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Effects of driving experience and sensation-seeking on drivers' adaptation to road environment complexity

Christina M. Rudin-Brown *, Jessica Edquist, Michael G. Lenné

Human Factors Team, Monash University Accident Research Centre (MUARC), Monash Injury Research Institute (MIRI), Human Factors North, Inc., 174 Spadina Ave, Suite 202, Toronto, ON M5T 2C2, Canada

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ABSTRACT

Theories of driving behaviour and behavioural adaptation aim to explain why and how drivers modify their behaviour according to changes in roadway conditions. Elements of a driver's personality and their level of driving experience may be contributing factors to the likelihood and nature of behavioural adaptation to road environment complexity. The present driving simulator study examined the effects of driving experience and sensation-seeking on drivers' adaptation to road environment complexity in urban areas. Three increasing levels of road environment complexity served as the experimental manipulation. Compared to drivers with between 1 and 5 years of licensed driving experience, drivers with 10 years or more experience displayed a greater degree of adaptation to increasingly complex urban environments in terms of reductions in speed. This enabled them to respond more quickly to a safety-relevant peripheral detection task (PDT) in the most complex road environment than a group of drivers with a moderate level (5–10 years) of driving experience. Although the effects of sensation-seeking were not consistent across measures, it may interact with level of road complexity in terms of changes in lane position and lane position variability. Collectively, results from this exploratory study suggest that driving experience and low sensation-seeking tendencies may be associated with an enhanced ability to appropriately assess the demands of the road environment. However, the assumed ability of drivers with 10 years or more experience to choose a more appropriate speed was only applicable in the most complex road environment.

1. Introduction

That the road environment influences driving performance is not a recent concept, nor is it one that has gone unexamined. Large-scale statistical modelling studies of the influence of roadway factors, including road width and abutting development, on vehicle speed and real-world crash risk have confirmed that roadway geometry is reliably associated with changes in real-world crash risk (Taylor et al., 2002; Taylor et al., 2000). Experimental studies conducted using driving simulation (Godley et al., 1999; Godley et al., 2002; Tenkink, 1988; van der Horst and de Ridder, 2007), and instrumented test vehicles (Bao and Boyle, 2008), further support this contention.

In urban road environments, increases in crash risk have been found to be associated with a number of roadway features, including the number of travel lanes (Sawalha and Sayed, 2001), minor junctions (Sawalha and Sayed, 2001; Taylor et al., 2000), and the density of adjacent driveways and pedestrian crosswalks (Sawalha and Sayed, 2001). A road environment feature that has also been found to be related to increased crash risk is the presence of on-street parking, such as that found in strip-style shopping centres (Greibe, 2003; Pande and Abdel-Aty, 2009; Roberts et al., 1995).

While the factors underpinning the increased crash risk associated with on-street parking remain undetermined, a contributing factor to increases in urban crash risk is vehicle speed, especially the appropriateness of a speed given a certain road environment (Aarts and van Schagen, 2006). Road environment can affect drivers' perceptions of both their own speed and of the appropriate speed for the road, via explicit information such as roadway signs, and through implicit sensory information, such as the rate of optic flow in the peripheral visual field (Gibson, 1958). Optic flow refers to the angular velocity of any point in the visual field of an individual as they move through the environment, relative to the eye, which is directly proportional to the speed at which the individual is moving. The angular velocity of a point that is close to the centre of the visual field, therefore, will be small, whereas the angular velocity of a point that is in the far periphery will be large. It is possible therefore that increases in road environment visual complexity result in faster perceived speeds through this mechanism. Interestingly, roads with open fields and no prominent side features on either side have little stimuli to create peripheral visual flow and speeds in these road environments are likely to be underestimated (Fildes and Lee, 1993). The presence of roadside trees or

* Corresponding author. Tel.: +1 613 986 4361; fax: +1 416 596 6946.
E-mail address: crudinbrown@hfn.ca (C.M. Rudin-Brown).

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buildings can decrease this effect, allowing drivers to better calibrate their vehicle speed to the conditions. Another moderating variable on drivers' choice of travel speed is the setback between the road edge and any buildings, trees or other objects that may influence the perceived width of the road, with drivers being more likely to move away from the edge of the road if they feel that lateral clearance is too narrow. Where lateral movement is not possible, drivers may compensate by slowing down (Martens et al., 1997; van der Horst and de Ridder, 2007).

Alongside these perceptual factors, theories of driver behaviour and adaptation propose that drivers may operate to maintain an acceptable level of risk (Wilde, 1982; Summala, 1988, 2007; Vaa, 2007) or, alternatively, task difficulty (Fuller, 2005; Fuller et al., 2008a,b; Fuller, 2011) during the driving task. For example, Wilde's (1982) 'risk homeostasis theory' sees society and individual drivers as attempting to maintain a target level of overall risk, whereby if risk in one area is reduced, then risk-*taking* in the same or another system will increase. Summala's 'zero-risk model' of driver behaviour (Summala, 1988) proposes that drivers attempt to maintain a stable balance between subjective and objective risk, wherein they avoid feeling fear (and experience "zero-risk") when they drive by anticipating some degree of risk during performance of the driving task. Summala's later 'multiple comfort zone model' of driver behaviour (Summala, 2007) sees driving as being controlled by the monitoring of various safety margins, rather than 'risk' as the sole control function. Similarly, Vaa's 'risk monitor model' of driver behaviour (Vaa, 2007) proposes a variety of target 'best feelings' that drivers aim for, which include feelings of risk. Fuller's (2011) Risk Allostasis Theory (RAT) of driver behaviour, which draws on an earlier Task Capability Interface (TCI) model, posits that, by comparing their own capability to perceived driving task difficulty, drivers make continuous, real-time decisions to maintain task difficulty (or risk) within a preferred range. A common feature of these models of driver behaviour is that maintenance of risk, or task difficulty, is thought to occur through changes in vehicle parameters, including for example, speed. Repeated studies have noted that ratings of perceived task difficulty correlate with a driver's ratings of feelings of 'risk' (Fuller et al., 2008b; Kinnear et al., 2008). The main mechanism by which drivers are assumed to modulate task difficulty (or risk) within their preferred range is by increasing or decreasing their vehicle speed. There is reasonable experimental support for these assumptions. When drivers interact with in-vehicle technologies such as mobile phones or entertainment systems, which increase overall driving task difficulty, reduction in vehicle speed is one of the most common changes in observed driver performance (Alm and Nilsson, 1995; Chisholm et al., 2008; Patten et al., 2004). Similarly, when vehicle speed is held constant by, for example, adaptive cruise control (ACC), drivers respond to changes in task demand by adapting their behaviour in other ways, for example by paying less attention to the road ahead and more attention to non-driving-related in-vehicle tasks (Rudin-Brown and Parker, 2004; Summala, 2002). Because of the association among vehicle speed, road environment complexity and crash risk, and the central role given to vehicle speed choice to maintain level of task difficulty, or risk, during the driving task, RAT (Fuller, 2011) was chosen as the theoretical basis to guide the present study's design, including selection of independent and dependent variables.

In RAT, a driver's perceived capability to perform the driving task depends on a number of contributing personal factors, including (amongst others): (1) relatively stable 'constitutional' (or biological) features, such as a driver's personality, (2) the level of driving education and experience, and (3) more transient 'human' factors, such as attitudes, fatigue and stress (Fuller, 2005, 2011; Fuller et al., 2008a). One constitutional factor that has been proposed is sensation-seeking (SS). Individuals who score high on measures of SS have been found not only to engage in more high risk driving behaviours than their low-SS counterparts (Jonah, 1997), but are also more likely to let themselves drive more recklessly given another unique or risky optional task to perform (Burns and Wilde, 1995; Jonah et al., 2001; Jonah, 1997). Fuller and colleagues (Fuller et al., 2008a) view high sensation-seekers as "clearly opting for a higher level of task difficulty or risk threshold than other (lower SS) drivers" (p. 64). Similarly, high-SS drivers are more likely to engage in a demanding secondary task when their vehicle speed and headway is controlled by ACC, with slower response times than low-SS drivers to a safety critical hazard detection task (Rudin-Brown and Parker, 2004). Based on these findings, it is reasonable to expect that SS may play a role in any observed driver adaptations to changes in road environment complexity.

Research indicates that level of driving experience may influence a driver's perceived capability to perform the driving task. Novice drivers are notoriously high risk drivers with a wealth of research demonstrating that the risk of a driver being involved in a crash is highest during the first year of driving (Williams, 2003; World Health Organization, 2004; Shinar, 2007). Kinnear and Stradling (2011) propose that, compared to more experienced drivers, novice drivers have not yet developed the ability to make decisions by "gut feeling" or, in other words, to associate high risk driving situations with a somatic (bodily) response, and so they fail to emotionally appraise developing hazards. Instead, they are more likely than experienced drivers to rely on a 'cognitive-analytical' or 'cost-benefit' approach to decision-making while driving. Physiological research using skin conductance response supports this notion. Novice drivers who had a total accumulated mileage of less than 1000 miles had anticipatory physiological (skin conductance) scores similar to those of learner drivers, whereas novice drivers who had driven more than 1000 miles had skin conductance scores approaching those of experienced drivers (Kinnear et al., 2013; Kinnear et al., 2009). It is possible that differences in the development of road safety-related learned associations, or somatic responses, may mean that less experienced drivers react differently than more experienced drivers to changes in road environment complexity.

The present study extends upon previous research (Edquist et al., 2012) that found changes in driving performance in response to different levels of road environment complexity and on-street parking. The objective of the present study was to investigate the contribution of driving experience and SS to any observable changes in driving performance that result from increased road environment complexity. Driving experience and SS were chosen specifically as independent variables of interest as, according to RAT and as indicated by previous research (Rudin-Brown and Parker, 2004; Kinnear et al., 2009, 2013), they may influence a driver's appraisal of their capability to perform the driving task (Fuller, 2005, 2011; Fuller et al., 2008). It was hypothesized that increases in road environment complexity would be associated with behavioural adaptation in terms of reduced vehicle speed, a more central lane position, increases in lane position variability, slower reactions to a safety-relevant peripheral detection task (PDT), and increases in subjective driver workload (H1). Further, less experienced drivers were predicted to adapt their driving behaviour to a lesser extent than more experienced drivers (H2), and those who scored high on a SS scale were hypothesized to be less likely than low-SS drivers to adapt their behaviour to changes in road environment complexity regardless of their experience level (H3).

2. Method

2.1. Design

A three-way ($3 \times 3 \times 2$) mixed design with road condition (within-subjects: 'Set back', 'Built-up', and 'On-street Pkg'), experience