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Are older drivers' on-road driving error rates related to functional performance and/or self-reported driving experiences?

S. Koppel[a,*], J.L. Charlton[a], N. Richter[a], M. Di Stefano[b], W. Macdonald[b], P. Darzins[c], S.V. Newstead[a], A. D'Elia[a], B. Mazer[d], I. Gelinas[d], B. Vrkljan[f], K. Eliasz[e], A. Myers[f], S. Marshall[g]

[a] Monash University Accident Research Centre, Monash University Australia
[b] La Trobe University, Australia
[c] Eastern Health, Australia
[d] McGill University, Canada
[e] McMaster University, Canada
[f] University of Waterloo, Canada
[g] Ottawa Hospital Research Institute, Canada

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1. Introduction

1.1. Older drivers

Over the next five decades, there will be a substantial increase in both the number and proportion of older people in most industrialized countries (OECD, 2001). With the aging of the population, it is also anticipated that there will be an increase in older drivers' licensing rates (Koppel and Berecki-Gisolf, 2015). Further, the private motor vehicle is likely to remain the principal mode of transport for emerging cohorts of older drivers who will be more mobile and travel both more frequently and greater distances compared with earlier cohorts (OECD, 2001). Demographic growth, increased licensing rates and increased motor vehicle use will combine to produce a marked increase in the number of older drivers on the road.

Although there is strong support around the world for older people to maintain independent vehicular mobility for as long as possible, their safety is also a serious community concern necessitating development of innovative measures to reduce crash and injury risk (Langford and Koppel, 2006). Although current figures show that older drivers are involved in few crashes in terms of absolute numbers, they represent one of the highest risk groups for crashes involving serious injury and death per number of drivers and per distance traveled (Koppel et al., 2011). This has largely been attributed to their greater frailty and reduced tolerance to injury, as well as their age-related sensory, cognitive, and physical impairments (Augenstein, 2001; Li et al., 2003; OECD, 2001). To enable maintenance of an appropriate balance between mobility and safety, it is important to understand how declines in older drivers' functional performance relate to safe on-road driving behavior and whether the declines in those abilities put older drivers at an increased risk of crash-related injuries and/or death. If older drivers are able to modify their driving to compensate for such declines, this will undoubtedly have some bearing on their likelihood of crash involvement.

1.2. On-road assessments

On-road assessments have been described by driving rehabilitation specialists as the 'gold standard' for determining a drivers' true driving ability (Di Stefano and Macdonald, 2005; Justiss, 2005; Korner-Bitensky et al., 1994; Odenheimer et al., 1994). Although studies are limited in this area, most acknowledge the value of standardizing on-road assessments to allow objective measurement of driving behavior (e.g. Di Stefano and Macdonald, 2010; Korner-Bitensky et al., 2006; Withaar et al., 2000). On-road assessments are standardized by developing geographically replicable pre-determined maneuvers rated on explicit criteria on fixed routes (Kowalski and Tuokko, 2007). Moreover, it has been argued that

* Tel.: +61 3 9905 4739; fax: +61 3 9905 4363.
E-mail address: sjaanie.Koppel@muarc.monash.edu.au (S. Koppel).

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when a representative range of traffic conditions at an appropriate level of difficulty are performed by a driver, competence is more accurately evaluated, as the assessor is able to observe critical aspects of driver behavior (Di Stefano and Macdonald, 2003).

While standardized on-road assessments serve a vital purpose in distinguishing safe from unsafe older drivers (MacDonald et al., 2006), there are circumstances where a less-structured assessment route and protocol may be justified. The appropriateness and value of assessments conducted over routes familiar to, and chosen by, the older driver has been asserted by driving rehabilitation specialists and researchers (Justiss, 2005; Withaar et al., 2000). These on-road assessments, commonly referred to as personalized assessments, are inherently non-standardized (MacDonald et al., 2006). While in theory all drivers are expected to deal with environmental demands, in practice, the intensity and quantity of such demands are unique to each driver (Nasvadi, 2007). The core assumption behind the use of non-standardized tests is that customized assessments are more ecologically valid in terms of reflecting assessment requirements with the real world driving experience of the driver in question (Nasvadi, 2007).

A major consideration for on-road assessments is whether to use the driver's own vehicle, or an instrumented, dual-control test vehicle. Using the same instrumented vehicle with dual-control brakes for each assessment enhances the standardization of the evaluation by ensuring that the mechanical conditions of the vehicle are the same for each driver, and it also improves safety for both passenger and assessor because of the dual brake set-up (Fox, 1989; Kowalski & Tuokko, 2007). However, research has shown that older drivers experience difficulties in adapting to an unfamiliar vehicle, which compromises the validity of the overall assessment (Lundberg and Hakamies-Blomqvist, 2003). Moreover, Lundberg and Hakamies-Blomqvist (2003) suggested that various features of compensatory behavior will not emerge unless the driver can make strategic decisions regarding choice of the vehicle used during assessment.

1.3. The Candrive/Ozcandrive study

The Candrive/Ozcandrive study is a longitudinal, multi-center international research program with the core objective of identifying means of promoting older drivers' safe mobility (Marshall et al., 2013). It involves 928 drivers aged 70 years and over in Canada and 302 drivers aged 75 years and older in Australia and New Zealand (Australia: $n = 257$; New Zealand: $n = 45$). Using a longitudinal study design, the project is tracking this cohort of older drivers for up to 6 years, assessing changes in their functional performance, driving practices (e.g. exposure and patterns), as well as crashes and citations. The primary purpose is to determine and validate a screening test (decision rule) to identify potentially at-risk drivers. Older drivers' usual (or naturalistic) driving practices (e.g., trip distance, duration, type of road and speed) are recorded through an in-car recording device (ICRD) installed in older drivers' vehicles and measures of older drivers' functional performance, medical conditions and self-reported driving-related comfort, abilities and practices are documented annually. In addition, a subset of older drivers' driving behavior is evaluated annually through an on-road driving observation. The data reported here are from the Australian (Ozcandrive) component of the study.

1.3.1. The electronic Driver Observation Schedule (eDOS)

The eDOS is an observation schedule, designed for use within Candrive/Ozcandrive cohort study, to enable systematic and reliable observations of on-road driving behavior, and monitoring of potential on-road driving behavior changes over time (Koppel et al., 2013; Vlahodimitrakou et al., 2013).

The Person–Environment (P–E) Fit theory of driving competence (Willis, 2000) and Michon's Model of Driver Behavior (Michon, 1989) were influential in developing the eDOS. Specifically, it was determined that the eDOS should be undertaken on driver-selected routes to observe drivers' competency in environments encountered in their everyday driving and be conducted in the older driver's own vehicle (Lundberg and Hakamies-Blomqvist, 2003).

In addition, item selection and operationalization of the eDOS was based on: older driver crash epidemiology (e.g., Catchpole et al., 2005; Fildes et al., 1994; Langford & Koppel, 2006), older driver self-regulatory behavior (e.g., Baldock et al., 2006; Charlton et al., 2006) and published driving measures (Di Stefano and Macdonald, 2003; Dobbs et al., 1998; Galski et al., 1993; Hunt et al., 1997; Justiss, 2005; Kowalski & Tuokko, 2007; Ott et al., 2012). Six categories of driving behaviors were selected to be scored within the eDOS as appropriate or inappropriate during intersection negotiation, lane changes, merges and low speed maneuvers. These categories include: (a) observation of road environment; (b) signaling; (c) speed regulation; (d) gap acceptance; (e) road-rule compliance; and (f) vehicle/lateral lane positioning (see Table 1 for the definitions of inappropriate driving behaviors).

The eDOS was initially developed with a paper-based recording procedure. Vlahodimitrakou et al. (2013) evaluated the inter-rater reliability, feasibility and acceptability of this procedure with a sub-sample of 33 Ozcandrive older drivers (male = 61%; mean age = 80.12 years, SD = 3.39, range: 75–88 years). The authors reported that the eDOS could be implemented in older drivers' own vehicles, could be scored reliably ($r(18) = 0.83$, $p < 0.05$), was practical in terms of duration, and was acceptable to older drivers. Koppel et al. (2013) revised the eDOS procedure to include: (i) an electronic scoresheet to record and score driving behavior and (ii) video-recording equipment in older drivers' vehicles to capture images of the driver and the forward driving environment throughout the drive. The authors reported that with this revised eDOS procedure it was possible to observe and score the required details of driving behavior and that it demonstrated both practicality and high user acceptance. More recently, Koppel et al. (2016) reported high levels of appropriate driving behavior (96%, $n = 6969$ maneuvers) for 227 Ozcandrive older drivers (male: 70%; age: M = 81.53 years, SD = 3.37 years, range: 76–96 years) and that while driving behavior was not related to older drivers' functional performance, it was significantly related to perceived driving abilities and reported frequency of driving in challenging situations.

1.4. Aims

This study examined a cohort of Ozcandrive older drivers whose on-road driving behavior was observed during the eDOS on two occasions approximately 12 months apart (Times 1 and 2). These observations of older drivers were analyzed to determine whether: (1) self-selected driving routes changed over time; (2) driving behavior changed over time, and (3) on-road total driving maneuver error rates are related to functional performance and/or self-reported driving experiences.

2. Method

2.1. Participants

The on-road driving behavior of 200 Ozcandrive older drivers during the eDOS was observed on two occasions approximately 12 months apart (Times 1 and 2) in Melbourne, Australia. The eDOS was completed by Ozcandrive participants from the Melbourne site ($n = 257$). Of the 257 older drivers recruited from the larger Ozcandrive study, only 227 participants completed the eDOS at Time 1. Reasons for non-completion of the eDOS at Time 1 included: withdrawal from the study prior to the eDOS appoint-