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Driver behavior in use of guide and logo signs under distraction and complex roadway conditions

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ABSTRACT

White-on-blue logo signs on the sides of highways are typically used to notify drivers of food, gas, and lodging at an upcoming interchange. The current research assessed driver performance and attention allocation in a simulated freeway driving task when exposed to six-panel logo signs, nine-panel logo signs, mileage guide signs, and roadway work zones both with and without an in-car navigation device. The objective was to identify the impact of signage types on driver behavior under realistic driving conditions. Results revealed glance durations and fixation frequencies to guide signs to be significantly lower than with six-panel and nine-panel logo signs, but no differences were found between six-panel and nine-panel logo signs. There were also statistical differences among the independent variables for speed deviation and lane deviation, but magnitudes were not large enough to be considered practically significant in terms of driving safety. Overall, there were minor differences in sign processing time between logo signs and mileage guide signs, but such differences did not translate to degradations in vehicle control.

1. Introduction

Highway agencies in the United States use white-on-blue logo signs to notify drivers of food, gas, and lodging businesses at highway interchanges. In some cases, the number of businesses at an interchange that seek to advertise exceeds the typical maximum of six available panels per logo sign as specified by the Federal Highway Administration. Logo signs with nine panels have been permitted for evaluation at a limited number of locations to assess safety implications (North Carolina Department of Transportation, 2006), but these are not otherwise permitted by the 2009 Manual on Uniform Traffic Control Devices (MUTCD; FHWA, 2009). The 2009 MUTCD does not provide a justification for the maximum of six panels per logo sign.

A concern with the use of nine-panel logo signs is that the addition of more information on signs may increase driver visual distraction from the highway. Driver distraction is a diversion of attention, away from activities critical for safe driving, toward a competing activity (Lee et al., 2005). Carter and Wang (2007) conducted an observational study of motorist behavior near logo signs in which they recorded instances of unusual driving behaviors (e.g., braking, drifting and/or dashed/edge lane line encroachment) for six-panel, nine-panel, and overflow combination signs, on which panels from one type of business that do not fit on one logo sign are placed on a second logo sign. Among the different signs, there were no significantly different rates of unusual behaviors. Furthermore, Simpson (2007) studied the before-and-after crash history at 19 nine-panel and 11 overflow combination signs and found no significant differences between crash rates at those sites compared to sites with six-panel signs.

Recently, Hummer and Maripali (2008) showed slides of six-panel and nine-panel signs for 1.0 or 2.5 s to subjects scanning for a particular brand. Subjects made more errors with nine-panel signs, but the difference was not large (in terms of absolute sign count). In a driving simulator experiment, Zhang et al. (2013) found that the nine-panel signs drew greater visual attention than six-panel signs, but this actually translated to more conservative or safer driver behavior. None of the differences in visual behavior

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translated to driving performance decrements or safety implications in terms of vehicle control.

One difficulty in interpreting the results from both of the above experiments has been in obtaining perspective or identifying a point of reference. It is possible that nine-panel signs are more distracting than six-panel signs, but we do not know how the level of distraction caused by both types of logo signs compares to, for example, distraction imposed by standard green guide signs, which are considered to be safe by highway design standards.

Beyond this issue, it is possible that driver distraction due to roadway displays may be compounded by the use of in-vehicle navigation aids and exposure to hazardous roadway conditions. Distraction has become a roadway safety concern recently as a result of the proliferation of cell phones and in-vehicle technologies such as navigation aids (Ma and Kaber, 2005). Research has shown that driver use of navigation aids in a simulator led to an increased number of crashes due to drivers changing lanes into traffic (Green, 1997). Medenica et al. (2011) conducted an experiment demonstrating that the proportion of visual dwell time spent focusing on the roadway, as well as lane deviations and steering wheel error, was worse when using standard visual navigation aids. Kaber et al. (2012a) recently found that the complexity of the roadway environment compounded driver performance problems caused by hazard exposure, such as a construction zone. With these findings in mind, it was also considered instructive to examine driver use of traffic control devices, such as logo and guide signs, when posed with in-vehicle distractions and under a variety of roadway conditions from normal to unusual.

1.1. Objectives

Based on the literature reviewed above, the objectives of this research were to compare visual attentional demands of six-panel vs. nine-panel logo signs and then to add perspective by comparing both of these logo sign types to standard guide signs. Furthermore, this research sought to evaluate driver use of logo and standard guide signs in combination with in-vehicle distraction conditions as well as unusual on-road conditions. Achieving these objectives was expected to support highway agencies and researchers in gauging the extent of distraction resulting from nine-panel logo signs and whether such distraction should be a focus of concern, given current day driver activities and roadway situations.

1.2. Hypotheses

Seven research hypotheses were formulated based on the literature review. The first three concerned driver visual behavior when exposed to various types of signs:

- H1. Driver detection of a target business panel on a logo sign was expected to be accurate and consistent among 6-panel and 9-panel signs as well as consistent with detection of destination and distance targets in guide signs.
- H2. Driver visual attention to 6-panel and 9-panel logo signs was expected to be comparable.
- H3. Driver visual attention to guide signs was expected to be greater than for logo signs due to information content (e.g., destination and mileage text).

The remaining hypotheses concerned driver performance when using different types of signs and when exposed to different roadway conditions:

- H4. Driver performance (operationalized below) was expected to be comparable when using 6-panel or 9-panel logo signs.
- H5. Driver performance was expected to degrade when using guide signs as compared to logo signs (due to increased distraction of information content).
- H6. In general, driver performance was expected to degrade when using any roadway signs compared to no-sign conditions.
- H7. Driver performance was, however, expected to improve when exposed to hazardous roadway conditions as compared to no hazard and no sign conditions.

2. Methodology

To achieve the project objectives, a driving simulation experiment was conducted in which the desired distractors were systematically presented to participants. Driver visual behavior and performance responses were recorded with high resolution (described below).

2.1. Participants

Forty (40) participants (21 male and 19 female) with an average age of 38.25 years (range: 25–59) completed the experiment. Chen et al. (2007) previously reported that the number of traffic accidents decreased for drivers 25–60 years of age and increased for persons outside this range. On this basis, participant age in the present study was required to be within 25–60 years. This inclusion criterion promoted a relatively uniform sample in terms of driving ability. All participants had a valid North Carolina Driver's License and 20/20 vision; glasses or contact lenses were permitted in this study (and did not influence eye tracking system data collection).

2.2. Dependent measures

All response measures were recorded over distances in which participants attempted to detect sign targets. The “detection phase” started 650 ft (198.12 m) from a sign, when drivers could see the sign in foveal vision, and ended 112 ft (34.14 m) from the sign, where vehicle fixtures, such as the rear-view mirror, obstructed viewing of the sign (a total distance of 538 ft (163.98 m)).

2.2.1. Signal detection

Sign detection performance was evaluated in terms of driver accuracy in correctly identifying food business logos on pre-interchange logo signs as well as destinations and mileages on post-interchange distance guide signs. Signal detection responses were recorded as follows: “Hit” if a participant correctly identified a sign target, “Correct Rejection” if the participant correctly dismissed a sign without a target, “Miss” if the participant did not respond at all to a sign including a target, or “False Alarm” if the participant identified a target that was not present on a sign.

2.2.2. Eye tracking

Eye tracking measures were determined for an area of interest (AOI) in which guide and logo signs appeared during simulator trials. The AOI extended horizontally from the left edge of a sign when first visible in foveal vision, to the right edge of the simulated vehicle windshield. The AOI extended vertically from the lower edge of a sign when first visible, to the lower edge of the simulated vehicle rear view mirror (which obstructed the view of signage at a distance of 112 ft (34.14 m) or less). There were two eye tracking response measures derived from the eye movement data, including: (1) the maximum glance duration to the AOI; and (2) the AOI fixation frequency. The maximum glance duration was defined as the longest interval of any set of consecutive fixations to the AOI