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Driving simulator study on the influence of digital illuminated billboards near pedestrian crossings

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ABSTRACT

Objective: To evaluate the effect of display time and distance of digital illuminated billboards near a pedestrian crossing on glance and driving behavior.
Background: Several functional characteristics and placement conditions of digital billboards influence glance and driving behavior.
Method: Forty-one participants drove seven different routes (3.8–5.2 km) in a driving simulator. We performed a repeated measures ANOVA with presence of billboard, display time of the message (3 s, 6 s and 15 s), distance from a pedestrian crossing (41 m and 65 m) and road environment (transition road to a built-up area and retail zone) as the manipulated conditions in a randomized order.
Results: Shorter display times and retail zone resulted in a significantly higher number of eye glances towards the digital billboard. Participants reported a significantly higher mental workload and a lower estimation of personal driving performance in the presence of a digital billboard. Scenarios with a digital billboard resulted in a somewhat higher approaching speed towards the pedestrian crossing with the minimum approaching speed reached closer to the crossing. The first time a pedestrian crossed the road, reaction time to the crossing pedestrian was higher in presence of the digital billboard (this was not tested statistically).
Conclusion: The presence of a digital billboard, especially with short display time, leads to visual distraction, which has a negative impact on driving behavior and traffic safety.

1. Introduction

1.1. Advertising signs/digital billboards

Despite obvious financial benefits of (digital) advertising signs, the downside of roadside advertisement is driver distraction. Roadside advertising attracts visual attention and cognitive central processing, so billboards would be expected to cause task interference with driving tasks that require visual fixation and central processing (Wickens, 2008). Given that people have limited attentional resources, if attention is pulled away from the driving task towards a roadside advertisement, this may leave insufficient attentional capacity for the adequate execution of the driving task (Wickens, Hollands,

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Banbury, & Parasuraman, 2015). However, a direct causal relationship between distraction from advertising billboards and road crashes is difficult to prove (SWOV, 2012).

To investigate the effects of roadside advertising, different studies focused generally on three outcome measures: glance behavior, cognitive factors (e.g. driver workload), and driving behavior (e.g. driving parameters and crashes). Different eye movements studies while driving (Beijer, Smiley, & Eizenman, 2004; Belyusar, Reimer, Mehler, & Coughlin, 2016; Crundall, Van Loon, & Underwood, 2006; Garrison & Williams, 2013; Lee, McElheny, & Gibbons, 2007; Misokefalou, Papadimitriou, Kopelias, & Eliou, 2016; Smiley et al., 2005; Stavrinos et al., 2016) provide evidence that billboards may capture drivers' visual attention and hold it for some period. An overall conclusion is that the presence of a digital billboard results in a higher mental workload (Chattington, Reed, Basacik, Flint, & Parkes, 2009; Edquist, Rudin-Brown, & Lenne, 2009; Young & Mahfoud, 2008). Backer-Grøndahl & Sagberg (2009) have shown that distraction related to advertising billboards increases crash risk by a factor of 17 (self-reported behavior), and Gitelman, Zaidel, & Doveh (2012) found a statistically significant increase of crash rate near billboards (before-and-after study). Other studies (Izadpanah, Omrani, Koo, & Hadayeghi, 2014; Smiley et al., 2005; Yannis, Papadimitriou, Papantoniou, & Voulgari, 2013) have suggested that the contribution of roadside advertising to crashes is likely to be relatively small or even non-existent (before-and-after study). On the basis of the results it cannot be concluded that (digital) billboards increase crash risk nor can it be concluded that they have no effect on crash risk at all.

1.2. Pedestrian crash data analysis

Pedestrian fatalities greatly vary among the different countries in the European Union. The lowest rate of pedestrian fatalities per million inhabitants (year 2014) is in the Netherlands (3) and Denmark (4), while the highest is in Lithuania (37) and Latvia (35) with an average of 11 for the European Union (European Road Safety Observatory, 2017). Considering all fatalities (year 2014; excluding Lithuania), pedestrians have a share of 21% (European Road Safety Observatory, 2016). Compared with other modes of transport, pedestrians have only a decrease of 35% during the decade 2005–2014 (while the overall average decrease in number of fatalities in the EU is 42% (European Road Safety Observatory, 2016). Speeding, drink-driving, drug-driving and distracted driving are risk factors that contribute to pedestrian fatalities (WHO, 2015).

1.3. Distraction and (in)attention

Driving a car requires substantial cognitive effort and attention (Borghini, Astolfi, Vecchiato, Mattia, & Babiloni, 2014), and distraction is one of the main challenges. A recent overview of the relevant literature reveals that distraction is likely to be a contributing factor in 10–30% of all European road accidents (European Commission, 2015). Although distraction receives much attention, a uniform definition is still lacking (Hedlund, Simpson, & Mayhew, 2006; Lee, Young, & Regan, 2008). According to Regan, Hallett, and Gordon (2011) distraction in driving always comprises the following: (1) diversion away from (safe) driving; (2) attention diverted towards a competing activity inside or outside the vehicle, which may or may not be driving related; (3) the competing activity may or may not compel or induce the driver to divert his attention towards it; and (4) there is an implicit or explicit assumption that safe driving is adversely effected. A distinction is made between visual distraction (e.g., looking away from the roadway), auditory distraction (e.g., responding to a ringing cell phone), biomechanical distraction (e.g., manually adjusting the radio volume), and cognitive distraction (e.g., being lost in thought) (Ranney, Mazzae, Garrott, & Goodman, 2010).

For (in)attention as well, there is no uniform definition (Talbot, Fagerlind, & Morris, 2013). While some definitions are confusing due to (partial) overlap with distraction, others clearly distinguish from distraction by referring specifically to driver states (e.g. mind-wandering or drowsiness). Inattention simply relates to not paying attention to activities deemed necessary for safe driving with distraction possibly resulting in driver inattention. However, inattention is not necessarily the outcome of distraction (Regan & Strayer, 2014; Regan et al., 2011).

1.4. Aim

The SEEV model (Wickens, Goh, Helleberg, Horrey, & Talleyr, 2003; Wickens, Helleberg, Goh, Xu, & Horrey, 2001) is a model of scanning behavior describing the probability that a given area of interest will attract attention. SEEV refers to the Salience, Effort, Expectancy, and Value associated with a particular area of interest (e.g. billboard). Salience will refer to the physical properties of a billboard while effort will refer to both the effort involved in reallocating attention to the billboard and to the current mental workload. Expectancy will refer to the expectancy of gaining information from the message of the billboard and value will refer to an objective measure of the value or cost of processing or failing to process the information of the message of the billboard. Thus, it is clear that not all objects or billboards will attract the same amount of attention. A literature review (Brijs, Brijs, & Cornu, 2014) on the impact of outdoor (digital) advertising billboards came to the conclusion that the effect relates to several functional characteristics and placement conditions such as panel location, position, size, and luminance level, and, message-related factors such as type, content, complexity, display time, and transition speed. Another conclusion was that there are no uniform guidelines.

This driving simulator study focusses on two characteristics of digital illuminated billboards: display time of the message (also called cycle time or message duration; i.e. the time that one message is visible) and location of a digital billboard. Various countries currently adopt different standards, guidelines and regulations with respect to practical or legislative issues