Draft Technical Report

Nighttime Conspicuity of Highway Signs as a Function of Sign Brightness, Background Complexity and Age of Observer

by

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Introduction

The nighttime conspicuity (i.e., detection) of highway signs is highly dependent upon brightness. However, the enhancement in conspicuity due to increasing sign brightness appears to "saturate" at relatively low luminance levels.[1] This suggests that the introduction of ultrabright signing materials will do little to improve the delectability of highway signs. There is some evidence, however, that the optimal brightness level for sign conspicuity may be markedly elevated under conditions of high background scene complexity. [1]

The current study was designed to evaluate glance conspicuity for highway signs as a function of sign luminance and background complexity. Since there is some evidence that older adults may be disproportionately affected by background "clutter" [2] -- older as well as younger drivers were examined.

Specific *a priori* research hypotheses guiding this study included: (1) Conspicuity will decrease as background complexity increases; (2) Conspicuity will increase as sign brightness increases for high complexity backgrounds but not for low complexity backgrounds; and, (3)(4) The effects predicted in (1) and (2) above will be significantly magnified among the older group of research participants.

Method

Subjects. Experimental participants included 40 individuals equally divided across the grouping factors of age (young vs. old) and gender (see Table 1).

Table 1.
Sample characteristics

	Young	Old
Mean Age	31.8	71.5
Age Range	22-44	61-80
Mean Acuity	20/15	20/22

Apparatus and Stimuli. Visual scenes depicting 1:1 scaled views of the road (from the driver's perspective) were constructed using a combination of photographic and computer-based image synthesis techniques. Three background scenes varying in complexity were constructed using these techniques: The low complexity scene depicted an isolated 2-lane rural highway. The moderate complexity scene depicted a typical street in the commercial district of a small city. The highest complexity scene depicted a downtown street of an urban area complete with scores of commercial establishments with illuminated business signs (i.e., a very highly "cluttered" background). A single stimulus sign could then be superimposed upon a background scene using image processing techniques. The target sign could appear at one of four predefined locations within the scene: left vs. right together with near vs. far (see Figure 1).

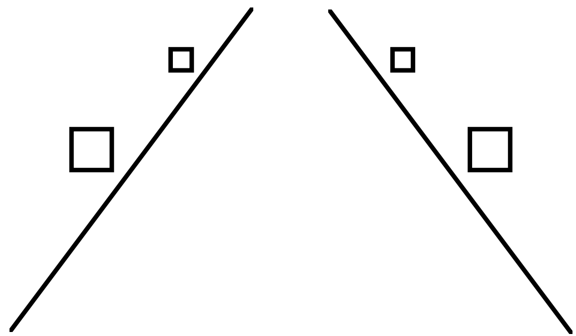

Figure 1.
Target sign locations.

Two highway signs were used as foreground (target) stimuli in this study: a black-on-white SPEED LIMIT 25 sign and a white-on-green BUSINESS DISTRICT sign. Each of these signs could be presented at two luminance levels designed to simulate their respective brightnesses if constructed from normal vs. ultrabright retroreflective sheeting materials (see Table 2).

Table 2.
Stimulus sign luminance levels (cd/m^2).

	Luminance Level	
Sign	Bright	Ultrabright
Speed Limit	15	120
Business District	5	50

A total of 48 stimulus scenes were constructed: (3) backgrounds by (2) brightness levels by (4) positions by (2) sign colors. These stimulus scenes were transferred to 35 mm slides using a special techniques developed for the FHWA's *Nighttime Scene Simulator*. That is, the brightest region of the scene (e.g., oncoming headlights and overhead illuminaires) were printed separately. Hence, each stimulus scene was constructed using two slides: one slide depicted the entire scene and the other slide depicted only the very bright objects in the scene. These two slides were then projected simultaneously upon precisely aligned and overlapping regions of a highly retroreflective screen using the dual-projector system schematically presented in Figure 2. Using this innovative technique, the Nighttime Scene Simulator is capable of capturing most of the dynamic range of stimulus luminance values that characterize the real-world visual environment of the driver (i.e., 40 dB and greater).

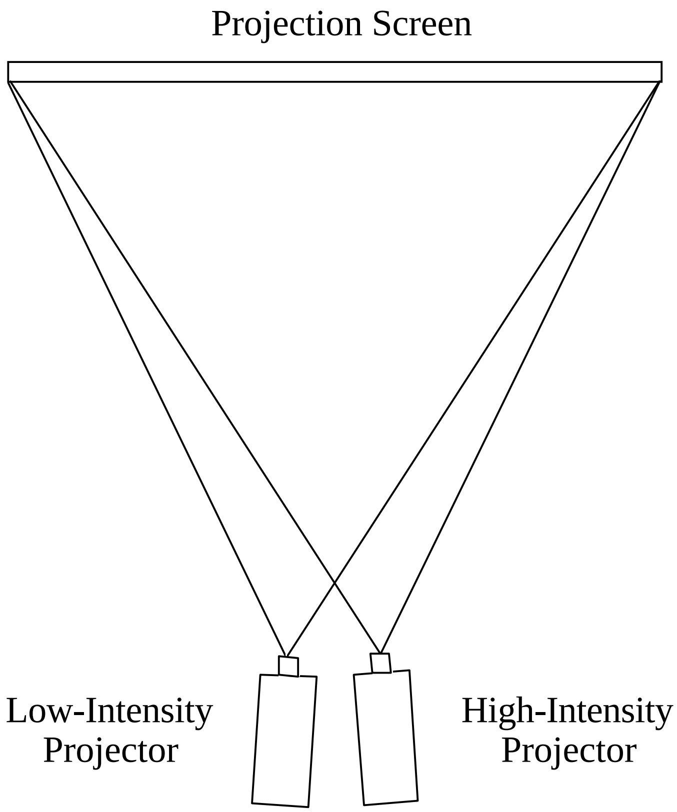

Figure 2.
Dual-projector *Nighttime Scene Simulator*.

The slide projectors were equipped with computerized electronic shutters to control exposure duration. The same computer used to control exposure duration was also equipped with a set of response buttons which were used to collect millisecond precision reaction time data.

Procedure. An experimental trial consisted of a 250 msec exposure of a stimulus scene. Each scene (as described above) contained a single highway sign target. The subject's task was to report the location of the target sign (left vs. right side of the road) as quickly as possible using a set of push buttons. After making the speeded localization response, the subject then verbally reported the color of the sign (white vs. green). These measures, taken together, provide the basis for establishing an index of glance conspicuity. [3,4] The 48 stimuli were presented in random order. This sequence was repeated four times for a total of 192 trials per participant.

Results and Discussion

A (2) age by (3) background complexity by (2) sign brightness analysis of variance (ANOVA) was conducted upon both the sign localization reaction time data and the color identification accuracy data. These factors are currently under investigation in a parallel effort aimed at modeling our conspicuity results using the U.S. Army's TARDEC[5] Visual Performance Model.

Reaction time. The analysis of the RT data was limited to trials upon which the correct sign color identification response was given. The ANOVA results are summarized in Table 3. Although all of the main effects (age, brightness and background complexity) were statistically significant, discussion will be limited to the higher-order interactions of these same effects. Most noteworthy is the highly significant interaction of sign brightness and background complexity. Referring to the graphical depiction of this interaction in Figure 3, one can see that enhanced sign brightness offered no response time advantage when evaluated under conditions of low background complexity. This finding replicates the brightness saturation effects reported in the highway sign conspicuity research literature/database. However, enhanced sign brightness exerted a significant advantage in reaction-time estimates of glance conspicuity under conditions of elevated background scene complexity. These results are consistent with research hypotheses 1 and 2. However, the marginally significant 3-way interaction with the age factor failed to provide sufficient evidence to support research hypothesis 4. The significant age by background complexity interaction provided direct support for research hypothesis 3. That is, the deleterious effects of increasing background complexity upon reaction-time estimates of glance conspicuity were magnified among the older observers (see Figure 4).

Table 3.
Glance conspicuity response time ANOVA summary.

Effect	**F**-test	*p*-level
Age	$\mathbf{F}(1, 46) = 12.5$	0.0009
Complexity	$\mathbf{F}(1.8, 84) = 23.7$	0.0001
Age x Complexity	$\mathbf{F}(1.8, 84) = 4.7$	0.01
Brightness	$\mathbf{F}(1, 46) = 19.8$	0.0001
Age x Brightness	$\mathbf{F}(1, 46) = 4.56$	0.03
Complexity x Brightness	$\mathbf{F}(1.7, 79) = 10.0$	0.0003
Age x Complexity x Brightness	$\mathbf{F}(1.7, 79) = 2.56$	0.09 (not significant)

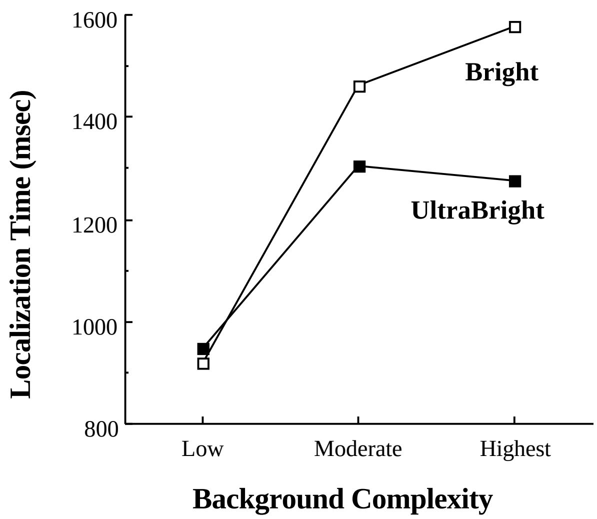

Figure 3.
Glance conspicuity response time as a function of sign brightness and background scene complexity.

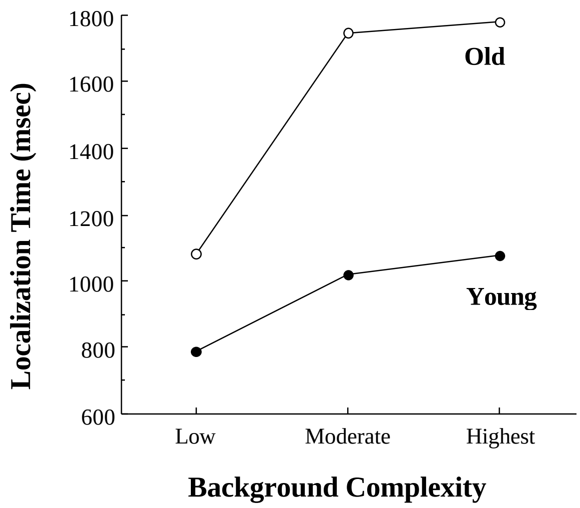

Figure 4.
Glance conspicuity reaction time as a function of observer age and background scene complexity level.

Response accuracy. The results of the ANOVA performed upon the accuracy data for target sign color identification are summarized in Table 4. The overall pattern of results mirrors those obtained for the reaction time measures of glance conspicuity reported above. The most noteworthy finding from the ANOVA was the observation of a highly significant sign brightness by background complexity interaction (see Figure 5). As was the case for the reaction time data, enhanced sign brightness had no effect upon accuracy for the low background complexity condition. However, the brighter signs demonstrated significantly greater resistance to the reductions in response accuracy imposed by increasing background complexity levels.

Table 4.
Glance conspicuity accuracy ANOVA summary.

Effect	**F**-test	*p*-level
Age	$\mathbf{F}(1, 46) = 45.7$	0.0001
Complexity	$\mathbf{F}(1.8, 84) = 230.9$	0.0001
Age x Complexity	$\mathbf{F}(1.8, 84) = 17.7$	0.0001
Brightness	$\mathbf{F}(1, 46) = 114.5$	0.0001
Age x Brightness	$\mathbf{F}(1, 46) = 0.15$	not significant
Complexity x Brightness	$\mathbf{F}(1.7, 79) = 33.4$	0.0001
Age x Complexity x Brightness	$\mathbf{F}(1.7, 79) = 0.79$	not significant

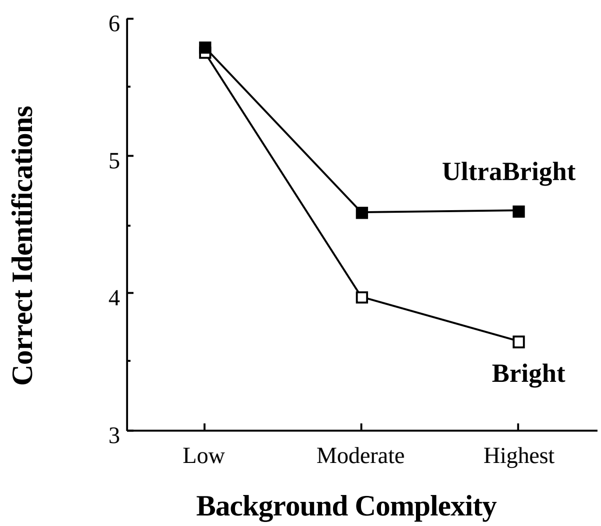

Figure 5.
Number of correct identifications as a function of
sign brightness and background scene complexity level.

Summary and Conclusions

The results of this study support the notion that enhanced brightness levels yield little or no improvement in highway sign conspicuity under typical test conditions (i.e., low background scene complexity). However, increments in sign brightness have been shown to significantly improve highway sign conspicuity under conditions of higher background scene complexity. These findings suggest that ultrabright retroreflective signing materials have the potential for improving highway sign conspicuity in cluttered visual environments (e.g., city centers and busy suburban shopping districts). Additional work is needed to parameterize the effects of sign brightness under these conditions. This study also found evidence that older drivers may be more susceptible to the interfering effects of competing background scene clutter while searching the environment for highway sign information. Finally, the current investigation introduced and successfully tested an innovative technique for capturing the dynamic luminance range of nighttime driving scenes in laboratory-based research.

References

1. Olson, P.L. (1988*). Minimum requirements for adequate nighttime conspicuity of highway signs*. Ann Arbor, MI: University of Michigan Transportation Research Institute (Technical Report no. UMTRI-88-8).

2. Kaussler, D.H. (1991). *Experimental psychology, cognition and human aging (2nd edition).* New York: Springer.

3. Dewar, R.E. and Ells, J.G. (1974). A comparison of three methods for the evaluation of traffic signs. *Transportation Research Board*, *504*, 38-47.

4. Dewar, R.E. (1989). Traffic signs. In D. Osborne (Ed.), *International Reviews of Ergonomics*. London: Taylor and Francis. pp. 65-86.

5. Witus, G. (1996). *TARDEC National Automotive Center Visual Performance Model (NAC-VPM): Analyst's manual (*Final Report: U.S. Army contract no. DAAE07-94-C-R11). Ann Arbor, MI: OptiMetrics Corporation. (Technical Report No. OMI-577).