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# Driver distraction and performance effects of highway logo sign design

Yu Zhang [a], Elizabeth Harris [b], Meghan Rogers [a], David Kaber [a,*], Joseph Hummer [b], William Rasdorf [b], Jia Hu [b]

[a] Department of Industrial & Systems Engineering, North Carolina State University, Raleigh, NC 27695-7906, USA
[b] Department of Civil, Construction & Environmental Engineering, North Carolina State University, Raleigh, NC 27695, USA

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ABSTRACT

Driver distraction and safety concerns have been identified for new highway logo sign configurations. This study assessed driver perception of logo signs and distraction under nine-panel, overflow-combination, or standard six-panel formats. A nine-panel sign has nine business panels within a single sign; a six-panel sign has six panels within a sign; an overflow-combination consists of a standard six-panel sign and a six-panel sign displaying two different services (e.g., food and gas). In this study, twenty-four participants searched for target food business logos while driving in a high-fidelity driving simulation under each signage condition. Gas and lodging signs were also displayed along the road in conventional six-panel formats. Dependent variables included signal detection, visual attention allocation, and vehicle control measures. Experiment results showed nine-panel signs drew greater visual attention and produced lower average speed than overflow-combination signs, and produced a lower speeding percentage compared to six-panel signs. However, there was no evidence the new configurations (nine-panel and overflow) caused substantive performance changes with safety implications. This study suggested the use of nine-panel and overflow-combination logo signs may be suitable for interchanges where there are more than six qualifying businesses in a category in terms of driver performance and safety.



## 1. Introduction

The number of businesses providing motorist services has grown at many highway interchanges. Highway agencies in the U.S. sometimes use specific service signs, or “logo” signs, which are white-on-blue in color, to alert drivers to the presence of these businesses in lieu of billboards. Service categories eligible for signs include gas, food, lodging, etc. In some cases, the number of businesses qualifying for inclusion exceeds the current maximum of six panels per sign. To cope with the increasing business advertising demands and driver information needs, the 2009 Manual on Uniform Traffic Control Devices (MUTCD) presented a revised U.S. logo sign policy permitting the use of a new format, specifically overflow-combination signs (U.S. Federal Highway Administration (U.S. FHWA, 2009)). An overflow-combination sign is actually two signs: one six-panel logo sign for a specific service and another combination sign containing more panels for that specific service and panels for another service category. However, the Manual maintained that no more than six panels could be displayed on a single specific service sign. Beyond permitting the usage of the overflow-combination, in 2005 the North Carolina Department of Transportation (NCDOT) received permission from the Federal Highway Administration (FHWA) to install nine-panel signs at some locations as part of a pilot study to assess safety implications (NCDOT, 2006). Two studies were initiated as part of this assessment, which will be detailed later in this section (Carter and Wang, 2007; Simpson, 2007).

The major concerns associated with these new formats are whether more signs, or signs with more information, might increase visual distraction from the roadway and/or degrade driver detection of desired services (NCDOT, 2006; U.S. FHWA, 2009). Such concerns are not limited to the U.S. The U.K. Department of United Kingdom Department for Transport (2011) has stated that there is a need to manage roadway sign clutter while attempting to satisfy increasing driver information needs.

To address the concerns above, Hummer and Maripali (2008) sought to describe driver behavior in perceiving nine-panel logo signs by a slide-based experiment. Participants were required to identify a predetermined target sign within a short and varying time. This study found correct response percentages for the

* Corresponding author. Tel.: +1 919 515 0312; fax: +1 919 515 5281.
*E-mail address:* dbkaber@ncsu.edu (D. Kaber).

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presence of target logos in a nine-panel sign to be competitive with overflow-combination signs but worse than six-panel signs. The study concluded no driver performance basis for prohibiting use of nine-panel signs at highway interchanges. They also found that most drivers scanned signs for a particular brand versus reading all logos. The duration of scanning was also dependent on service type with gasoline drawing greatest attention followed by food or lodging. However, one limitation of this study is that drivers performed the sign detection task without actually driving a car or simulator.

Related to this, Carter and Wang (2007) recorded instances of unusual driving behaviors (braking, drifting, and dashed/edge lane line encroachment) for six-panel, nine-panel, and overflow-combination signs. Unusual behavior rates for nine-panel and overflow-combination signs were not significantly different from those for six-panel signs. Simpson (2007) compared the before and after crash history at 19 nine-panel and 11 overflow-combination sign locations to the crash history of six-panel logo sign locations in the same corridor with similar traffic volumes. They found no significant evidence to discontinue using nine-panel or overflow-combination logo signs. Lee et al. (2005) studied overflow-combination signs using a before and after crash study and found no additional safety risk by having more than six logos on two sign structures. One limitation of these studies is that they were based on field observations with limited experimental control and, consequently, less sensitivity for detecting safety implications of the new sign formats.

Opposite to these results, roadside signs have often been considered to be a major source of driver distraction potentially diverting attention away from activities critical for safety (Regan et al., 2009). Some crash reviews have even related roadside signs to increased accident rates (Wallace, 2003). Unfortunately, prior ergonomics investigations have not sufficiently addressed these safety concerns related to highway signs.

Young et al. (2009) reported decrements in lane control and slight increases in crash rates when drivers experienced advertising billboards in urban environments, but not on motorways. They also observed greater off-road fixation frequency, which may be resulted in the driver performance problems. As suggested by Senders et al. (1967), when drivers look away from the road, uncertainty about the roadway situation increases. When uncertainty reaches a certain threshold, drivers look back to the road to prevent potential accidents. Therefore, drivers may balance the need to perceive roadway events as well as roadside signs by using short but frequent off-road glances. Related to this, Wierwille (1993) quantified the threshold of single off-road glance duration at 1.8 s on a straight road and 1.2 s on a curve. The U.S. National Highway Traffic Safety Administration (NHTSA, 2012) also suggested a 2 s threshold for a single off-road glance for in-vehicle interactions.

Edquist et al. (2011) claimed roadway billboards may be potentially dangerous based on degraded lane changing performance. However, according to eye tracking data reported in this study (Edquist, 2009), drivers only spent 9.4% of their time (with a range between 6% and 12%) looking at an off-road billboard during a 7.2 s interval. That is, the average off-road glance time associated with a billboard was only 0.68 s (ranging between 0.43 s and 0.86 s), which is far below the 1.8 s off-road glance threshold for in-vehicle distractions (Wierwille, 1993).

Most other similar studies have evaluated roadway signs under urban environment conditions, which have higher visual clutter than highway settings (Crundall et al., 2006; Lee et al., 2003). Therefore, results may not be generalized to highway environments.

Although the results of the above studies may not be sufficient to conclude distraction effects of roadside signs, they support the use of simulators to conduct controlled laboratory assessments of driver behavior under various roadway conditions. Simulation studies have also been shown to be effective for evaluating distractions related to in-vehicle devices (Ma and Kaber, 2005) and comparing interaction alternatives (Rydström et al., 2011; Mitsopoulos-Rubens et al., 2011). Such approaches provide high consistency in evaluating visual attention and driving performance with field tests (de Winter et al., 2008; Wang et al., 2010; Santos et al., 2005).

In the present study, we sought to complement prior research by specifically addressing roadway signs that might lead to increased driver distraction in a highway setting by using a high-fidelity driving simulation environment. The objective was to compare driver perceptual and performance responses with nine-panel, overflow-combination and six-panel logo signs. Fig. 1 shows the formats of signs tested in the study. The utility of the present study is how on-road signage may contribute to driver distraction levels based on roadway and performance degradations.

Based on the literature review, it is possible that multiple logo signs, and/or logo signs with more panels, might lead to greater driver "eyes-off road" time and an increased potential for distraction and collisions. Our primary hypothesis was that use of nine-panel and overflow signs would yield lower target detection rates and greater visual distraction from driving tasks than with six-panel signs (Hypothesis 1). It was also expected that reduced visual attention on-road would cause degraded control in speed maintenance (Hypothesis 2), steering error or lane deviation (Hypothesis 3) and an increased crash probability (Hypothesis 4).

## 2. Methodology

### 2.1. Apparatus

An STISIM Drive M400 driving simulator (System Technology, Inc.) was used in this study. This is a fixed-based driving simulator providing a 135-degree field of view of the driving environment through three 38-inch HD TVs (see Fig. 2). The simulator configuration also includes a realistic vehicle cab with a driver's seat and complete set of full-size driving controls. High-resolution digital sensors and a vehicle-dynamics model are used to provide drivers with real-time feedback of steering and speed control. The cab also integrates audio speakers for presentation of roadway sounds and driver warnings.

An ASL EYE-TRAC® 6 Series head-mounted eye tracker integrated with a head motion tracker (Flock of Birds 6-DOF sensor) was used to collect driver eye movement data at a sampling rate of 60 Hz (see Fig. 2).

### 2.2. Participants

Twenty-four healthy drivers with 12 females participated in this study. Participants represented a random sample of ages from 18 to 58 years ($M = 30.4$; $SD = 11.5$). Each had a valid driver's license and drove at least 5 h per week. Subjects were required to have 20/20 vision without wearing glasses or contacts to ensure accurate tracking of their gaze patterns with the eye tracker. A pilot study and a power analysis were conducted to determine an appropriate sample size for sensitivity of statistical tests. Results indicated a minimum of 19 subjects in total were required to achieve a statistical test power $\geq 0.8$ based on two dependent measures (maximum off-road glance duration and average speed; see Section 2.6). Due to the randomization scheme for test trials and need for balancing gender, participants were recruited in multiples of 6; consequently, 24 persons were used in the study.