al., 2013; Rubin et al., 2007; Bowers et al., 2013).

Studies of naturalistic driving behavior have shown that crashes result from a combination of inattention and the occurrence of a sudden unexpected event (e.g., Dingus et al., 2006). As an alternative solution to crash predictors, Hancock and de Ridder (2003) advocate for examining crash avoidance behaviors to better understand and predict traffic collisions. While the presentation of crash-inducing driving situations in the real-world is impossible

* Corresponding author. Tel.: +1 613 562 5800x2271; fax: +1 613 562 5147.
E-mail address: sgagnon@uottawa.ca (S. Gagnon).

http://dx.doi.org/10.1016/j.aap.2015.04.030
0001-4575/

for obvious safety reasons, driving simulators allow for the systematic presentation of driving-related stimuli and the collection of behavioral response data in real-time (Fisher et al., 2011). Research has found that driving simulators are a reliable and valid apparatus upon which to examine driving behavior (Gibbons et al., 2014; Bédard et al., 2010).

Using driving simulators, Hancock and de Ridder (2003) observed that adult drivers (mean age 21.4) facing challenging driving situations were more likely to swerve and less likely to brake. The authors concluded that a restricted viewing time of a complex situation (about 1.2 s) prevents the activation of simultaneous maneuvers and reduces drivers' response patterns to single reactions such as swerving or braking. In this age group, driving speed could be seen as an important moderator of the driving reactions. Interestingly, the difficulty in simultaneously engaging several driving maneuvers has also been observed in the older population on a standard road course (Hakamies-Blomqvist et al., 1999). Using an instrumented vehicle, Hakamies-Blomqvist et al. (1999) observed that a subgroup of older drivers were more likely to address situations requiring many maneuvers in a serial fashion (i.e., serialization). For instance, while turning left they broke down the maneuver into a sequence of simpler responses. According to these authors, this time consuming compensatory strategy could be unsafe when facing time pressured road situations that require rapid and simultaneous execution of multiple controls.

More recently, Boer et al. (2011) examined age differences in intersection negotiation behavior in data collected from an instrumented vehicle. The authors found that older drivers performed the majority of their steering while their vehicle remained still which was in stark contrast to the younger drivers who performed their steering while accelerating. The authors suggest that the serialization observed among older drivers reflects a compensatory strategy to accommodate age-associated changes in cognition, which serves to reduce attentional demand while driving. Similarly, in an investigation of distracted driving among older adults, Thompson et al. (2012) found that older drivers tended to hold the gas pedal steady while they completed a distraction task. The authors posit that in an effort to reduce the task demands, older drivers may engage in serialization, temporarily ignoring one component of the task (i.e., speed maintenance) while attending to another (i.e., a distraction task).

In a previous study, we examined the 'serialization' interpretation of the crash avoidance behaviors of 20 younger and 20 older adults who were tested in a driving simulator (Bélanger et al., 2010). After being acclimated to the simulator, participants completed driving scenarios that contained three events deemed challenging. Prior data supported the challenging nature of the event through lower performance (accuracy and response time) on a peripheral secondary task while driving (Cyr et al., 2006). We decomposed the drivers' reactions to the events by averaging the various driving parameters (acceleration and deceleration parameters as well as lane deviation indices) into six short intervals prior to and during the event. We observed an increased crash rate in the older group (65% older vs. 30% younger drivers) in reaction to an overtaking event that required simultaneous swerving and braking reactions within a short window of 2.7 s. In this event, the driver saw a bus coming toward him/her in the opposite lane. A car was hidden behind the bus and quickly passed the bus using the drivers' lane. An analysis of the drivers' reactions according to the six short time intervals revealed that older drivers who crashed failed to activate simultaneous reactions (i.e., braking and swerving) while the few younger crashers were found to swerve in the wrong direction and tried to squeeze in between the bus and the car coming toward them. Our study also indicated that UFOV test scores and peripheral detection dual task responses while driving the simulator were significantly associated with the occurrence of a crash (similar to Lee and Lee, 2005; Rizzo et al., 1997, 2001). The other events failed to generate more crashes in the group of older drivers although they were found on average to drive more slowly and to apply the brake later (similar to Fildes et al., 2007; Horberry et al., 2006; Merat et al., 2005; Schaap et al., 2008; Yan et al., 2007).

Key features of the *car overtaking* event were a lack of avoidance space and a lack of contextual avoidance cues. Specifically, in this event, drivers had to use the road edge to avoid crash. Older drivers might have been reluctant to use the edge of the road to avoid crashing into the oncoming vehicle. In one of the other events, a parked car on the side of the road moved rapidly in the driver's lane, which could potentially influence the reaction of the driver, that is, trying to escape the situation using the left lane. Moreover, the time allowed to react to the scenarios varied greatly between the three challenging events. When sufficient time is allocated, older drivers may be able to safely avoid crash by engaging in serialized driving reactions. The factors present in scenarios administered in Bélanger et al. (2010) may have prevented older drivers from launching simultaneous defensive driving responses and may have contributed to our previous findings. Similarly, the above results were obtained while drivers were also completing a peripheral secondary task. As indicated above, it is reasonable to speculate that the secondary task contributed to the complexity of the scenario, thereby straining drivers' attentional resources (Cantin et al., 2009; Merat et al., 2005).

In the current study we further investigated age-related differences in crash avoidance behavior by manipulating contextual avoidance cues (e.g., presence of a shoulder) during challenging events and by maintaining the same level of time pressure across events. Unlike Bélanger et al. (2010), participants in this study were required to drive the simulator as they normally would in their own vehicle and were therefore not submitted to a secondary task. We also assessed cognitive functions known to be related to driving outcomes in older drivers (i.e., single and choice reaction time task, UFOV, and trail making tests; Anstey et al., 2005).

A secondary goal of this research was to examine the reliability of the findings across simulator platform. Driving simulators vary tremendously in terms of set-up and realism and research has shown that behavior across platforms is comparable under everyday driving conditions. Lemieux et al. (2014), for example, compared driving responses during a simulated assessment course in a low-cost desktop driving simulator and a mid-level driving simulator. The data consistently showed moderate to high correlations between the two platforms, suggesting comparability between the two platforms. Using a similar protocol, Gibbons et al. (2014) found moderate positive linear relationships between performance on a standardized assessment course on a single-screen simulator and performance on a three-screen driving simulator. It is unclear, however, whether low cost driving simulators can be employed to examine measures of driving behavior in response to highly complex driving situations that can induce crash. In order to further replicate our previous findings and to increase the reliability of the study, we tested participants with one of two driving simulators of varying set-ups (i.e., mid-level and low-cost desktop).

In terms of hypotheses, we expected to replicate older drivers' increased crash frequency when the simultaneous activation of several controls, such as braking and swerving, was required. Older drivers were also expected to benefit from contextual avoidance cues provided (i.e., direction provided by the obstructive car or avoiding space). Finally, we anticipated a similar pattern of results on both simulator platforms.