EFFECTS OF VISUAL DISTRACTION ON REACTION TIME IN A SIMULATED TRAFFIC ENVIRONMENT

C. JOSH HOLAHAN

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EFFECTS OF VISUAL DISTRACTION ON REACTION TIME IN A SIMULATED TRAFFIC ENVIRONMENT

C. Josh Holahan

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16. Abstract

Existing studies of the relationship between visual distractors and traffic accidents are both limited and contradictory. The present study investigates the effect of: (a) number of distractors, (b) color of distractors, and (c) location of distractors, on the perception of a target stimulus. Reaction time was the response measure. Analysis of variance showed that all three dimensions have a significant effect on reaction time, with location having the greatest effect. Conclusions are that: (1) legal limits be placed on distractors, and (2) engineering decisions be oriented toward counteracting the potential negative effects of the background distractors.

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EXECUTIVE SUMMARY

At the present time, the relationship between commercial signs (visual distractors) and traffic safety must be based on limited and contradictory research findings. Some studies have shown a positive correlation between both the presence of advertising devices and the number of elements in the roadside environment, and traffic accidents. Other research has found no relationship between adverising signs and highway accidents. Controlled laboratory experiments provide little more information.

The present study investigates the effect of: (a) the number of distractors (2, 4, 6, or 10), (b) the color of distractors (six combinations of red, orange, and the cool colors of blue, green and black), and (c) the location of distractors (proximate or distant), on the perception of a target stimulus (stop sign). Reaction time in responding to the target stimulus was the response measure.

Subjects were 56 Introductory Psychology students (29 males). Each subject responded to 96 stimulus pictures, presented on an 18" by 12" screen, by depressing "stop" or "go" buttons, depending on the presence or absence of the target stimulus. The 96 pictures represented pairs of the 48 possible combinations of the three dimensions under study, one with the target stimulus and one without. Presentation of the slides and measurement of the reaction times were controlled by a PDP8 computer.

A 4 by 6 by 2 analysis of variance with reaction time as the dependent variable showed statistically significant main effects and both two-way and three-way interaction effects. Of the three dimensions under study, proximity was found to have the greatest effect on reaction times. This suggests that the dominant process was the subject's inability to discriminate figure from ground.

In general, these results suggest that: (1) appropriate ordinances be established to legislatively limit the effect of distractors, and (2) that engineering decisions involving design changes in the target signal be oriented toward counteracting the potential negative effects of the background distractors.

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EFFECTS OF VISUAL DISTRACTION ON REACTION TIME IN A SIMULATED TRAFFIC ENVIRONMENT

The character of commercial development in many urban and suburban areas has resulted in a plethora of advertising signs, neon lights, and gaudy billboards amassed along the roadside environment. While some recent studies[1] have attempted to evaluate the impact of such development from an essentially aesthetic perspective, surprisingly little research has examined the relationship between this array of potential visual distractors in the roadside environment and traffic safety. As part of a program to identify potentially effective traffic safety countermeasures, it was decided that a study should be developed to evaluate the effect of background visual distractors due to commerical development on human performance associated with traffic safety.

Although ordinances exist in most local communities which regulate the placement, size, and light intensity of commercial signs, such regulations are often very vague. One local regulation, for example, prohibits "any change in light intensity, motion, or color which subconsciously fixates or attracts the eyes of the motorist when they should be driving."[2] Typically, these ordinances are written by policy makers whose decisions are based not on actual traffic safety evidence, but rather on personal intuition. Shoaf describes how traffic managers in San Francisco developed an elaborate, restrictive policy for the placement of advertising signs near freeways, while acknowledging that the evidence relating such signs to highway accidents remained inconclusive.[3]

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[1] Boston Redevelopment Authority, City Signs and Lights, (Boston, 1971); G. Winkel, R. Malek and P. Thiel, "Community Response to the Design Features of Roads: A Technique for Measurement," Highway Research Record, 305 (1970), pp. 133-145.

[2] R. T. Shoaf, "Are Advertising Signs Near Freeways Traffic Hazards?," Traffic Engineer, 26, No. 2 (1955), pp. 74.

[3] Ibid.

Very little inquiry has been directed toward visual distractors and traffic accidents in field settings, and those data that do exist are both contradictory and open to methodological criticism. Two studies[4] have reported positive correlations between the presence of advertising devices and automobile accidents on multilane highways. In addition, two studies[5] have indicated a positive relationship between traffic accidents and the number of elements in the roadside environment, such as commercial establishments, intersections, driveways, and traffic signals. Other evidence,[6] however, has reported no relationship between highway accidents and advertising signs.

In contrast, while a large body of research in a controlled experimental format has examined perception of the target traffic stimulus,[7] e.g., the color, size and lettering of road signs, almost no inquiry has systematically investigated perception of the target traffic signal as a function of distractors in its environmental background. Thus, while traffic engineers possess considerable knowledge relevant to the construction of adequate traffic signs isolated from their environmental context, very little is known about how to evaluate features of the background environment which may contribute to or reduce road sign effectiveness. An exception is a recent laboratory study

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[4]Madigan-Hyland, Inc., Signs and Accidents on New York State Thruway, Report prepared for the New York State Thruway Authority, February 1963; Minnesota Department of Highways, Minnesota Rural Trunk Highway Accident, Access Point, and Advertising Sign Study, (Minneapolis: 1952).

[5]J. A. Head, "Predicting Traffic Accidents from Elements on Urban Extensions of State Highways," Highway Research Board Bulletin, 208 (1959), pp. 45-63; J. Versace, "Factor Analysis of Roadway and Accident Data," Highway Research Board Bulletin, 240 (1960), pp. 24-30.

[6]J. C. McMonagle, "Traffic Accidents and Roadside Features," Highway Research Board Bulletin, 55 (1952), pp. 38-48; J. C. McMonagle, "The Effects of Roadside Features on Traffic Accidents," Traffic Quarterly, 6, No. 2 (1952), pp. 228-243.

[7]T. W. Forbes, "Factors in Highway Sign Visibility," Traffic Engineering, 39 (1969), pp. 20-27; T. W. Forbes, T. E. Snyder and R. F. Pain, "Traffic Sign Requirements I: Review of Factors Involved, Previous Studies and Needed Research," Highway Research Record, 70 (1965), pp. 48-56.

of distraction by irrelevant information,[8] which lends partial support to the contention that such distractors reduce driving performance under high information load conditions. In addition, Kahneman, Ben-Ishai, and Lotan[9] afford some indirect evidence, utilizing a selective attention task with bus drivers, demonstrating an inverse correlation between task performance and traffic accident history.

The purpose of the present study was to systematically examine the effect of manipulations along a number of specific dimensions in the background environment on reaction time in responding to a target traffic stimulus, using a controlled experimental simulation of a traffic environment. The dimensions of the background environment investigated were selected both on the basis of the results of the small number of available field studies and on the probability of affording applicable information to traffic engineers. The background dimensions studied were: (1) number of distractors, (2) color of distractors, and (3) location of distractors relative to the target stimulus. Reaction time in responding to the target signal was selected as the response measure because it was assumed to relate to both attentional deficits and accident risk in real driving situations. A controlled experimental format was chosen to afford the type of unequivocal data previously lacking in this area of investigation. It was hypothesized that increasing numbers of distractors, greater similarity of color between distractors and target, and closer proximity of distractors to the target would all exert significant increases in reaction time.

METHOD

Subjects

Subjects were 56 Introductory Psychology students who fulfilled a course requirement by their participation in the study. The sample included 29 males and 27 females.

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[8] A. W. Johnston and B. L. Cole, "Investigations of Distraction by Irrelevant Information," Australian Road Research, 6, No. 3 (1976), pp. 3-23.

[9] D. Kahneman, Ben-Ishai, and M. Lotan, "Relation of a Test of Attention to Road Accidents," Journal of Applied Psychology, 58, No. 1 (1973), pp. 113-115.

Apparatus

Target and distractor stimuli. The target traffic stimulus consisted of an octagonal 2-inch (5.08 cm. diagonal measure) replica of a standard traffic stop sign with white lettering on a red background. The background distractors consisted of 1 3/4-inch (4.45 cm.) square replicas of commercial signs with white lettering on solid backgrounds of five colors (red, orange, blue, green, and black). A different four-letter word was printed on each distracting sign; the words were chosen from Kucera and Francis[10] to have a moderately high English language occurrence. The differential shapes of the target and distractors were chosen to simulate the situation in the actual traffic environment where a stop sign's octagonal shape is typically contrasted with rectangular commercial signs.

Visual displays. The visual displays were constructed through photographic slides of the target in a number of contrasting distractor backgrounds. The field behind the target and distractors was pale blue, simulating the sky color against which such stimuli are often perceived in the actual environment. The manupulations of the background environment were operationalized as follows:

(1) Number of Distractors - the number of distractors were 2, 4, 6, and 10.

(2) Color of Distractors - the color of the distractors was defined as the color of the sign's background, and included either high similarity to the target (red), intermediate similarity (orange), or low similarity (cool colors of blue, green, or black). This dimension was varied by altering the color combinations of distractors as follows: all red, all orange, all cool, combined red and orange, combined red and cool, combined orange and cool.

(3) Location of Distractors - the locations of the distractors were either proximate to the target or distant from the target. The distinction between proximate and distant was operationalized by dividing the field into a 7 x 5 grid (the grid was not visible on the slides) of 2 inch (5.08 cm.) squares. Under the proximate condition, no distractor was further than 4 1/2 inches (11.4 cm.) from the target; distractors were randomly placed within this range. Under the distant condition, no distractor was closer than 4 1/2 inches (11.4 cm.) to the target; distractors were randomly placed within this range.

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[10] H. Kucera and W. N. Francis, Computational Analysis of Present-Day American English, (Providence, R.I.: Brown University Press, 1967).

Three distractor dimensions were crossed, resulting in a total of 48 distractor combinations.

Slide presentation. The subject sat facing an 18-inch (45.72 cm.) by 12-inch (30.48 cm.) frosted glass panel approximately three feet (.91 m.) away on which stimulus slides were projected from behind by a Kodak Carousel slide projector. A PDP8 computer was used to coordinate the slide presentations and to measure and record reaction time in milliseconds to each presentation. A table immediately in front of the subject held a console (connected to the PDP8) with two buttons, labeled either "stop" or "go."

Procedure

Subjects were tested singly. Each subject was presented a sequence of 106 slides. The slides consisted of 48 pairs of distractor combinations, one with the target stop sign present and one with the stop sign absent. In addition, ten initial practice slides were presented to familiarize the subject with the equipment. Following the ten practice slides, the order of presentation for the slides was randomized. The following verbal instructions were presented to each subject:

> You will see a series of slides on the screen in front of you. While all of the slides will contain some square signs, some slides will contain, in addition, a replica of an ordinary traffic stop sign. If a stop sign is present, press the button on your left/right with your left/right forefinger. If no stop sign is present, press the button on your right/left with your right/left forefinger. You are to react as quickly as you can, while also attempting to avoid mistakes.

Subjects responded using the forefingers of their right and left hands. For half of the subjects the "stop" button was placed on the right, and for half of the subjects it was placed on the left. Each slide remained on until either the subject responded or 1.5 seconds had elapsed. A one-second inter-trial interval preceded the presentation of the next slide. Errors were eliminated from the analysis. (Errors constituted only two percent of responses, and their pattern approximated the reaction time curve of correct responses.)

RESULTS AND DISCUSSION

Table 1 presents the results of a 4 by 6 by 2 analysis of variance (number by color by location) with reaction time as the dependent variable.* These results strongly support the proposed hypotheses. Number, color, and location showed statistically significant (α = .01) main effects, with increasing number of distractors, greater similarity in color between distractors and target, and closer proximity of distractors to target all demonstrating positive relationships to reaction time. In addition, all two-way and three-way interactions were statistically significant.

TABLE 1

SUMMARY OF THREE-FACTOR ANALYSIS OF VARIANCE
(NUMBER OF DISTRACTORS X COLOR X LOCATION)
WITH REACTION TIME AS DEPENDENT VARIABLE

SOURCE	df	F	p
A (Number)	3	14.63	.0001
B (Color)	5	6.26	.0001
C (Location)	1	52.00	.0001
A x B	15	9.93	.0001
A x C	3	5.57	.0012
B x C	5	5.47	.0002
A x B x C	15	9.57	.0001

Mean reaction times for the number dimension were: 2 (587.56 ms.), 4 (588.84 ms.), 6 (611.38 ms.), and 10 (616.28 ms.). Interestingly, this curve reflects a nonlinear function, with a step-wise increase in reaction time occurring between 4 and 6 distractors. For the color dimension, mean reaction times in order of increasing magnitude were: all orange (581.65 ms.), combination of orange and cool (595.06 ms.), all cool (600.72 ms.), combination of red and cool (602.07 ms.), all red (612.04 ms.), and combination of

*The analysis is limited to the slide presentations where the stop sign target was present. A separate analysis of the slides where the target was absent revealed a similar pattern of responses.

red and orange (614.57 ms.). Although this effect is complex, the dominant factor in affecting reaction time is the presence of at least some red distractors. Mean reaction times for the location dimension were: distant (586.93 ms.) and proximate (615.10 ms.).

The two-way interactions between the background dimensions were especially interesting. Table 2 shows mean reaction times for number by location and color by location. All proximate distractors yielded high reaction times, while distant distractors reflected differential effects due to both number and color of distractors. Table 3 shows mean reaction times for number by color. While this interaction is complex, it appears that when some red distractors are present, reaction times are highly independent of the number of distractors, while with no red distractors, reaction time varies as a function of number of distractors.

Based on these interactional findings, it is possible to offer some speculation concerning underlying psychological processes that may have mediated the effects of background distractors on reaction time in this study. The overwhelmingly strong effect due to proximity indicates that the dominant process was the subject's inability to discriminate figure (target stop signal) from ground (array of background distractors). The failure of either number or color to appreciably affect reaction time in the proximate condition suggests that this figure-ground separation operated as a gestalt, rather than a sequential screening of each distracting element. In contrast, the strong effects due to both number and color under the distant arrangement may indicate that here the subject reverted to an alternative process involving a visual scanning of the discrete distracting elements.

In light of these results, a number of practical suggestions may be offered to traffic engineers concerned with minimizing the potential negative effects of background distractors in the traffic environment. Most importantly, the present findings underscore the need for the traffic engineer to accept broader legislative and engineering responsibility for the total traffic environment, including both the public roadway and the contingent environmental context. In general, such feedback falls under two areas of application: (1) the establishment of appropriate ordinances to legislatively limit the effect of distractors, and (2) engineering decisions involving design changes in the target signal oriented toward counteracting the potential negative

TABLE 2

MEAN REACTION TIMES
FOR NUMBER AND COLOR OF DISTRACTORS
BROKEN DOWN BY LOCATION

LOCATION	NUMBER					
	2	4	6	10		
Distant	564.16	568.23	605.13	610.21		
Proximate	610.97	609.46	617.64	622.35		
	COLOR					
	All Orange	Orange & Cool	All Cool	Red & Cool	All Red	Red & Orange
Distant	556.85	579.66	573.19	587.96	609.27	614.67
Proximate	606.45	610.47	628.25	616.18	614.81	614.46

TABLE 3

MEAN REACTION TIMES FOR NUMBER OF DISTRACTORS
BROKEN DOWN BY COLOR

NUMBER	COLOR	
	No Red Distractors	Some Red Distractors
2	563.60	611.53
4	582.32	595.37
6	618.35	604.41
10	605.63	626.93

effects of background distractors.

The particularly strong effects in the present study relating to figure-ground discrimination, suggest that the location of distractors relative to the target signal is of paramount importance. Any number or color of distractors located proximally to the target are likely to reduce the driver's ability to effectively discriminate a target traffic device. Where proximate distractors cannot be legislatively restricted, a wider range of engineering alternatives may be needed to counteract their potentially serious effects. Such developments might involve designing larger or brighter target signals or employing neutral background shields to more effectively contrast the target with its surrounding context. The present findings pertaining to visually scanning the environmental field, support the need for appropriately restrictive legislation relevant to more distant commercial stimuli, which due to either their high number or similarity in color to traffic regulatory devices may operate as potential traffic hazards.

Clearly, the present study represents only a first step in a complex sphere of investigation. Caution needs to be exercised in generalizing these findings in a controlled laboratory arrangement to the problem of roadside distractors in the natural environment. Further research is needed to demonstrate that the type of differences in reaction time found here relate to actual traffic accidents. In fact, under a continued contract with the Texas Office of Traffic Safety, we are initiating a field study investigating the relationship between these distractor dimensions identified as important in the laboratory and traffic accidents in the natural environment. This type of research is especially important as it is apparent that established traffic research knowledge, traditional engineering alternatives, and existing environmental legislation may be inadequate for coping effectively with the burgeoning visual complexity of the contemporary environmental scene.

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BIOGRAPHICAL SKETCH

C. Josh Holahan is an Assistant Professor in the Department of Psychology and an Associate Director of the Community Psychology Training Program at The University of Texas at Austin. He received his educational training at Duquesne University in Pittsburgh, Pennsylvania (B.A., 1967), the University of Massachusetts in Amherst (M.S., 1970; Ph.D., 1971), and the City University of New York (post-doctoral, 1973).

Holahan has done extensive research, authored several articles and has participated in a number of conferences in psychology-related areas.

His special interests lie in the areas of Environmental and Community Psychology, with particular interest in the coping mechanisms humans utilize in dealing with their complex built and social environment.

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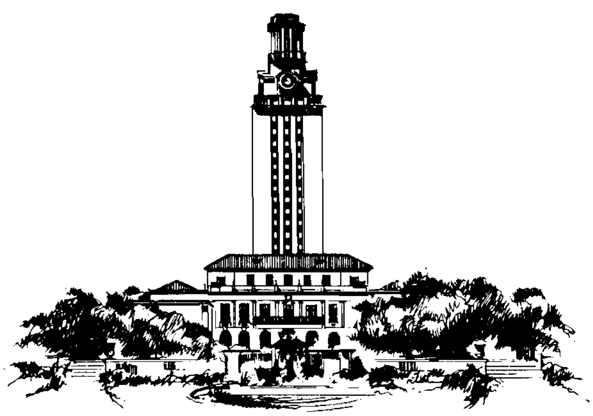

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EFFECTS OF VISUAL DISTRACTION ON REACTION TIME IN A SIMULATED TRAFFIC ENVIRONMENT

C. JOSH HOLAHAN