Accident Analysis and Prevention 49 (2012) 293–299

Contents lists available at SciVerse ScienceDirect

Accident Analysis and Prevention

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

Age and inconsistency in driving performance

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ARTICLE INFO

Article history:
Received 31 October 2011
Received in revised form
16 December 2011
Accepted 4 January 2012

Keywords:
Age
Driving
Intraindividual variability
Inconsistency
Cognitive
Simulator

ABSTRACT

Research in cognitive neuropsychology suggests that investigation of the within-person variability, or inconsistency, of cognitive performance may provide valuable insights into ageing mental processes. It is rare though, for this interest in intraindividual variability to extend to everyday activities. As this may provide important information about driving behaviour, we therefore assessed age differences in driving inconsistency in younger ($n=24$, M age = 21.29 years) and older ($n=21$, M age = 71.24 years) persons who drove in residential, urban and motorway conditions in a fully immersive driving simulator. In measures of headway (maintaining a safe distance to a preceding vehicle) and lateral lane position, older drivers exhibited significantly greater performance inconsistency, and this was particularly marked in the faster motorway condition. Older drivers also recorded greater perceived mental demands associated with driving, and greater within-person variability across a range of cognitive measures. The findings suggest that age-related deficits in attentional and executive control may affect the consistency of driving performance in older persons. Discussion considers interventions to introduce in-vehicle systems to help maintain attention in older drivers, and to intervene when safety-critical boundaries are exceeded.

1. Introduction

With greater longevity in modern societies, it is important that independence and quality of life are extended into old age for as long as possible. A major contributor in this respect is mobility, and specifically in the present context, an individual's ability to drive a motor vehicle to facilitate practical and recreational activities. Concerns about increasing numbers of older drivers and their possible impact on road safety have been well documented (e.g., Adrian et al., 2011; Young and Bunce, 2011) and numerous studies have assessed age and driving performance using a variety of methods (see Reger et al., 2004). However, an area that has been neglected in ageing research, and provides the main focus for the present paper, is the moment-to-moment inconsistency, or variability, in driving performance (Young and Bunce, 2011). There is good reason to believe that the more inconsistent driving performance is, the greater the risk of an accident. For example, inconsistency in maintaining headway (a safe distance behind a preceding vehicle) or lateral lane position, clearly distinguishes good from poor drivers (Young and Stanton, 2007a,b), and is central to safe driving practice (Young et al., 2011). Indeed, Evans (2004) describes US data suggesting that rear-impact accidents, related to headway, account for 30% of all accidents. However, little is known of how these key performance variability components of driving ability vary with age. As insights into age differences in the inconsistency of driving performance may provide valuable information relevant to assessment and intervention, the first major objective of the present research was to assess the consistency of driving performance in younger and older adults.

The potential importance of information on moment-to-moment inconsistency in older drivers is underlined by research on intraindividual reaction time (RT) variability taking place in cognitive neuropsychology. Such measures index moment-to-moment fluctuations in RT performance over successive trials of a given cognitive task, and are thought to provide an index of neurobiological integrity (Hultsch et al., 2008; MacDonald et al., 2006). Consistent with this view, increased within-person variability is associated with older age (e.g., Bunce et al., 2004; Hultsch et al., 2002) and a range of neurological conditions including mild dementia (Hultsch et al., 2000), Parkinsons disease (de Frias et al., 2007), and traumatic brain injury (Stuss et al., 1994). Importantly, RT inconsistency is associated with neurobiological integrity in cognitively intact persons living in the community. For example, a recent neuroimaging study (Bunce et al., 2007) of 60–64 year olds found that RT inconsistency was related to the burden of microscopic white matter lesions in the frontal cortex, a finding that has also been demonstrated in healthy 44–48 year olds (Bunce et al., 2010). These studies clearly suggest that cognitive measures of RT inconsistency are not only sensitive to subtle ageing effects, but also neurobiological integrity.

The second major objective of the present study therefore, was to assess the within-person RT variability of a range of laboratory tasks covering perceptual speed, attention and memory, domains

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doi:10.1016/j.aap.2012.01.001

implicated in driving performance. Importantly, we were interested in whether these variables were associated with measures of driving performance inconsistency. To obtain these latter measures, we assessed driving performance in a fully immersive driving simulator in three contrasting driving scenarios (residential, urban and motorway). Given the neuropsychological evidence of age-related increases in intraindividual variability, we hypothesised that within-person variability would increase with age in both cognitive and driving simulator measures. Of particular interest was whether the two types of variability measure were strongly intercorrelated.

2. Method

2.1. Participants

Participants were recruited through advertisements placed around the university campus and contacts with older persons' activity groups. To be included in the study, participants were required to have possessed a full driving licence for a minimum of one year, to be regular drivers (i.e., drive a minimum of 6000 miles per year), and to have normal, or corrected-to-normal, vision. All participants lived in the proximity of the university which is in west London, an area populated by road scenarios used in the study. Twenty-four younger (age $M = 21.29$, $SD = 1.71$, women = 13) and 21 older drivers (age $M = 71.24$, $SD = 6.83$, women = 6) participated in the study. As is often the case in ageing studies, older participants recorded higher National Adult Reading Test scores (NART: Nelson, 1982), a measure predictive of IQ (younger = 104.32, older = 110.95, $p < .05$).

2.2. Driving simulator and measures

The Brunel University Driving Simulator (BUDS) is a fixed-base, fully interactive immersive simulator installed in a 2006 Jaguar S-Type full vehicle body. The simulator software is provided by STISim (Systems Technology Inc, Hawthorne, CA; Build 2.08.04), which has state-of-the-art graphics hardware enabling a real-time, fully textured, anti-aliased, 3-D graphical scene of the projected virtual world. The images are projected via three Toshiba TDP-T95 digital projectors onto three 2.4 m × 2.0 m (viewable area) screens at a resolution of 1280 × 1084 pixels, thus giving the forward facing scene plus the left and right peripheral scenes. In total, from the driver's seat the projection covers a 150° horizontal and 45° vertical field-of-view. Simulated images of the dashboard instrumentation as well as rear view and side mirrors are projected onto the viewing screens. The simulator is controlled by a Logitech multimedia driving unit (G25 Racing Wheel) consisting of steering wheel, gear lever and pedal block (including clutch pedal), fitted in the car as a UK-standard right-hand drive vehicle. The Logitech driving unit allows for simulation of manual or automatic transmission, with six-speed manual being used in the present study.

The design of the study called for three different scenarios – residential, urban and motorway – each presented separately as a within-subjects factor. The residential scenario presented a single-carriageway, two-lane road (i.e., one lane in each direction of travel), with each lane being 12 feet (3.66 m) wide. The driving speed was 30 mph (48 km/h), and the length of the run was 2.84 miles (4.57 km). For the urban scenario, a two-lane dual-carriageway was used (two lanes in each direction), and lanes were again 12 feet (3.66 m) wide. The length of the run was approximately three miles (4.88 km), and driving speed was 40 mph (64 km/h). The motorway scenario was approximately six miles (9.75 km) long, and consisted of two three-lane carriageways, with lanes 15 feet (4.6 m) wide. Driving speed on the motorway was 70 mph (113 km/h). Each scenario lasted for approximately five to six minutes, and presentation of the conditions was counterbalanced across participants. A "follow-that-car" paradigm was used to maintain a set pace for the study, by placing a lead vehicle at the beginning of each scenario. Thus, there were no other cars in the driver's lane to overtake, although a moderate volume of additional and opposing traffic was placed in each scenario.

The simulator automatically recorded driving performance variables at a rate of 2 Hz. Dependent variables for the present study were derived measures of *headway* and *lateral lane position*, as advocated by Bloomfield and Carroll (1996) and successfully applied in several studies by Young and colleagues (e.g., Young et al., 2008; Young and Stanton, 2007a,b). Driving inconsistency was quantified through the standard error of the regression line for each measure, and reflects the drivers' relative consistency in their own performance, rather than deviation from an absolute measure (as with standard deviation).

In order to provide insights into the mental demands associated with driving performance, subjective mental workload was assessed using the *NASA Task Load Index* (TLX: Hart and Staveland, 1988), administered after each condition. This multi-dimensional measure is considered to be one of the most effective available (Hill et al., 1992; Nygren, 1991) and assesses perceived demands on six dimensions. (1) *Mental Demands*: 'How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?'. (2) *Physical Demands*: 'How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?'. (3) *Temporal Demands*: 'How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?'. (4) *Own Performance*: 'How successful do you think you were in accomplishing the goals of the task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?'. (5) *Effort*: 'How hard did you have to work (mentally and physically) to accomplish your level of performance?'. (6) *Frustration Level*: 'How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?'. Each dimension was rated from 0 (low/poor) to 100 (high/good).

2.3. Cognitive measures

A short battery of cognitive measures was administered using E-Prime version 1.2 (Psychology Software Tools). Several of these measures were used in previous studies of within-person variability (e.g., Bunce et al., 2008a,b). For all tasks, participants were instructed to respond as quickly and as accurately as possible. Presentation was pseudorandomized where appropriate, and RTs from correct responses only were used to compute the measures of within-person variability described below.

2-choice RT (*2-CRT*): here, a black circle (25 mm diameter) was randomly presented to either the left or right of the computer screen (inter-trial interval of 500 ms). For 12 practice trials, and 48 test trials, participants pressed the X key or M key of the keyboard if the stimulus appeared to the left or right respectively. *4-choice RT* (*4-CRT*): this was the same as the 2-CRT task but included two additional choices. Black circles appeared either top or bottom, or left or right, of the computer screen, and mapped spatially onto the S, X, M, and K keys for responses. *Simple visual search*: in this task, 16 practice trials were followed by 64 test trials. Half of the trials involved presentation of a 6 × 6 array of the letter "O", and half involved a similar array of "O" letters, but with one target "Q" letter embedded within. All arrays were presented in green ink.