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Vertical field of view restriction in driver training: A simulator-based evaluation

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A B S T R A C T

The young driver problem requires remedial measures against speeding and overconfidence. Previous research has shown that increasing the task difficulty during training can enhance subsequent retention performance and prevent overconfidence. In this driving simulator study, we evaluated the training effectiveness of vertical field of view restriction during a self-paced lane-keeping task. Sixty-two young, inexperienced drivers were divided into three groups: a near view (NV) group (upper part of the screen was blanked), a far view (FV) group (lower part of the screen was blanked), and a control group driving with full sight. All groups drove three training sessions lasting 8 min each on a curved rural road, followed by two retention sessions with full sight. The first retention session took place on the same rural road and the second session on a highway. Compared to the control group, the NV group drove with lower mean speed and had more road departures during training. Furthermore, NV drivers reported significantly lower confidence during the training sessions and the second retention session. NV drivers directed their eye gaze more closely to the vehicle during training and both retention sessions. FV drivers approached corners with lower speed compared to the control group during training and had a higher number of rapid steering wheel turns during training and both retention sessions. In conclusion, removing visual information resulted in lower reported self-confidence (NV) and altered steering behavior (FV) in retention sessions compared to driving with full sight. Furthermore, NV training caused drivers to direct their gaze closely to the vehicle during retention, which may be negative for road safety. Possible effects of simulator-based driver training on eye-scanning and safety are discussed.

1. Introduction

Worldwide, 1.2 million fatalities occur in traffic every year, and millions more individuals are injured (World Health Organization, 2009). Young drivers are vastly overrepresented, a public health concern also known as the young driver problem (Drummond, 1989; Organization for Economic Co-operation, 2006; Williams, 2006).

It is possible to classify the causes of the young driver problem using a three-level behavioral taxonomy developed by Michon (1985; see also Lee, 2007). At the strategic level, young drivers are overconfident in their own abilities and have an elevated acceptance to take risks and commit traffic violations (Brown & Groeger, 1988; Horswill, Waylen, & Tofield, 2004; Matthews & Moran, 1986). Loss of control due to speeding is a particularly frequent cause of accidents among young

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drivers (Laapotti & Keskinen, 1998; McGwin & Brown, 1999). At the tactical level, young drivers demonstrate inadequate hazard perception and inadequate 'calibration' of task demands with respect to their own abilities. The lowest level is the operational level, at which young drivers tend to have imperfectly learned skills for longitudinal and lateral vehicle control. Furthermore, young drivers tend to experience a high mental workload, particularly in environments that are new to them. There is growing consensus that driver training that focuses solely on the operational level (i.e., what the driver is able to do) is ineffective in reducing accident risk and that the higher levels (i.e., what the driver is willing to do) have to be targeted as well (Goode, Salmon, & Lenné, 2013; Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002; Mayhew & Simpson, 2002).

For many decades, researchers have studied the effectiveness of training and enforcement methods, but the young driver problem has proven to be robust to interventions (Beanland, Goode, Salmon, & Lenné, 2013; Elvik, 2010). Based on a meta-analysis, Elvik and Vaa (2004) concluded that formal driver training is not an effective road-safety measure. Their analysis included 16 studies that compared formal driver training provided by driving schools with informal driver training, that is, self-training or training provided by family or friends. An analysis of the methodologically best studies (i.e., experiments that distributed participants randomly between formal and informal driver training) showed that formal driver training resulted in a 0% difference in the number of crashes per driver and 11% more accidents per kilometer driven compared to informal training. Elvik and Vaa (2004) also showed that the more lessons one had taken, the more the crash rate increased. Possible reasons for the lack of effectiveness may be that basic driver training increases self-confidence (Mayhew & Simpson, 2002) and normalizes risk taking behavior.

Driving simulators are recognized as tools that may be effective for driver training and driver assessment, although much research still needs to be done in these areas (Beanland et al., 2013; Goode et al., 2013; Medeiros, Weinreb, Boer, & Rosen, 2012; Pollatsek, Vlakveld, Kappé, Pradhan, & Fisher, 2011). An advantage of using simulators for training relative to on-the-road training is the controllability of road infrastructure, weather, and traffic, as well as the fact that dangerous situations can be practiced without risk of collision. Such conditions open up possibilities for new types of driver training, such as learning from errors (Ivancic & Hesketh, 2000; Underwood, Crundall, & Chapman, 2011; Vlakveld, 2011) and exposing drivers to abstracted environments that depart from physical reality (Rizzo, Severson, Cremer, & Price, 2003).

Research in motor learning shows that by making the training task difficult—for example, by depriving the trainee from knowledge-of-results feedback—long-term retention and generalizability of skills can improve (Schmidt & Bjork, 1992). A driving-simulator study by Ivancic and Hesketh (2000) as well as a driving simulator study by De Groot, Centino Ricote, and De Winter (2012) showed that by eliciting errors during training, performance in transfer-driving tests improved. Driving with reduced visibility, such as driving at night or driving in fog, reduces drivers' confidence and increases the perceived risk level (Saffarian, Happee, & De Winter, 2012; Stasson & Fishbein, 1990). Gregersen and Nyberg (2003) observed reduced accident rates in the first years of licensure for novice drivers who had completed a driver training course under dark driving conditions. Reduced visibility may cause drivers to become more vigilant, allowing them to react more accurately to hazardous events (Van der Hulst, Rothengatter, & Meijman, 1998). Additionally, emotional arousal promotes memory consolidation (Kleinsmith & Kaplan, 1963; McGaugh, 2000) and may therefore benefit driver training (Vlakveld, 2011).

Many studies have demonstrated the importance of visual information during driving (e.g., Mourant & Rockwell, 1972; Riemersma, 1979; Sivak, 1996; Wallis, Chatziastros, Tresilian, & Tomasevic, 2007). A number of studies have used visual occlusion (i.e., a technique whereby the driving scene is temporary occluded, typically by means of shutter glasses) to determine visual demand while driving (Backs, Lenneman, Wetzel, & Green, 2003; Senders, Kristofferson, Levison, Dietrich, & Ward, 1967; Van der Horst, 2004). Occlusion techniques have also been used to determine the effect of visual information on drivers' speed choice and curve driving performance (Cavallo, Bran-Dei, Laya, & Neboit, 1988; Godthelp, 1986; Hildreth, Beusmans, Boer, & Royden, 2000; Kondo & Ajimine, 1968; McLean & Hoffmann, 1973; Tsimhoni & Green, 1999).

Land and Horwood (1998) found that for low speeds (<12.5 m/s), a narrow horizontal visual aperture ranging from 7 to 8 deg below the horizon is sufficient for lateral vehicle control, as it yielded lane-keeping performance that is equivalent to the performance achieved with the whole scene visible. For higher speeds, Land and Horwood (1995) showed that with two narrow visible horizontal apertures displayed concurrently—one near the vehicle and one far from the vehicle—drivers achieved similar lane-keeping accuracy to that attained when driving with full sight. More recent studies (Chatziastros, Wallis, & Bülthoff, 1999; Cloete & Wallis, 2011; Neumann & Deml, 2011) with larger sample sizes and more sophisticated simulator technology have tried to replicate the experiments by Land and Horwood (1995). Using two narrow apertures placed 8.3 and 12.8 m in front of the vehicle, Neumann and Deml (2011) showed that steering precision was equivalent to that achieved under a condition with full sight, confirming the findings of Land and Horwood (1995). Cloete and Wallis (2011) did not find evidence of equivalent lane-keeping performance between driving with two narrow apertures and driving with full sight. The authors observed that lane-keeping accuracy was always substantially poorer when two narrow apertures were available compared to that under a control condition with full sight. These results suggest that drivers use more visual information (such as tangent points) than can be perceived through only two narrow apertures and/or that the position of relevant visual features changes dynamically depending on road curvature and speed (Cloete & Wallis, 2011).

Eye-tracking studies (e.g., Gordon, 1966; Lappi, Lehtonen, Pekkanen, & Itkonen, 2013; Wilkie & Wann, 2003) have shown that drivers direct their visual attention to the near and far parts of the visual environment during straight-path driving and curve negotiation. Most researchers agree that the distant region is used by drivers to anticipate oncoming vehicles, obstacles, and road curvature (Lehtonen, Lappi, & Summala, 2012), whereas the near region of the road is used to estimate lateral position in the lane. This concept of preview vs. lateral position estimation is consistent with several models of driver steering behavior (Donges, 1978; Salvucci & Gray, 2004). These models distinguish between anticipatory open-loop control