



Driving manoeuvre during lane maintenance in older adults: Associations with neuropsychological scores



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ABSTRACT

Older drivers experience difficulties in lane maintenance under challenging driving sections due to age-related cognitive declines, yet there is little comprehensive evidence on associations between cognitive functions and the lane maintenance in this population. In this study, fifty older drivers completed an on-road driving assessment and a battery of standard neuropsychological tests. Mean Lane Position (MLP), Standard Deviation of Lane Position (SDLP) and manoeuvre time calculated from precise vehicle movement trajectories were used as the lane maintenance parameters. The GNSS tracking vehicle movement presents comprehensive and reliable vehicle position data, which is more sensitive for detecting subtle variations of lane maintenance in older drivers. Statistical analysis results show that lower visual attention (selective and divided attention) was associated with higher MLP and SDLP; MLP was also correlated to spatial abilities, executive function, and motor speed; manoeuvre time was negatively correlated with drivers' risk-taking personality (all $p < .01$). Selective attention was found to be the best predictor of MLP in lane maintenance. A combined eight variables from three neuropsychological tests, UFOV 2 and 3, BD and BJLO, D-KEFS TMT 1, 2, 3, and 4, correctly classified 80.4% of participants with good versus low-performing lane maintenance.

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1. Introduction

Older drivers have higher crash rates per distance driven compared with most other age-group drivers, and these crashes result in greater morbidity and mortality (Molnar et al., 2007). Various aspects of cognition, particularly visual attention and executive function, were found to link with crash risk among older drivers (Owsley & McGwin, 2010; Richardson & Marottoli, 2003). According to previous studies, older drivers were over-involved in angle collisions, crashes at intersections, turning, and changing lanes (Charlton et al., 2006; Clarke, Ward, Bartle, & Truman, 2010; Marmeleira, Ferreira, Melo, & Godinho, 2012; McGwin, 1999). Maintaining lateral control within the driving lane is a key aspect of safe driving for older

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adults (Johnson, Dawson, & Rizzo, 2011). Drivers normally adopt safety margins to avoid the consequences of their errors (Ranney, 1994). Effective safety margins need preservation from the entire distribution of responses, involving neuropsychological capacities that are mediated by multiple areas of the brain, e.g., visual, attentional, perceptual, cognitive and psychomotor abilities (Anstey, Wood, Lord, & Walker, 2005; Dawson, Uc, Anderson, Johnson, & Rizzo, 2010). The occurrence of crashes with respect to increasing steering variability in older drivers indicates inadequate safety margins performed during lane maintenance (Ranney, 1994). Understanding the critical cognitive abilities underpinning older drivers' lane maintenance would provide insights into older drivers' behaviour and safety.

One category frequently reported in driving assessment is about the direction and lane control, which is related to the ability of the driver to control the vehicle heading along the desired route in the correct lane (Vichitvanichphong, Talaei-Khoei, Kerr, & Ghapanchi, 2015). A driver on road, as the position controller at the stabilisation level, keeps the vehicle as near as possible to the desired position along the given path (Evangelou, 2004). To describe dynamic steering characteristics of a driver, the control theory is mostly appropriate to use (Jürgensohn, 2007). Maintaining a car in the right position and with proper speed are typically regulation tasks which the driver is the centre and controller. Inattention to the road ahead while driving has been identified a primary cause of unsafe behaviours and a factor leading to vehicle accidents (Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005). When turning, the driver should make the manoeuvre as accurate as possible, wide turning or cutting a turn too sharply can be risky due to the reduced safe margins on the road (Phondeenana, Thitipatanapong, Klongnaivai, Noomwongs, & Chantranuwathana, 2014; Ren, Xu, & Li, 2014).

Lane maintenance in driving tests generally assesses the lateral (side to side) positioning of the vehicle during turning, straight ahead driving and lane changing. A typical error in lane maintenance is drifting out of the driving lane (Classen, Shechtman, Awadzi, Joo, & Lanford, 2010; Justiss, 2005), while some performance, such as zigzagging, cutting corners and wide turns indicating inappropriate behaviour or poor car control of the drivers. Lane maintenance performance of a driver can be examined with traditional measures of the central tendency, using mean and standard deviation of lane position, together with performance criterion measures, such as lane exceedance counts or time in and out of the lane (Cooper, Medeiros-Ward, & Strayer, 2013). These measures present intuitive links with lane departure crashes (Ball, Edwards, & Ross, 2007). The most commonly used measure of lateral control in is the standard deviation of lane position (SDLP), since all the factors contributing to lane departures have an influence on the standard deviation of lane position (Green, 2013; Verster & Roth, 2011). Studies by Green (2013) have measured SDLP with an on-road and some driving simulator experiments, the typical values and likely variation provided a practical implication for data collection in future studies.

Lateral position can be measured as the deviation in meters from the centre of the driving lane. Since the increment of mean lane position (MLP) and SDLP may ultimately cause lane crossings onto the road shoulder or the adjacent traffic lane, measurements of MLP and SDLP have been used as potential indexes of driving behaviour and safety, which ensures the construct validity of the study observed (Verster & Roth, 2011). Moreover, on-road driving tests with lane position measure demonstrate a higher content and ecological validity when compared to closed road tests, driving simulators, and clinical psychometric tests (Odenheimer et al., 1994). A measure of lateral lane maintenance can also be used an index of road-tracking precision for individual driving performance (Wester, Böcker, Volkerts, Verster, & Kenemans, 2008) and can provide a sensitive measure for detecting drivers' impairment (Cuenen et al., 2015). Ben, Frank, and Robert (2008) stipulated that the parameters of time-in-lane and SDLP are both indices of driving related visual performance by the ambient visual system, which involves both central and peripheral portion of the visual field for movement control (Schmidt & Wrisberg, 2008). Sandberg, Wahde, Anund, Kecklund, and Åkerstedt (2013) investigated the relationship between SDLP and the drivers' physical conditions, found a significant difference in the average lane position for sleepy and alert drivers. Verster and Roth (2011) addressed that the SDLP measure with its high test-retest reliability, can be used as an index of "driving weaving" for a measure of stability in driving.

Older drivers experience difficulties in lane maintenance under challenging driving sections, such as urban conditions at intersections or at roundabouts (Gstalter & Fastenmeier, 2010). Although many studies showed that age-related cognitive declines are correlated to decreased driving performances in older adults, there is little comprehensive evidence on associations between cognitive functions and the lane maintenance in this population, especially in real-world driving conditions (Ott, Papandonatos, Davis, & Barco, 2012).

In parallel to on-road and simulated driving tests, assessing drivers' level of functioning has been used as a clinical approach to determine the risk of vehicle crashes in older adults. Static visual acuity, visual fields, visuospatial skills, processing time, selective attention (the ability to focus on a particular object while simultaneously ignoring irrelevant information), divided attention (the ability to maintain attention in multiple stimulus) all decline with age and may adversely affect driving skills (Anstey et al., 2005; Owsley, Wood, & McGwin, 2015). The functional visual field or "useful field of view" (UFOV) measure has been found to correlate with crash data in older drivers (Owsley, Ball, McGwin, et al., 1998). So far a variety of cognitive abilities declines with increasing age have been well-researched, including attention, processing speed, and problem-solving (executive function) (Mathias & Lucas, 2009). Although these findings can be important when considering the established links between basic cognitive abilities and everyday functional abilities (Ball et al., 2007), no single cognitive test is able to provide sufficient sensitivity and specificity to discriminate safe drivers from unsafe older drivers (Bédard, Weaver, Dārzin, & Porter, 2008). For predicting fitness-to-drive among older drivers, cautions should be taken when using those cognitive tools (Bédard, Campbell, Riendeau, Maxwell, & Weaver, 2016). Driving places demands on multiple cognitive

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