Applied Ergonomics 60 (2017) 136–145

Contents lists available at ScienceDirect

Applied Ergonomics

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

Investigating the impact of static roadside advertising on drivers' situation awareness

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ARTICLE INFO

Article history:
Received 21 June 2016
Received in revised form
13 November 2016
Accepted 18 November 2016

Keywords:
Driver distraction
Situation awareness
Roadside advertising
Billboards
On-road study

ABSTRACT

Roadside advertising has the potential to create a crash risk for drivers as it may distract attention from driving at critical times. In an on-road instrumented vehicle study, we examined if and how static advertising billboards affect drivers' situation awareness across different driving environments. Nineteen fully licensed drivers drove an instrumented vehicle around a 38 km urban test route comprising freeway, busy urban retail and arterial road sections. The route contained a number of static billboards. Drivers provided continuous verbal protocols throughout the drive. Results indicated that the structure and content of drivers' situation awareness was not appreciably affected by the billboards in any of the road environments examined. Drivers focused their attention on the billboards when driving demand was low, such as when driving on the freeway with light to moderate traffic, in lower speed zones, or when stationary. However, when drivers were required to perform a manoeuvre or driving demands increased, drivers directed less attention to the billboards and focussed their awareness on the immediate driving task. This suggests that drivers can, at least under some conditions, effectively self-regulate their attention to billboards when required to focus on the immediate traffic or driving situation.

1. Introduction

Driving is becoming progressively more complex and drivers more distraction prone due to both in-vehicle (e.g., technologies) and external (e.g., road signs, advertising) factors. Driver distraction, defined as the "diversion of attention away from activities critical for safe driving towards a competing activity" (J. D. Lee, Young and Regan, 2009, p 34), is acknowledged internationally as a growing threat to road safety (WHO, 2011). In Australia, distraction has been reported as a contributing factor in 14 percent of serious crashes resulting in hospital attendance (McEvoy et al., 2007), and in 10 percent of fatal and 18 percent of injury crashes in the US (NHTSA, 2015).

Distractions arising from outside the vehicle constitute a significant proportion of distraction −related crashes. In the US, up to 30 percent of police-reported distraction-related crashes are linked to external sources (Stutts et al., 2001). Among the various external sources of distraction present in the road environment, roadside advertising represents a source that, by its very nature, is designed to attract drivers' attention. Unlike directional and information-based roadside signage, which can provide wayfinding, information on road conditions and hazards and road safety messages, billboards are highly conspicuous due to their size, colour and their close proximity to roadways. In particular, digital billboards have been suggested to be a potential source of distraction given that their movement and flicker can involuntarily capture drivers' attention (Abrams and Christ, 2003; Roberts et al., 2013). Given their attention-grabbing properties, it is reasonable to posit that billboards could distract drivers' attention from the driving task and negatively impact driving behaviour. Indeed, basic visual search research conducted in laboratories indicate that the presence and decreased proximity of distractors increases reaction time to a target stimulus (Johnston and Cole, 1976; Pashler, 1987); suggesting that roadside advertising could disrupt drivers' ability to detect driving-relevant information and objects in the road environment.

While some crash-data based studies have shown a correlation between roadside advertising and higher crash rates (e.g., Farbry et al., 2001; Wallace, 2003), others have found no correlation (e.g., Yannis et al., 2013). Indeed, there is currently no direct, conclusive evidence that roadside advertising plays a significant causal role in distraction-related crashes (Roberts et al., 2013).

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http://dx.doi.org/10.1016/j.apergo.2016.11.009
0003-6870/

However, there is a range of evidence from simulation and on-road research suggesting that roadside advertising can negatively impact a range of more subtle behavioural indicators (Wachtel, 2009).

Research conducted in a controlled simulated environment has demonstrated that drivers can look at roadside advertising too frequently and for too long (Crundall et al., 2006). Crundall et al., for example, found that drivers in their study spent, on average, almost half a second looking at raised level advertising billboards and close to one second looking at street level billboards. To put this into perspective, the authors found that drivers spent less time looking at potential driving hazards in the same region. Other researchers have also shown that time spent looking at roadside advertising is detrimental to safe driving (Edquist et al., 2011; Young et al., 2009). In particular, drivers' lateral (Young et al., 2009) and longitudinal control, as well as their reaction times to driving events (Edquist et al., 2011), have been demonstrated to be adversely affected by the presence of advertising billboards.

Research conducted in real traffic conditions largely support simulator study findings regarding visual attention. Dukic et al. (2013), for example, found that the middle-aged Swedish drivers in their instrumented vehicle study made more frequent and longer glances toward electronic billboards than standard road signs. On average, drivers in their study spent 2.25 s fixating on electronic billboards while driving during the day, compared to an average of 0.87 s for other traffic signs. The dwell times for the electronic signs is almost double what was found in Crundall et al.'s (2006) simulator study for static street level billboards and suggests that the changing display on electronic billboards may attract drivers' attention for longer. It is also interesting to note that glances away from the forward roadway of more than two seconds increased crash and near-crash risk by at least two times that of normal, undistracted driving (Klauer et al., 2006).

Both simulation and on-road research shows that the impact of roadside advertising on driver behaviour is likely to vary depending on the characteristics of the billboard (Crundall et al., 2006; Wallace, 2003). More specifically, the impact of roadside advertising on driving behaviour has been found to increase when the billboard is positioned at street level rather than raised, or when it is located at curves or junctions (Crundall et al., 2006) and the content of the images are emotion laden (Trick et al., 2012). The impact can also vary across type of display (static or dynamic; Lee et al., 2007), with rapidly changing or moving stimuli, in particular, appearing to exacerbate the effects of roadside advertising both in terms of capturing visual attention and degrading driving performance (Belyusar et al., 2016; Decker et al., 2015; Dukic et al., 2013).

Based on the results of previous research, roadside advertising has been shown to negatively impact a range of driver behaviours, including visual attention, reaction time, and lateral control. Another aspect of driver behaviour, shown to be impacted by driver distraction (e.g., Kass, Cole and Stanny, 2007; Strayer and Fisher, 2015; Young, Salmon and Cornelissen, 2013), but that has not been examined in relation to roadside advertising is situation awareness (SA).

Driver SA is defined as activated knowledge, regarding road user tasks, at a specific point in time (Salmon, Stanton and Young, 2012). To safely navigate dynamic road environments, drivers must perceive and attend to relevant information and use this to anticipate and react to changes and events in the environment to avoid conflicts with objects and other road users; that is, drivers must achieve and maintain adequate SA (Gugerty, 2011). Achieving SA involves a range of cognitive processes including perception and pattern recognition (Kass, Herschler and Companion, 1991), attention and comprehension (Steven J. Kass et al., 2007; Wickens and Hollands, 2000), and decision-making (Endsley, 1995; Ma and Kaber, 2005). Engaging in distracting activities that compete for these same cognitive resources can lead to a breakdown in drivers' SA and, ultimately, impaired driving performance and hazard detection (Kass et al., 2007). Directing visual and cognitive attention toward roadside advertising rather than to surrounding road and traffic information could, therefore, result in a breakdown in driving-related SA and, ultimately, to drivers missing critical information regarding a change in the traffic situation that could lead to a collision.

The current study examined, in an on-road context, how static advertising billboards affect drivers' situation awareness in different driving environments: freeway, retail area and arterial road. In particular, we aimed to identify if the presence of billboards impacts on drivers' awareness of the behaviour of other road users or events occurring in the roadway, and in particular if drivers miss safety-critical elements in the environment in the vicinity of billboards (e.g. other drivers, pedestrians, traffic signal changes). Driver SA was modelled through propositional networks, which were constructed based on a content analysis of the verbal protocols provided by participants while driving a pre-defined urban test route. Network-based analysis of driver SA, drawn from verbal protocols, represents SA as information 'elements' and the relationships between them (Walker et al., 2011). Thus, the method provides a comprehensive picture of driver SA that reflects breakdowns in SA due to perceiving fewer information elements in the driving environment, as well as failures of drivers to integrate these perceived elements into a situational model.

2. Method

2.1. Participants

A total of 19 fully licensed drivers (males = 12), provided complete and useable data sets. Drivers ranged in age from 22 to 47 years ($M = 30.8$, $SD = 8.0$), had held a valid licence for 2–30 years ($M = 12.8$, $SD = 8.2$) and drove between 1 and 100 h each week ($M = 16.0$, $SD = 23.5$). Participants reported that 70% of their weekly travel was for private purposes.

Participants were recruited through a weekly on-line Monash University newsletter and were compensated for their time and travel expenses. The study was approved by the Monash University Human Research Ethics Committee.

2.2. Materials and equipment

2.2.1. On-road test vehicle (ORTeV)

The study was conducted using MUARC's On-road Test Vehicle (ORTeV). The ORTeV is an instrumented GM Holden Calais sedan with automatic transmission and is equipped to simultaneously collect vehicle-related and roadway scene data and record driver-vehicle interactions. A discrete V-Box data logger records vehicle speed, GPS location, longitudinal acceleration and deceleration, steering variation and total distance travelled. Four unobtrusively mounted cameras capture forward and rear roadway views, each spanning 90°. Video data of the driver's facial expressions and their interactions with the cockpit (see Fig. 1) are also recorded. Audio data from inside the vehicle are captured via small ceiling mounted microphones. A small hand-held dictaphone was also placed in the vehicle as a backup for audio recordings.

A smart phone was mounted on windscreen to the left of the driver, above the centre fascia. This provided voice-guided navigation information to drivers throughout the driving route. A tracking program installed on the phone also streamed real time GPS data to the experimenters, allowing online monitoring of each