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Driver distraction in an unusual environment: Effects of text-messaging in tunnels

Christina M. Rudin-Brown[a,*], Kristie L. Young[a], Christopher Patten[b], Michael G. Lenné[a], Ruggero Ceci[c]

[a] Human Factors Team, Monash University Accident Research Centre (MUARC), Clayton, VIC, Australia
[b] Swedish National Road and Transport Research Institute (VTI), Borlange, Sweden
[c] Swedish Transport Administration, Sweden

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ABSTRACT

Text messaging while driving can be distracting and significantly increases the risk of being involved in a collision. Compared to freeway driving, driving in a tunnel environment introduces factors that may interact with driver attentional resources to exacerbate the effects of distraction on driving safety. With planning and design of the 18 km Stockholm Bypass tunnel ongoing, and because of the potentially devastating consequences of crashes in long tunnels, it is critical to assess the effects of driver distraction in a tunnel environment.

Twenty-four participants (25–50 years) drove in simulated highway and tunnel road environments while reading and writing text messages using their own mobile phones. As expected, compared to driving alone, text messaging was associated with decrements in driving performance and visual scanning behavior, and increases in subjective workload. Speeds were slower compared to baseline (no text-messaging) driving when participants performed the text-messaging tasks in the tunnel environment compared to the freeway, suggesting that drivers may have attempted to compensate more for the increased text-messaging-related workload when they were in the tunnel. On the other hand, increases in lane deviation associated with the most complex text-messaging task were more pronounced in the tunnel compared to on the freeway. Collectively, results imply that driver distraction in tunnels is associated with generally similar driving decrements as freeway driving; however, the potential consequences of these decrements in tunnels remain significantly more serious. Future research should attempt to elucidate the nature of any differential compensatory behavior in tunnel, compared to freeway, driving. In the meantime, drivers should be advised to refrain from text messaging, especially when driving in tunnels.

1. Introduction

A new tunnel project is currently underway in Sweden. The Stockholm Bypass is a new motorway linking southern and northern Stockholm, which when completed in 2020 will be approximately 18 km in length, making it one of the longest road tunnels in the world. The Swedish Transport Administration estimates that, by 2035, the Bypass will be used by approximately 140,000 vehicles per day (STA, 2011).

Although crash risk associated with tunnel environments is lower than that associated with open roads (Carvel and Marlair, 2005), safety measures are a high priority in tunnels because the consequences of traffic collisions can be far more devastating than in open-air surroundings. In particular, fire and asphyxiation are major concerns (Ministry of the Interior, 1999). It is therefore of highest importance to explore mechanisms by which to improve crash avoidance in tunnels. Only a handful of studies to-date has explored driver behavior in simulated tunnel conditions (Kircher and Ahlstrom, 2012; Manser and Hancock, 2007; Vashitz et al., 2008; Törnros, 1998).

The physical characteristics of tunnels differ from those of freeways. Most obviously, the presence of walls and a ceiling in tunnel environments limits visual complexity in terms of variety, color, and texture. Further, because they are enclosed, tunnels tend to be darker than freeways (at least during daylight hours); however, recent improvements in tunnel lighting and design have been used to create tunnels that are more appealing to drivers than previously (Jones, 2007).

Driving performance in tunnels differs from freeway driving in a number of important ways. Because of the enclosed environment, tunnel driving affects driving demand and workload by increasing the effort required to maintain lateral control of the vehicle and by increasing the frequency of driver eye fixations to the center of the road (Beall and Loomis, 1996; Chatziastros et al., 1999; Shimojo et al., 1995). Drivers may adopt lower vehicle speeds and rate

* Corresponding author at: Building 70, Wellington Road, Clayton, VIC, 3800, Australia. Tel.: +61 3 9905 1879; fax: +61 3 9905 4363.
E-mail address: missy.rudin-brown@monash.edu (C.M. Rudin-Brown).

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workload as higher in tunnels compared to on freeways because of the increased rate of optic flow in their peripheral visual field (Gibson, 1979), which leads to the mistaken perception that the road is more narrow (Lotsberg, 2001) and would similarly be expected to result in slower speeds (Godley et al., 1999). Strong evidence exists showing that vehicle velocity decreases with narrowing road width, while the number of erratic lateral maneuvers increases (Godley et al., 1999; OECD, 1990). Interestingly, the change in road width does not need to be perceived by drivers to produce the slower speeds. For example, when road width was manipulated in a driving simulator, the reduced speeds adopted on narrower roads were accompanied by drivers' increased ratings of risk despite their inability to identify any change in road width (Lewis-Evans and Charlton, 2006). In a simulator study of tunnel driving, tunnel wall visual pattern and texture were demonstrated to have clear attenuating effects on drivers' speed choice (Manser and Hancock, 2007). Similarly, findings of a recent simulator study were suggestive of an interaction between tunnel illumination and driver's visual distraction on lateral deviation within the lane (Kircher and Ahlstrom, 2012). There are, up until now, no studies that have compared tunnel and open road environments in a systematic way; however, there are reports of higher average speeds on freeways *vs.* tunnels with similar geometric characteristics and within the same speed zone (Diamantopoulou and Corben, 2001).

Driver distraction has been demonstrated, in on-road naturalistic studies, to be significantly associated with an increase in crash risk (Klauer et al., 2006), and therefore provides an area of crash causation on which to focus. Drivers who use mobile devices to send and receive text messages are at an increased risk of collision (Klauer et al., 2006; Olson et al., 2009), making this behavior of particular concern to road safety authorities worldwide. In Sweden, where there are legal requirements for drivers to maintain due care and attention but no laws specifically limiting the use of mobile phones while driving, 28% of over 3000 drivers surveyed in 2010 reported engaging in text messaging while driving, with 46% of these drivers being aged between 18 and 29 (If, 2010). Similarly, in Victoria, Australia, a large proportion (≅25%) of drivers admit to sending and receiving text messages while driving, despite a long-standing ban on that behavior (Young and Lenné, 2010). These online survey data reveal that 88% of young drivers who use a handheld mobile phone while driving reported *reading* text messages, while 77% admitted to *sending* text messages. Observational survey data support these rates of use. A recent roadside survey found a significant proportion (3.4%) of drivers to be engaged in handheld mobile phone use, including text-messaging (1.5%), at intersections in Melbourne (Young et al., 2010; Rudin-Brown et al., 2009). In line with other reports, younger (<30 years) drivers were over five times more likely than older (50+ years) drivers to be observed text-messaging (Young et al., 2010).

Not surprisingly, while driver distraction is associated with a number of decrements in driving performance, the visual–manual demands associated with mobile phone use, and of text messaging in particular, appear to have particular effects on performance measures involving supervision, or monitoring, of vehicle parameters (Victor et al., 2009). Lateral position metrics are particularly affected, with many studies demonstrating that dialing a mobile phone leads to significant deviation in drivers' lateral position and increased steering wheel movements (Brookhuis et al., 1991; Green et al., 1993; Horrey et al., 2006; Reed and Green, 1999; Törnros and Bolling, 2005). It is not only the biomechanical interference that affects steering behavior; when visual attention is drawn away from the forward scene to a mobile phone, drivers tend to maintain more of a fixed steering position, leading to over-corrections, weaving within the lane, and lane departures (Brookhuis et al., 1991; Törnros and Bolling, 2005). Similarly, texting places demands on visual attention that result in drivers having to switch their attention between activities, rather than sharing attention to two tasks at the same time. Driving simulator evaluations of text messaging have found that both sending and reading text messages negatively affects drivers' ability to control lateral position and their response to traffic signs (Drews et al., 2009; Hosking et al., 2009). Reading text messages *vs.* writing text messages may also have dissimilar effects on driving performance measures. Manual interaction with a mobile phone is associated with increased reaction times to peripheral stimuli and more missed traffic signals (Brookhuis et al., 1991; Törnros and Bolling, 2005), whereas reading text messages impairs drivers' reaction time to a lead vehicle's brake lights more so than composing texts (Drews et al., 2009).

The focus of the present simulator study was on driver distraction in the context of tunnel driving. More specifically, it sought to investigate the effects of text messaging on driving performance and driver visual behavior in tunnel *vs.* freeway environments. It was hypothesized that:

H1. Compared to on the freeway, driver distraction in the tunnel environment would be associated with differences in driving performance measures, including slower speeds, a more central position in the lane with less lane deviation, more glances of shorter duration to the mobile phone, and increased subjective workload; and

H2. Regardless of road environment, compared to driving alone, driving while text messaging would be associated with significant differences in driving performance measures, including more variable lateral control of the vehicle, slower and more variable vehicle speeds, fewer glances to the roadway, and increased subjective workload. Further, compared to *reading* a text message, the combined task of *reading and writing* a text message while driving would further exacerbate the expected differences in performance.

2. Method

2.1. Experimental design

A two-way (2×3) repeated measures design with road environment (tunnel *vs.* freeway) and task (Baseline, Texting—read only, and Texting—read and write) as within-subjects factors was used to test the two study hypotheses. To assess drivers' performance on the text-messaging tasks, speed and accuracy of text-messaging served as dependent variables. For driving performance, dependent variables included vehicle speed and speed variability, and standard deviation of lane position (SDLP). To investigate driver visual behavior during text-messaging, the percent of drivers' total gaze time on road centre *vs.* on the mobile phone (during text-messaging conditions) were used as dependent measures. Finally, to assess drivers' perceived workload between the road environments and across text-messaging tasks, ratings of subjective workload served as the dependent variable. Order of presentation of road environment was counterbalanced across participants, and order of task presentation was counterbalanced within each road environment.

2.2. Participants

Twenty-four licensed drivers aged between 25 and 50 years (mean = 33, SD = 10) who considered themselves to be "regular users of text messaging services" (mean number of minutes per week = 100, SD = 100) participated in the study. The decision to recruit a cross-section of 'middle aged' drivers was made to allow the assessment of a range of driver ages, with the within-subjects study design ensuring that each acted as their own control. Studies on the effects of age on driving behavior have shown that effects are gradual and tend to be limited to very young (*i.e.*, teenagers aged 16–19) or very old (*i.e.*, >75) drivers, whereas the effects of