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A field study on the effects of digital billboards on glance behavior during highway driving

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ABSTRACT

Developments in lighting technologies have allowed more dynamic digital billboards in locations visible from the roadway. Decades of laboratory research have shown that rapidly changing or moving stimuli presented in peripheral vision tends to 'capture' covert attention. We report naturalistic glance and driving behavior of a large sample of drivers who were exposed to two digital billboards on a segment of highway largely free from extraneous signage. Results show a significant shift in the number and length of glances toward the billboards and an increased percentage of time glancing off road in their presence. Findings were particularly evident at the time the billboards transitioned between advertisements. Since rapidly changing stimuli are difficult to ignore, the planned increase in episodically changing digital displays near the roadway may be argued to be a potential safety concern. The impact of digital billboards on driver safety and the need for continued research are discussed.

1. Introduction

Advances in electronics and low-cost lighting technology have paved the way for a shift in the nature of outdoor advertisement. Dynamic, electronically illuminated, light emitting diode (LED) billboards known simply as digital billboards (DBBs), provide advertisers with the ability to present drivers with graphical images that are refreshed every few seconds. Although, the number and distribution of these billboards has been rapidly increasing, only limited research is available on the impact these displays have on driver attention and safety. In 2007, the Federal Highway Administration (FHWA) deferred any legislation regarding digital billboards onto the states while providing guidance on their placement related to the roadway and the frequency with which content can be refreshed (Shepherd, 2007). It is well established that distractions to a drivers' attention can originate from sources in- or outside the vehicle (e.g. tuning the radio, adjusting the mirror or hearing a siren in the distance). Based upon the framework put forth by the National Highway Traffic Safety Administration (NHTSA) for dealing with driver distraction (2010), recent scientific research on driver attention has been heavily tuned toward in-vehicle interfaces. More limited recent efforts appear to focus on distractions such as DBBs originating from outside of the vehicle (Beijer et al., 2004; Bendak and Al-Saleh, 2010; Chattington et al., 2009; Decker et al., 2014; Dukic et al., 2013; Farbry et al., 2001; Herrstedt et al., 2013; Lee et al., 2007; Smiley et al., 2005).

The idea of driver distractions originating from outside of the vehicle is not new. It has long been suggested that overly complex roadway environments can divert drivers' attention from the operational task (Holahan, 1977; McMonagle, 1952; reviewed in Wallace, 2003). In a landmark study of driver attention related to external lighting, Holahan and colleagues systematically manipulated in a laboratory study the number, color and location of distractors relative to a target stop sign. The authors found that as the number of lighted distractors increased, there was significant increase in participant's reaction time to detect the target (Holahan et al., 1978). Yet, while most empirical research has suggested that driver 'inattention' could lead to increases in unsafe driving habits, the relative scarcity of collision events makes scientific study of the risks of roadway characteristics in natural environments difficult. A number of on-going efforts, such as the United States Strategic Highway Research Program's naturalistic study, aim to better understand how drivers adapt to roadway characteristics (Gordon et al., 2013). However, basic research assessing how drivers allocate attention to different objects in and around the roadway remains a core tool with which to understand how to appropriately minimize the level of demand from the operating environment such that driver's attention can remain primarily focused on the road.

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1.1. Attention

Generally speaking, visual attention is the mechanism by which one selects or orients toward objects, features or locations for further processing or action (Bisley, 2011; Goldberg and Bruce, 1985). Inherent in the concept of selecting one of 'several simultaneously possible objects or trains of thought' for further processing (James, 1890) is the rejection of others. We by definition cannot attend to everything at once. The source of the initiation of these shifts can be either salient items in the world (i.e. 'exogenous') or internally motivated (i.e. 'endogenous'). While both sources of attention-cueing may achieve enhanced perceptual processing, endogenous attention has been shown to be slower to respond (Hikosaka et al., 1996), and recede. In contrast, exogenous attention can be drawn very rapidly (less than 100 ms, Remington, 1980) and is automatic. Abrupt onsets of lights evoke near obligatory shifts of covert visual attention (Yantis and Jonides, 1984). It is unclear whether changing digital advertisements are an example of these abrupt onsets and, if so, whether they can be entirely ignored.

Shifts of covert attention are not identical to shifts of glance (see Corbetta, 1998). However, few would argue they are not very closely related (Hoffman and Subramaniam, 1995; Kustov and Robinson, 1996; Rizzolatti et al., 1987; Wurtz and Mohler, 1976). Belyusar et al. (2013) found electrophysiological signatures of obligatory attention shifts (8–14 Hz Alpha power) to briefly flashed targets, even when participants were instructed to attend to the opposite direction. Since drivers might find it difficult to avoid being covertly drawn to a flashing billboard, it is logical that glances to the billboard may follow. Although there is some debate on the best predictive measure of risk, increased numbers of or length of glances away from the road are associated with more frequent adverse incidents (Dingus et al., 2006; Klauer et al., 2006; Olsson and Burns, 2000; Victor and Dozza, 2011). One perspective provided by Victor and colleagues (Victor and Dozza, 2011) suggests that glances within about two seconds of the onset of an event were the best predictor of crashes or near crashes That is, it was not the duration, or total number of glances, but those occurring at 'the wrong time' that were most associated with incidents. On the other hand, Dingus et al. (2006) argued that glances greater than two seconds themselves were the strongest predictor. In either case, Rumar's (1990) observation that the 'delayed detection' of an event (other cars, pedestrians, etc.) is a 'main factor' in traffic incidents is well supported and elements of the driving environment that pull attention away from the forward road should be considered guardedly.

1.2. Previous literature

A literature review conducted for the FHWA in 2001 suggested "that EBBs (now called digital billboards) may be associated with a higher crash rate under certain conditions" (p. 10) (Farbry et al., 2001) and recognized a need for additional data. Subsequent research has produced somewhat conflicting results. A simulation study comparing static vs. video advertisements, suggested that billboards of all kinds can affect driver behaviors, such as lane position variability and speed (Chattington et al., 2009). In a field study of DBBs, Smiley et al. (2005) recorded the behavior of 16 participants ranging in age from 25 to 50 years old while driving through downtown Toronto. The drivers passed four digital billboards and an unreported number of traditional billboards and signs. The authors also observed traffic patterns and collected survey data from a different group of residents of the city. Considering all of these sources as a whole, the authors concluded that video advertising can "distract drivers inappropriately." In contrast, Lee and colleagues (2007) studied 36 experienced drivers (18 younger and 18 older) in Cleveland, Ohio in the presence of DBBs. They reported that overall driving performance was not significantly different in the presence of DBBs compared to the other potential distractors such as traditional billboards and 'comparison sites', which included on-premise signs, logos and murals. While comparisons did not always reach significance, both studies reported nominal differences in length and number of glances in the direction of electronic signage. It should be noted that both the Lee et al. (2007) and Smiley et al. (2005) investigations occurred in dense urban environments and used business signs with digital components as comparators.

More recently, Dukic et al. (2013) investigated the glance behavior of 41 older Swedish drivers (mean age 42) in relation to four DBBs, seven traffic signs (e.g. exit signs) and one traditional billboard. Half of the study participants drove at night and the other half during the day. The authors reported that DBBs attracted more and longer glances than other road signs. However, drivers in this study ignored the majority of signs entirely and looked less frequently at some electronic billboards at night than other stationary road signs such as overhead information (see Dukic et al., 2013; Fig. 3).

Finally, a field study on driver visual behavior related to DBBs commissioned by the FHWA in 2007 was recently published (Perez et al., 2012). The authors compared "glance behavior" during a section of road with no billboards ('control') to similar sections of road with digital and standard billboards in two cities. Data were collected during the day and night and across different road types. The authors concluded the presence of DBBs was not associated with "unacceptably long glances away from the road'. However, participants did in fact gaze more often to DBBs than standard billboards and in some cases more than twice as much (71% vs. 29% at night in Richmond). This is notable considering the fact the DBBs were in general smaller in size than the standard billboards.

Considering the planned propagation of DBBs and the inconsistent results that appear on how and to what extent DBBs impact on drivers' attention, additional data on the effect of digital signage on driver behavior is clearly needed. As part of larger field investigations of driver attention (Reimer et al., 2013b), data were collected during periods of highway driving where 123 drivers, distributed across two age groups (20–29 years and 60–69 years), passed a number of DBBs. One of these billboards was double sided and isolated from surrounding advertisements and major traffic signage on a section of interstate 93, approximately 11 miles north of Boston. By investigating driver behavior across this specific section of highway, this report assesses the effect DBBs have on drivers' attention. In contrast to earlier work, this study considers the behavior of a larger sample of drivers and allows for consideration of the possible significance of age.

2. Materials and methods

The data described in this report were drawn from two field driving studies during periods prior to and following the performance of a set of in-vehicle tasks aimed at assessing the demands of a production level embedded voice interface (Mehler et al., 2014; Reimer et al., 2013a). The data reported here consist of secondary analyses of periods in which participants were not engaged in any directed activity and were operating under the basic instructions "drive as you normally would". In essence, during the periods of analysis considered here, the driver was freely operating the vehicle and under no specific experimental instructions beyond the general safety briefing provided prior to departing the research facility. An overview of methods and participants relevant to this analysis is provided below. See Mehler et al. (2014) and Reimer et al. (2013a) for a full description of experimental procedures unrelated to this portion of the dataset, (e.g. training and structure of secondary tasks in each experiment, etc.)