Applied Ergonomics 63 (2017) 17–30

Contents lists available at ScienceDirect

Applied Ergonomics

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

The role of driver age in performance and attention allocation effects of roadway sign count, format and familiarity

Maryam Zahabi [a], Patricia Machado [b], Carl Pankok Jr. [a], Mei Ying Lau [a], Yi-Fan Liao [a], Joseph Hummer [c], William Rasdorf [b], David B. Kaber [a, *]

[a] Edward P. Fitts Department of Industrial & Systems Engineering, North Carolina State University, United States
[b] Department of Civil, Construction, and Environmental Engineering, North Carolina State University, United States
[c] Department of Civil & Environmental Engineering, Wayne State University, United States

ARTICLE INFO

Article history:
Received 7 May 2016
Received in revised form
25 March 2017
Accepted 1 April 2017
Available online 8 April 2017

Keywords:
Logo signs
Driving simulation
Driver performance
Driver distraction
Highway safety

ABSTRACT

White-on-blue logo signs are used to inform drivers of food, gas, lodging, and attraction businesses at highway interchanges. In this study, 60 drivers were asked to look for food and attraction targets on logo signs while driving in a realistic freeway simulation. The objective of the study was to quantify effects of the number of sign panels (six vs. nine), logo familiarity (familiar vs. unfamiliar), logo format (text vs. pictorial), and driver age (young, middle, and elderly) on performance, attention allocation and target identification accuracy. Results revealed elderly drivers to exhibit worse performance in comparison to middle-age and young groups even though they adopted a more conservative driving strategy. There was no significant effect of the number of panels, logo familiarity, and logo format on driver performance or attention allocation. In target identification, drivers were more accurate with familiar or text-based panels appearing in six-panel signs.

1. Introduction

Proper roadway signage design based on human factors principles can reduce the potential for driver distraction. Previous studies have revealed a link between roadside distractions, attention allocation, and vehicle control (e.g., Hummer, 1989; Kaber et al., 2012). In general, distractions result in a decrease of visual attention to the driving task, which can translate into vehicle control uncertainty (Wierwille, 1993). Recent work (e.g., Dagnall et al., 2013; Kaber et al., 2015) has examined these issues in the use of specific service logo signs, which present logos of gas, food, lodging and attraction businesses at upcoming interchanges on freeways.

1.1. Driver use of freeway logo signs

Currently, the Manual on Uniform Traffic Control Devices (MUTCD; Federal Highway Administration, 2009) limits the number of panels on specific service signs to six panels with no justification for this limit. In many instances, the demand for business advertising exceeds the available sign space, so the six-business limit results in lost potential revenue for state transportation departments. While this demand calls for additional panels on signs, safety concerns have been raised on the basis that target search may become more difficult and attention demanding as the number of distractors surrounding a target stimulus increases (Wolfe, 1998; Treisman and Gelade, 1980). In the context of driving, such demands could translate to impaired performance. With this in mind, existing work has assessed the effect of increasing the number of logo sign panels on attention allocation and driving performance (e.g., Kaber et al., 2012).

In general, three types of studies have been performed to assess the effect of increasing the number of panels on a logo sign: (1) observational studies, (2) presentation-based experiments, and (3) controlled simulated driving experiments. Observational studies, monitor driver behavior at various signage locations and have generally shown nine panel logo signs to yield no significant degradation in driver safety, as compared to six panel signs (e.g., Lee et al., 2005; Simpson, 2007; Carter and Wang, 2007). Both Lee et al. (2005) and Simpson (2007) conducted "before-and-after" crash data analyses for strategic interchanges where new logo sign

* Corresponding author. Dept. ISE, North Carolina State University, 400 Daniels Hall, Raleigh, NC 27695 United States.
E-mail address: dbkaber@nscu.edu (D.B. Kaber).

http://dx.doi.org/10.1016/j.apergo.2017.04.001
0003-6870/

configurations (including nine-panel signs) were installed. Carter and Wang (2007) conducted a field observation study to analyze unusual driving behaviors (e.g., drifting and breaking) at interchanges where nine-panel and overflow-combination signs were installed. One caveat to this research, and the findings of no impact, is that Costa et al. (2014) found drivers to fixate on only 25% of signs they passed while driving over an extended distance. Such behavior might mask real difficulties drivers have in searching larger signs. It is also important to note that these observational studies lacked experimental control (e.g., participant driving experience levels, vehicle status at time of sign exposure, etc.).

Presentation-based experiments deliver a series of static images to participants for varying pre-determined time durations. These studies have generally reported degraded search accuracy for nine-panel signs compared to six-panel signs for exposure durations ranging from 0.8 s to 2.5 s (Hawkins and Rose, 2005; Hummer and Maripalli, 2008). Furthermore, Dagnall et al. (2013) found that response time (RT) increased as the number of panels on a logo sign increased from four to six to nine, and that participants were generally able to recall three to four businesses, regardless of the number of panels on the sign. While presentation experiments provide a great degree of experimental control, there is an absence of competition for driver resources between the sign search task and driving task demands, severely limiting the generalizability of results to real-world driving behavior.

Regarding controlled simulation studies, Hummer (1989) found that lateral control and acceleration control degraded when four panels were presented rather than two, but the average differences were not large (0.12 ft for lateral control and 0.26 $\frac{ft}{s^2}$ for acceleration control), which suggests no functional change in vehicle control (e.g., violation of lane boundaries). In a study comparing driving performance and attention allocation to six-panel vs. nine-panel logo signs in which participants were asked to identify a target business logo, Zhang et al. (2013) found no significant differences in target identification accuracy, response time, maximum off-road glance duration, lane deviation, or reaction time to a hazard (a truck pulling out into the middle of the road) between sign types. They also found that participants adapted their driving behavior, by reducing vehicle speed, in association with the increased information on the nine-panel logo sign. In a continuation of this research, Kaber et al. (2015) found no differences in target identification accuracy, fixation frequency, longest glance duration, lane maintenance, or speed control when exposed to six-panel vs. nine-panel logo signs.

Beyond assessment of the number of business panels on freeway logo signs, the characteristics of logos may also impact driver visual behavior. Existing research suggests that, compared to pictorial logos, text-based logos lead to decreased vehicle control (Hummer, 1989), reduced sign content recall (Liu, 2005), and shorter RT (Dagnall et al., 2013). Driver familiarity with a target logo has also been demonstrated to increase search accuracy compared to search for an unfamiliar target logo (Hawkins and Rose, 2005); however, other research (Liu, 2005) has reported no differences in search accuracy between familiar and unfamiliar logos. Hummer and Maripalli (2008) reported that participants were more accurate in searching for an unfamiliar logo among familiar logos than when searching for a familiar logo among familiar logos, suggesting the effect of target familiarity is mediated by the content of surrounding logos (type of distractors) on a sign.

A wide range of experimental paradigms have been used in the study of logo format (text vs. pictorial) and logo familiarity. The breadth of research methods might be a factor in the disparate results in the literature. In general, current findings make it difficult to come to common inferences as a basis for effective and safe sign design.

1.2. Driver age

Several crash reports have identified a relationship between driver age and crash rates. For example, Tefft (2012) found that crash rates were highest for drivers between the age of 16–17, decreased until ages 60–69 but increased after age of 70. In an earlier National Highway Traffic Safety Administration (NHTSA) report, it was found that automobile crashes increased around age of 65. In addition, the fatality rate per million miles of travel for drivers over 65 years of age was found to be 17 times that of the 25–65 age group (NHTSA, 1997). The increase in accident rates for elderly drivers may be due to age-related degradation in sensory, cognitive and physical functions (Horswill et al., 2008). Vision impairment increases with age (Attebo et al., 1996) and several studies have found significant correlations with crash rates (e.g. Hills and Burg, 1974). Related to this, Anstey et al. (2005) conducted a literature review on articles concerning associations of changes in cognitive (e.g., short term memory, executive functioning), sensory (e.g., vision), and physical (e.g., arthritis) functions due to age with number of vehicle crashes and driving performance measures. They found driving capacity to be directly influenced by cognitive, sensory and physical functions. However, the authors also concluded that capacity along with perceptions of the need for self-monitoring also influence driving behavior. Decrements in sensory, cognitive and physical capabilities due to age may also influence multi-tasking behavior. For example, Yamani et al. (2016) compared driving plus secondary visual task performance of elderly and middle-aged drivers. Results revealed elderly drivers exhibited poorer performance in concurrent task performance as compared to middle-aged drivers.

The effects of age on driving task performance has been studied extensively. In an examination of standard driving and navigation tasks, Dingus et al. (1989) found that participants older than 50 years took significantly longer to complete tasks, including conventional driving tasks using a dashboard and navigation tasks using other in-vehicle instrumentation. Participants also exhibited longer glance times to in-car instruments and committed significantly more errors in performing the tasks than participants younger than 50 years. Similarly, Edquist et al. (2011) found that drivers 65 years and older were the slowest to change lanes in a lane changing task, followed by first-year drivers under 25 years of age. Both groups were slower than drivers between the ages of 25 and 55 years of age. Furthermore, researchers found that the presence of roadside billboards reduced fixation time to the road for all three age groups, but the effect was much less pronounced for drivers over 65. These findings can likely be explained by the results reported by Kaber et al. (2012). They observed that drivers older than 65 years of age develop a more conservative driving style (reduce vehicle speed) when exposed to hazard events in order to compensate for declines in abilities compared to younger drivers. However, age might not always have a negative effect on driving performance as older drivers may benefit from their experience in driving (McPhee et al., 2004) potentially offsetting degradations in perception, cognition and response behaviors. Related to this, elderly driver awareness of, and capability to compensate for any cognitive degradations as a result of age, may contribute to roadway safety (Anstey et al., 2005). Due to this interaction between decrements in cognitive abilities and increase in driving experience, it is important to further investigate the effect of age on driving performance and attention allocation under complex roadway stimulus conditions.

In assessing driver use of logo signs, Hummer (1989) showed that drivers over 50 years of age exhibited poorer speed maintenance and poorer acceleration control when in the presence of logo signs as compared to a group younger than 50 years of age. In their