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Addendum to Perception and Interpretation of Advance Warning Signs on County Roads

Sponsored by the Iowa Department of Transportation,
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Iowa DOT Project HR-256
ERI Project 1641
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DEPARTMENTS OF CIVIL ENGINEERING
SOCIOLOGY AND ANTHROPOLOGY, AND PSYCHOLOGY
ENGINEERING RESEARCH INSTITUTE
IOWA STATE UNIVERSITY, AMES

Iowa Department of Transportation

report

College of Engineering
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Departments of Civil Engineering,
Sociology and Anthropology, and Psychology
Engineering Research Institute
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engineering
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iowa state university

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INTRODUCTION

This contract extension was granted to analyze data obtained in the original contract period at a level of detail not called for in the original contract nor permitted by the time constraints of the original contract schedule. These further analyses focused on two primary questions:

1. What sources of variation can be isolated within the overall pattern of driver recognition errors reported previously for the 16 signs tested in Project HR-256?
2. Were there systematic relations among data on the placement of signs in a simulated signing exercise and data on the respondents' ability to detect the presence of a sign in a visual field or their ability to recognize quickly and correctly a sign shown them or the speed with which these same persons can respond to a sign for a driver decision?

RECOGNITION ERRORS AMONG HIGHWAY SIGNS

Appendix A, which contains a more detailed discussion of these findings, was submitted to the Transportation Research Board and presented at the 1985 Annual Meeting of the Transportation Research Board to gain peer reaction to these analyses from human factors specialists involved with signing research elsewhere. Discussions with other researchers confirmed the authors' confidence in these findings.

The data on sign recognition errors were reanalyzed with respect to how long the sign image was flashed into the tachistoscope for a driver to view the sign and the degree to which one sign message was confused with another.

The 16 signs tested were grouped into the four message types used in the earlier analysis. "Stop" messages included the standard red and white octagonal Stop sign (#1), the nonstandard red and white diamond Stop sign (#2), the standard red and white belted ball Do Not Enter sign (#3), and the black letters on white background rectangular Do Not Enter sign (#4). "Right" messages included the standard black arrow and bullet on white Keep Right symbol sign (#5), the alternate black and white word message with angled arrow Keep Right sign (#6), the standard black on yellow narrowing roadway Merge Right symbol sign (#9), and the alternate black on yellow word message Merge Right sign (#10). The "Left" messages included the arrow and bullet symbol Keep Left (#7), the angled arrow and word legend Keep Left (#8), the road narrows Merge Left symbol (#11), and the word legend Merge Left sign (#12). "Slow" messages included the symbol Stop Ahead advanced warning sign (#13), the word legend Stop Ahead black on yellow advanced warning sign (#14), the symbol legend Signals Ahead advanced warning sign (#15), and the word legend Signals Ahead black on yellow advanced warning sign (#16).

The overall rate of recognition errors was previously reported based on the average error rates for a driver attempting to distinguish between two signs that he or she had just been shown in a brief tachistoscope flash. That experimental result was reported in the March 1984 Project HR-256 report. While the numerical and graphical data presented therein were correct, subsequent analyses revealed that the interpretation of the data shown in Fig. 1 of both the previous report and this report (also Fig. 2 of Appendix A) needs to be revised for the average change in errors in recognizing the Stop Ahead sign. For Stop Ahead signs, on the average, fewer errors were made with <u>symbol</u> signs than with <u>word</u> signs when the flash exposure duration was 32 milliseconds, but when exposure duration was increased to 49 milliseconds, the number of errors for both word and symbol signs was reduced to about the same level. The indication is that the <u>symbol</u> version of the Stop Ahead sign can be recognized better if viewing time is extremely limited, but if sufficient viewing time is available, both word and symbol Stop Ahead signs can be recognized equally well. (Underlined words in this paragraph are those changed from the previous report. This does not change the research finding that the word sign is just as effective as the symbol sign at driver viewing times afforded by typical traffic engineering sign installation practices.)

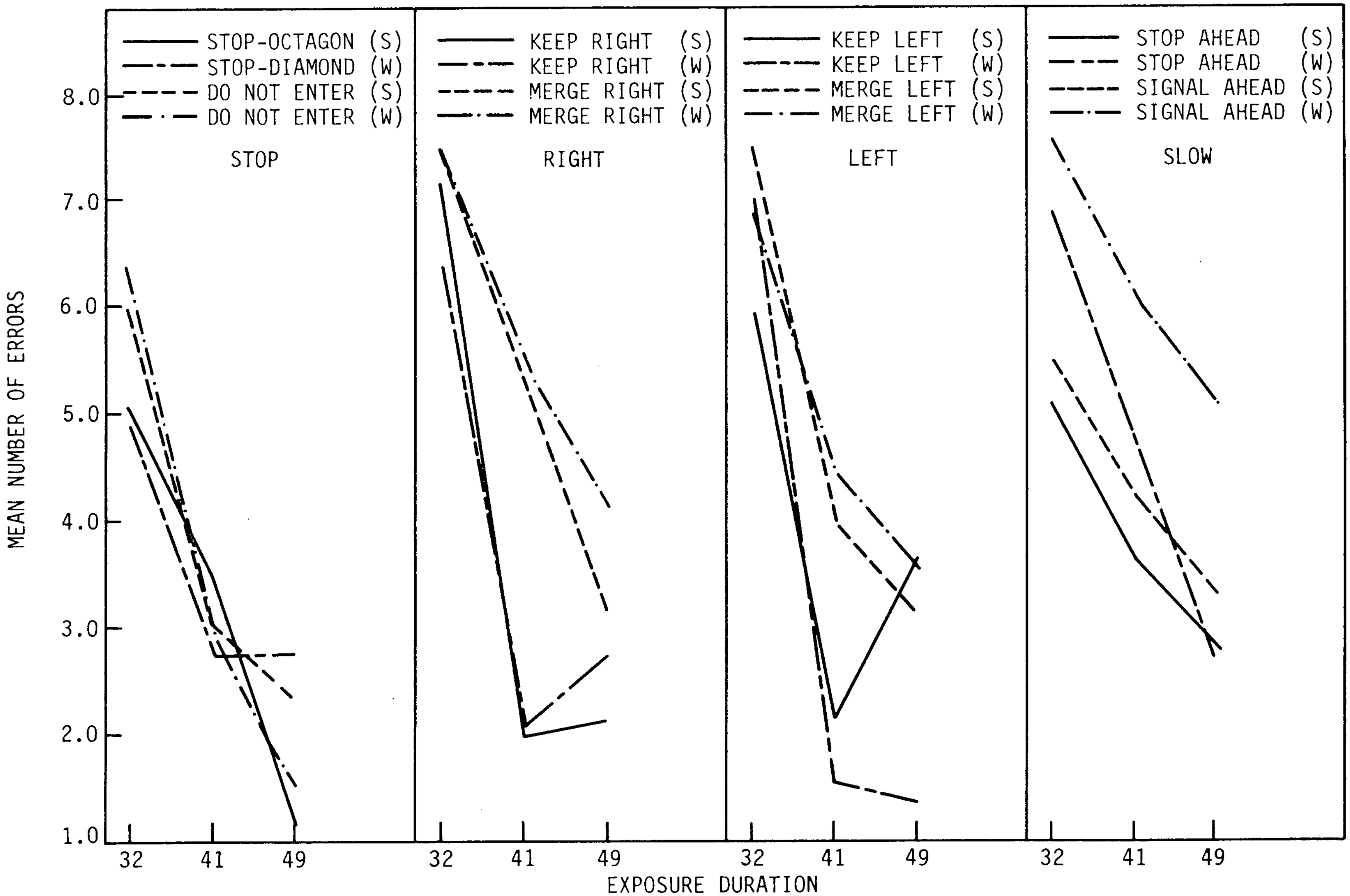

Fig. 1. Sign recognition errors.

The matrix of recognition errors among the signs was examined a second time for each driver group tested at 32, 41, and 49 millisecond flash presentation of a sign by computing the mean number of drivers who incorrectly identified one of the other 15 signs as the sign shown to them. A 99 percent confidence interval about the mean was then calculated for each sign shown to the test groups. Any sign erroneously chosen as the one displayed in the flash presentation more often than the upper bound of the 99 percent confidence interval was identified as a high error rate sign (Table 1). Any sign erroneously chosen as the sign shown in the flash presentation less frequently than the lower bound of the 99 percent confidence interval was identified as a low error rate sign (Table 2). Tables 1 and 2 are the same as those contained in Appendix A but are repeated here for ease in referring to them in discussion.

Note that in Table 1 the "Stop" message category of signs is very rarely confused with any of the other 15 signs tested at a high error rate. This is especially true as the flash exposure duration increases but is also true at very short flash exposure durations. This is very strong evidence that a driver needs only the briefest interval of time during the driving task in which to see a message requiring a stop action in order to detect the sign and correctly recognize exactly what the sign is. Thus, driver failure to act on that sign information must be related to the conscious and subconscious decision-making processes more than the traffic engineer's efforts to make the sign more detectable or more recognizable.

Table 1. Sign pairs producing high error rates.

		Error Choice Message											
		32 msec				41 msec				49 msec			
	Sign #	Stop	Right	Left	Slow	Stop	Right	Left	Slow	Stop	Right	Left	Slow
Stop Message	1	2				2				2			15
	2		9	8,11			5	12					
	3	1			13		6						
	4	2	9							2			
Right Message	5	1,2		12	16						6		
	6	2	10	7	14,16							12	
	9	1,3,4	6	11	13	1,3	5,6	7,11	13,16	1	6	11	13
	10	2	10	8	14,16	4		8,12	14		10		14
Left Message	7	2	10		13								
	8										5,6,9		13
	11	4	10	8	13	3,4	9		13		9	7,8	13,16
	12	3	19	7	13,15,16		10	7,8		2			13,14
Slow Message	13	3,4	5,6	7,8	14		6,9	7,8	15,16	1	6,9	11	
	14							7		4		7,8,11	
	15	2,3,4		11	13,14,16	2,3	6,9	7,8	13,14,16	3,4	6,9	8	13,14,16
	16	4					10	8,12					13,14

Table 2. Sign pairs producing low error rates.

	Sign #	32 msec Stop	32 msec Right	32 msec Left	32 msec Slow	41 msec Stop	41 msec Right	41 msec Left	41 msec Slow	49 msec Stop	49 msec Right	49 msec Left	49 msec Slow
		Error Choice Message											
Stop Message	1	4	5,6,9	8,11,12	14,16	3,4	5	7,11					
	2	1	6,10	7	14,15,16		9	7,11			5,10	8,12	13,15,16
	3		10		15	1,4	9,10		13,15,16	4	5,10		16
	4	1		7,12		3		8,10	11	3			
Right Message	5	4	9	11	14	1,3,4	9,10	11	15		10		15
	6	3	5			1,2,3,4	10		14,15,16			11	16
	9							12					
	10						5		13		9		
Left Message	7				16	1,2	6,8	9,10	13,14,15,16			11,12	13
	8	3,4		12	15	2,4	5,9	11	13,15,16				
	11				16		5						
	12	2		11		2,3							
Slow Message	13			12	15	1,2					10		15
	14	1	5,9	8,12	15	3,4	5						
	15	1	6										
	16			7,11,12	13								

Note the difference for high error sign selection between the symbol Stop Ahead (#13) and the word Stop Ahead (#14). Even though, as previously noted above in the correction to the interpretation of the average error rates reported, the symbol sign has a lower overall error rate than the word sign until the flash exposure duration is extended out near 50 milliseconds, the symbol sign is confused with far more signs at higher than 99 percent confidence interval rates until the 49 millisecond exposure duration is reached. Previous and continuing independent research by Avant has consistently shown that word messages are more precisely processed by the brain than nonwords and words are processed faster than nonword messages. These data in Table 1 clearly suggest that the symbol Stop Ahead is not an exact pictogram replacement for the word message Stop Ahead. Since an advanced warning sign is placed well beyond the driver action decision point, it is reasonable to assume that this potential confusion under the pressure of short response time is not critical. Continued presence of errors where the sign shown to the driver is confused with other signs in excess of the 99 percent confidence interval for both the word and symbol sign at the longer flash duration suggests that once a brief view of a sign is available to a driver, sign messages that are not critical may be subject to some kind of random error process. The evidence in Table 1 that the symbol Merge Right (#9), the symbol Merge Left (#11), and the symbol Signal Ahead (#15) all display confusion errors above the 99 percent confidence level with numerous other signs at all three levels of flash exposure durations suggests that the symbol format of sign message is subject to high recognition error rates unless the message can be perceived by the driver as urgent (i.e., stop).

Table 2 displays the recognition errors among the signs as each sign was identified to have an associated confusion with another sign at a rate less than the lower bound of the 99 percent confidence interval. At all levels of flash exposure duration tested, the signs with stop messages were confused with signs giving a message to move right or to move left or to slow down less than the lower band of the 99 percent confidence interval band about the mean. This reinforces the findings shown in Table 1 that signs with stop messages are perceived and interpreted by drivers in vastly different ways than warning and advanced warning signs.

Signs with move right messages or with move left messages are least likely to be confused with stop message signs and slow message signs. This finding combined with the data in Table 1 regarding the high error rate confusions suggests that the perception and interpretation of signs instructing a driver to move to the right or the left is not a highly specific response among possible interpretations. While it was tested in the experimental design of this research, these findings suggest that driver cues to move right or left in traffic control are likely to be affected more by the visibility of the roadway geometry and the perspective of physical barriers to movement than the messages on warning signs relating to movement. This finding in sign perception is, thus, consistent with behavioral findings of research on driver movements in advance of lane closures and traffic cone tapers in advance of maintenance and construction operations.

There is consistent evidence of signs being confused with slow message signs less than the 99 percent confidence level only at the shorter flash exposure durations. At the short flash exposures the brain must make an instantaneous recall. This requirement appears to limit any ambiguities in processing the information. While these data only hint at a relationship, note that Table 2 has been arranged so that the upper left-hand corner represents the shortest flash exposure time and the most severe message type. As the data move to the right and down the exposure durations become longer and the messages become less urgent, it appears that increasing exposure time does not make its perception and interpretation more precise if the sign does not call for a fairly specific and urgent response. This suggests that significant latitude and engineering judgment should be allowed in the application of (including the decision to apply) advanced warning signs for Stop Ahead or Signals Ahead.

SYSTEMATIC RELATIONSHIPS IN VISUAL DETECTION OF SIGNS

Data obtained in the experimental phases of Project HR-256 were reanalyzed and supplemented with subsequent data from independent research conducted by Avant and Thieman using a subset of eight of the original 16 signs. This experiment was designed to determine whether the human brain extracts the meaning of traffic signs when exposure durations are so brief that the driver cannot consciously detect whether the stimulus presentation is a traffic sign or is, instead, a blank flash. Three groups of subjects were tested with Dr. Avant's duration judgment procedure. One group was tested with 24 millisecond exposures; this is the average exposure duration at which subjects in Experiment One reached chance level (50 percent or less probability of correct response) in detecting sign presence versus absence. A second group of subjects was tested with 16 millisecond exposures, and a third group was tested with 8 millisecond exposures.

Results of the experiment are presented in Table 3 which shows differences in unconscious sign meaning analyses by the brain (as tested by the Neuman-Keuls test). When exposures were 8 milliseconds, the brain had already begun to analyze sign meaning as shown by the significant differences between slow message signs and both stop and right signs. When exposures were 16 milliseconds, the brain had apparently discriminated among the meanings of all sign message except for left and right messages. When exposures were 24 milliseconds, the brain apparently narrowed analysis to the most important distinction--the signs which required a stop action and signs presenting all other mes-

Table 3. Mean z' scores for each sign message at the three exposure durations in Experiment Two and results of the Neuman-Keuls tests applied to differences in mean z' scores among sign messages for each exposure duration used in Experiment Two.

(A) Mean z' scores.

	Sign Message			
	Stop	Slow	Left	Right
24 ms	.297	-.062	-.119	-.104
16 ms	.104	.361	-.156	-.305
8 ms	-.125	.305	.063	-.063

(B) Results of the Neuman-Keuls tests.

		Sign Message			
$MS_e^{24ms} = 0.393$		Right	Left	Slow	Stop
	Right		.185	.704	5.14*
	Left			.519	4.95*
	Slow				4.44*
$MS_e^{16ms} = 0.485$		Right	Left	Stop	Slow
	Right		1.66	4.55*	7.41*
	Left			2.89*	5.75
	Stop				2.85*
$MS_e^{8ms} = 0.539$		Right	Stop	Left	Slow
	Right		.380	2.35	4.91*
	Stop			1.97	4.53*
	Left				2.55

*Neuman-Keuls 0 statistic significant at $\alpha = .05$.

sages. Such prioritization of input information may lead to lowered sensitivity to critical signing messages, thus the engineering practice guideline to not "over sign" appears to have a valid relationship to visual processing by the brain at the very earliest stages of "seeing."

SYSTEMATIC RELATIONSHIP AMONG SIGN MEANINGS AND PERCEPTION

The complete text of "Highway Sign Meaning as an Indicator of Perceptual Response," which is a detailed analysis of drivers evaluating eight of the total 16 sign test set for meaning and effectiveness, is contained in Appendix B. It has long been a principle of marketing research that a person's psychological association with a product will strongly influence that person's reaction to it. Some of the symbol signs currently in the Manual on Uniform Traffic Control Devices were tested using the same semantic scales for meaning utilized in Project HR-256 in order to explain why the signs were or were not good signs to use. The driver behavioral assumption is that drivers will respond more rapidly and more precisely to signs that seem to them to convey better, stronger, clearer, etc., messages.

Analysis of the correlation of laboratory test results on detection experiments, recognition experiments, and decision-reaction data with the driver meaning test evaluations indicates no consistent, statistically significant association among perception and interpretation tests and meaning. A total of 1,152 correlations were computed, and 32 were found to be significant at the 0.05 level or better. Even among these 32, the variation pattern did not provide any intuitive consistency.

SYSTEMATIC RELATIONSHIPS IN INTERSECTION SIMULATION

Introduction

In the following section, the results of a comparison of test subjects' use of advance warning signs on a tabletop simulation and their preferences in laboratory Experiment One through Experiment Three are presented. Extensive discussion of the layout and operation of the tabletop simulation in conjunction with laboratory tachistoscope experiments can be found in Project HR-256 final report dated March 1984. The present discussion will summarize the major points of correspondence between performance in the laboratory tests of perceptual operation and sign placements in the tabletop simulation.

Experiment One

In Experiment One, the subject was expected to differentiate among sign types in terms of simple, presence/absence detection. Placement of advanced warning signs at the two intersection types (crossroad and tee) were contrasted with respect to presence/absence detectability of symbol, word, and mixed format signs.

For those subjects placing a first or nearest advance warning sign at the tee intersection, there was a difference in detection rates. Word signs were detected better than mixed format signs which were in turn detected better than symbol signs.

For those persons placing a second advance warning sign at the tee intersection, there was no difference in detection of the three sign formats.

Those persons placing a first or nearest advance warning sign at the crossroad intersection displayed no substantial difference between word and mixed format sign detection, but both of these formats were detected better than symbol signs.

Persons placing a second advance warning sign at the crossroad intersection displayed no substantial difference between word and mixed format sign detection nor between symbol and mixed format sign detection. However, word signs were detected better than symbol signs for this group of subjects. Note that there was an interaction between the detectability of word and symbol signs and their placement of the advance warning sign indicating that symbol users demonstrated some differences in their detection of signs in the laboratory situation (words better than mixed or symbols). As was noted earlier, for participants using symbols, detectibility for word signs was better than for symbol signs.

Experiment Two

In Experiment Two the dependent variable (combined for subjects presented 32, 41, and 49 millisecond exposures) was the probability of correctly recognizing specific signs presented in the laboratory operations.

For those subjects placing a first or nearest advance warning sign at the tee intersection in Experiment Two, mixed format signs were correctly recognized less frequently than word signs which, in turn, were correctly recognized less frequently than symbol signs.

When a subject placed a second advance warning sign at the tee intersection the mixed format signs were correctly recognized more frequently than word or symbol signs. Word and symbol signs were recognized at approximately equal rates for this group of subjects.

Those persons placing only one advance warning sign or placing the first of several at the crossroad intersection correctly recognized mixed format signs more frequently than word signs which were, in turn, correctly recognized more frequently than symbol signs.

When a subject placed a second advance warning sign at the crossroad intersection, the same recognition pattern resulted: mixed format sign was correctly recognized more frequently than word format sign which was correctly recognized more frequently than symbol signs.

It should also be noted that subjects who used a symbol sign as the first advance warning sign at the crossroad intersection had a higher probability of correctly recognizing signs shown in Experiment Two than those who used a word sign as the first advance warning sign at the crossroad intersection.

Experiment Three

In Experiment Three, the dependent variable was the speed of correct driver decision to stop, to go right, to go left, or to slow down in response to a sudden presentation of a sign.

For those subjects placing a single advance warning sign or placing the first of several advance warning signs at the tee intersection, decision-reaction times for Experiment Three were shorter for mixed format signs than for symbol signs and shorter for symbol signs than for word signs.

When a subject placed a second advance warning sign at the tee intersection, decision-reaction times were shorter for mixed format signs than symbol signs and shorter for symbol signs than for word signs. The same relationship existed regardless whether a person used one advance warning sign or used several on the tee intersection.

Persons placing a single advance warning sign or placing the first of several advance warning signs at the crossroad intersection exhibited decision-reaction times having the same relationship as for the tee intersection (i.e., shorter reaction times for mixed format signs than symbol signs and shorter times for symbol signs than word signs). The group of subjects using this sign placement at the crossroad intersection was the same group of subjects who used this sign placement at the tee intersection, and the correspondence between sign placement and performance in Experiment Three was necessarily the same in this case.

Persons selecting a second advance warning sign at the crossroad intersection displayed the same decision-reaction time pattern noted in the other tests. They had shorter times for mixed format signs than for symbol signs, and symbol signs yielded shorter times than word signs.

CONCLUSIONS

It must be recognized that these data result from vision and signing experiments which have been designed to simulate in a laboratory the tasks a driver encounters in processing highway signing information. However, the extensive analysis of the research numerical data base permits drawing the following conclusions:

1. Driver errors in recognizing signs, once a sign is detected in the visual field, are lower for signs requiring a stop action by the driver than for those signs requiring a driver to either slow down or move laterally.
2. Errors in recognizing signs decrease sharply with very small increases above threshold presence/absence detection exposure durations; and errors in perceptual recognition operations are likely to occur within the first 50 milliseconds of viewing time after which recognition errors tend to level off.
3. At flash exposure durations of 32 milliseconds or less a <u>symbol</u> Stop Ahead sign is more correctly recognized than a <u>word</u> legend Stop Ahead sign, but at flash exposure durations of 50 milliseconds or greater the two types of sign legends for Stop Ahead signs are about equally correctly recognized.
4. A synergistic conclusion associated with conclusions 1, 2, and 3 is that failure of drivers to respond to stop message signs are likely because of factors other than perceptual operations if the driver has had more than 0.1 second of viewing time on a sign instructing the driver to stop, and

that the form of any advance warning sign to the stop is not crucial to the driving task.

5. The human brain sorts highway signing for importance of message as it is processed so that only signs necessary to guide, warn, and regulate the driver in ways not obvious in the visual geometry of the roadway should be installed in order to minimize the opportunity for processing errors.
6. For drivers preferring advance warning signs to intersections, driver decision-reaction times are better for signs with both word and symbol components in the message than with either symbol signs or word signs.
7. For drivers preferring advance warning signs to intersections, driver visual detection of signs is better for signs with word format than signs with both words and symbols which is, in turn, better than symbol-only signs.
8. Drivers preferring advance warning signs to intersections make less recognition errors when the sign is a symbol format sign than when the sign is a word-only format sign which, in turn, yields less recognition errors than signs containing both words and symbols.
9. A synergistic conclusion associated with conclusions 6, 7, and 8 is that when Stop Ahead warning signs are installed, different perception and interpretation processes are optimized by different sign formats of symbols, words, or combinations of words and symbols.

10. The meaning and value drivers associate with a highway sign are not related to the ability to detect, recognize, or react to a highway sign.

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APPENDIX A: RECOGNITION ERRORS AMONG HIGHWAY SIGNS

RECOGNITION ERRORS AMONG HIGHWAY SIGNS

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RECOGNITION ERRORS AMONG HIGHWAY SIGNS

ABSTRACT

Forced choice recognition errors were examined for tachistoscopic presentations of four sign messages (Stop, move Right, move Left, Slow Down) displayed in word versus symbol format. Sign exposure durations were 1, 2, and 3 standard deviations (32, 41, 49 milliseconds) above the mean exposure duration for chance level presence/absence detection of a traffic sign in the visual field (24 milliseconds). As exposure duration increased, recognition errors decreased more rapidly for Stop message signs than for other messages. Word versus symbol format differentially influenced reductions in recognition errors for Right, Left, and Slow messages but had little influence on errors on Stop message signs. Several pairs of signs were shown to be reciprocally confused with each other, and Merge Right signs were frequently confused with signs presenting three different action messages. For the signs tested, those which are likely to produce recognition errors that result in accidents and those for which recognition errors are unlikely to produce accidents were identified.

INTRODUCTION

The present research was prompted by two major concerns. One concern was the pragmatic concern of civil engineers interested in effective traffic signing to safely guide traffic flow. The second was the theoretical need to discriminate between (a) the purely perceptual operations performed by the brain in extracting sign information and (b) the mental operations involved in driver actions that occur after the recognition process is completed.

The interface between these concerns has become obvious in accident liability claims against Iowa highway agencies. It is frequently impossible to determine whether a driver accident was caused by ineffective signing or, instead, an error in the driver's recognition, memory recall, or subsequent action decision processes. These pragmatic and theoretical concerns resulted in a series of experiments designed to more clearly discriminate among the mental operations involved in sign detection, recognition, and action decisions.

The research was initiated by a focus on the failure of drivers to recognize and/or properly respond to the symbol legend Stop Ahead standard sign W3-1a [1]. The specific circumstance indicating the urgency to examine these issues involved the intersection of two paved county trunk highways in Buena Vista County, Iowa. The highways cross at right angles in rolling terrain. The North-South route is Stop sign controlled, and East-West traffic is through traffic. Signing of the intersection is clearly visible to drivers approaching from all four directions. Northbound traffic and westbound traffic encounter a sight obstruction in the southeast quadrant of the intersection, making it imperative that drivers approaching from the South obey the Stop sign on that leg of the intersection. Soon after new symbol legend Stop Ahead signs were erected to precede the Stop signs, a number of accidents involved failures of drivers to respect the Stop signs. This unexpected increase in accident frequency prompted the County Highway Engineer to request research to more clearly differentiate the factors that cause such accidents. This paper reports a portion of the data from that research - the types of errors that occur between the driver's detection that a sign is present in the visual field and the driver's subsequent recognition of the sign message.

EXPERIMENTATION

Introduction

The pragmatic concern that initiated the research focused on potential differences in the effectiveness of the word and symbol versions of the Stop Ahead advance warning sign. However, considerations of proper experimental designs dictated that a larger sample of signs be studied, and the set of 16 signs shown in Fig. 1 were selected.

Three laboratory experiments were conducted. Experiment One tested effects of these signs on drivers' detection of sign presence/absence in the visual field when tachistoscopic exposures of the signs reduced overall detection performance to chance level. Experiment Two increased exposure durations above detection level and investigated sign recognition errors as time for the recognition process increased. Experiment Three measured the time required for deciding what driver action was appropriate for each sign. This paper reports a portion of the data from the second experiment and an interpretation of the recognition error patterns for traffic engineering purposes.

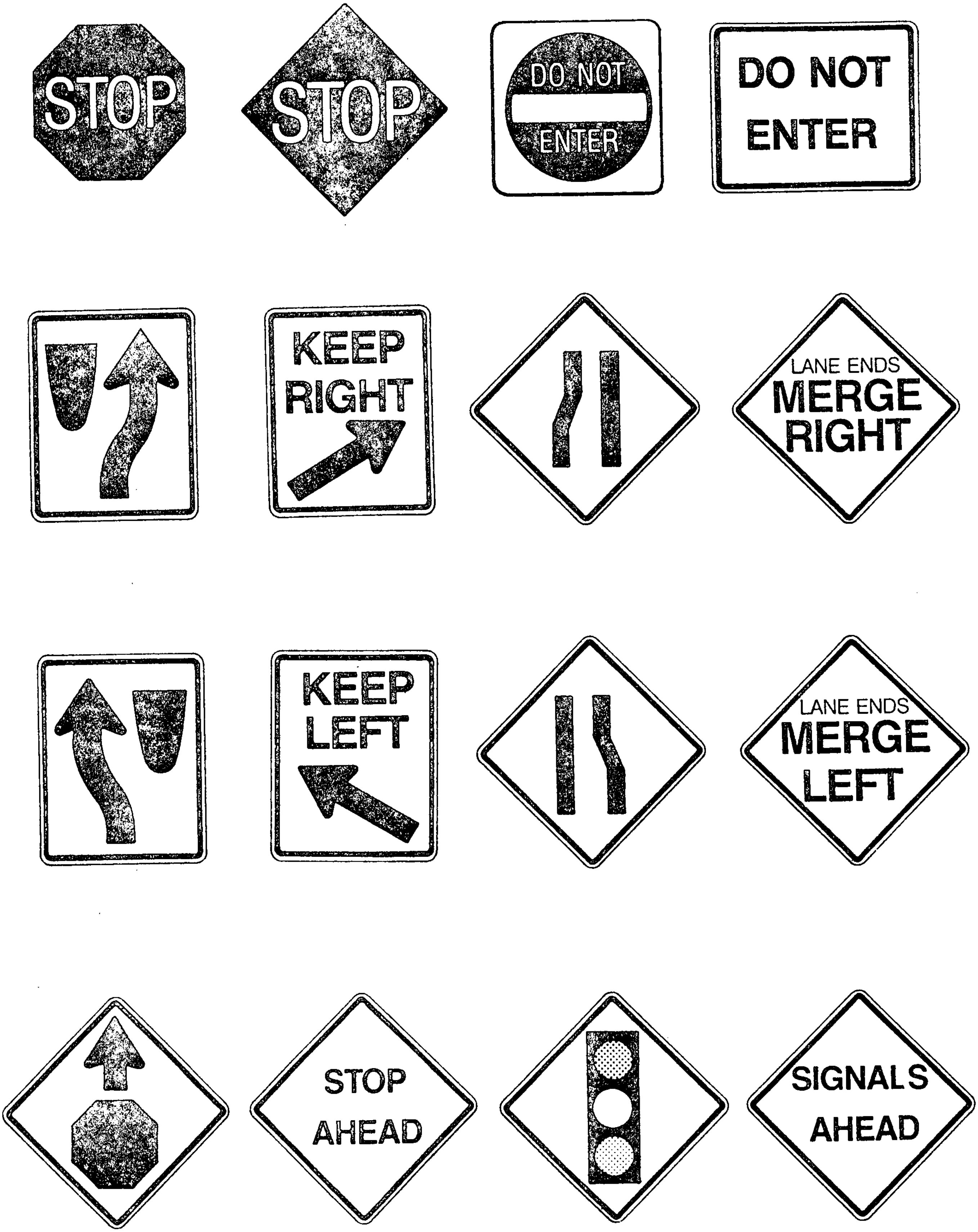

Fig. 1. Matrix of signs for detection, recognition, and reaction experiments.

Procedure

The intent of the experiment was to determine whether the 16 test signs produced differences in the perceptual operations that extract sign information and generate conscious recognition of the signs. Respondents who participated in the experiment were 36 volunteers from undergraduate courses, faculty, or administrative staff at Iowa State University; all respondents were licensed drivers. Tests of visual acuity were not conducted because (a) our concern was to obtain a representative sample of Iowa drivers rather than a sample of drivers with 20/20 visual acuity and (b) the experimental design and testing equipment made differences in visual acuity an irrelevant consideration. Age of respondents was not asked since a measure of driving experience was obtained (and found not to be a significant influence on performance in any of our analyses).

The general procedure was to present the subject a road sign tachistoscopically and then have the subject decide which of two signs (the just-presented sign and another sign) shown outside the tachistoscope in clear vision was the sign presented on that trial. Each trial began with the subject viewing the mask slide shown in Fig. 1, and sign presentation was essentially an interruption of the subject's viewing of the mask. The experiment required 240 trials for each subject. This permitted 15 test trials for each sign; that is, 15 trials on which a given sign was presented tachistoscopically and then paired with each of the other signs for the forced choice identification of which sign had been shown on that trial. The performance measure was the number of error choices, of a possible 15, that each subject made for each sign.

The 36 subjects were assigned to three groups of 12 subjects each, and exposure durations differed for the three groups. Exposure durations were based on the results of the detection experiment (Experiment One). For groups 1, 2, and 3, exposure durations were 32, 41, and 49 milliseconds respectively. These durations were, respectively, 1, 2, and 3 standard deviations above the mean exposure duration for chance-level presence/absence detection in Experiment One (24 milliseconds). This manipulation permitted evaluation of the influence of sign message (Stop, go Left, go Right, Slow Down) and sign format (word versus symbol) on reducing recognition errors as time for completion of the recognition process increased.

RESULTS AND DISCUSSION

Mostly simply stated, the results of this experiment showed that the perceptual operations performed in recognizing highway signs differ considerably among signs. The message presented by the sign, the symbol versus word format of the sign, and exposure duration all interacted in determining number of recognition errors. This complex interaction is summarized graphically in Fig. 2. However, findings of pragmatic concern were clear in the data.

As expected, the number of recognition errors decreased as exposure duration increased, and most of the reduction in errors occurred as exposure duration increased from 32 to 41 milliseconds; further reduction in errors when exposure duration increased from 41 to 49 milli-

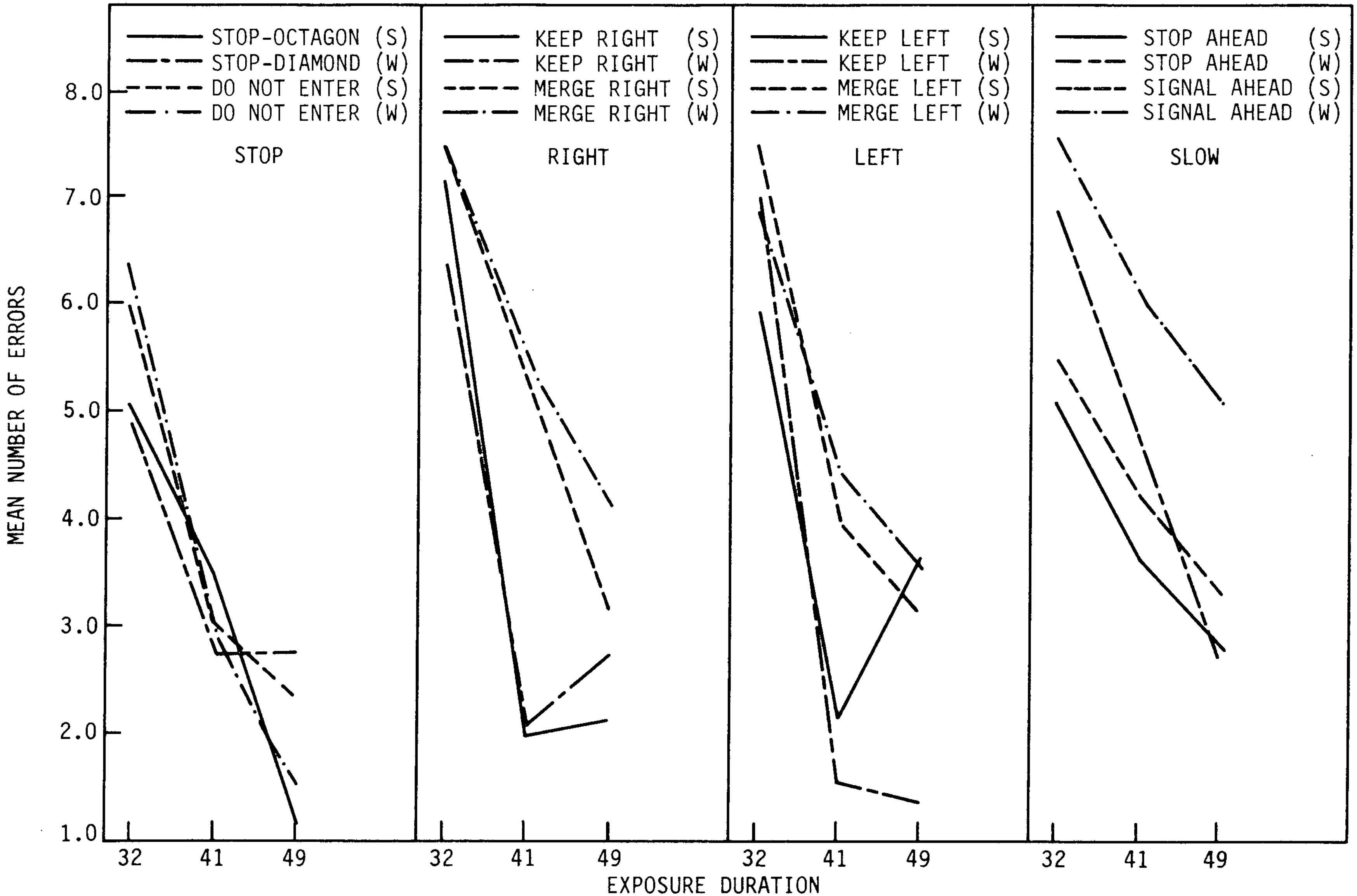

Fig. 2. Sign recognition errors.

seconds was not significant. The important implication here is that the perceptual operations of sign recognition are completed very rapidly, and the action decision triggered by those perceptual operations occurs in a time period that is likely to be less than 50 milliseconds. A second finding of practical interest was that fewer recognition errors were made for signs that instruct a driver to stop than for signs that instruct a driver to go right, go left, or slow down. This result conformed to the result from Experiment One, reported elsewhere [2], showing that, even when overall presence/absence detection performance was at chance level, stop message signs were detected more accurately than were signs instructing a driver to go right, go left, or slow down.

These findings are, in general, evident in the data presented graphically in Fig. 2. Inspection of Fig. 2 also reveals informative differences in the patterns of error reductions for Stop, go Right, go Left, and Slow down sign messages. For Stop-action message signs, errors declined in about the same fashion for Stop and Do Not Enter signs whether they were symbol or word format signs. For go-Right-action and go-Left-action signs, similar patterns of error reduction were evident. As exposure duration increased, the number of recognition errors decreased more rapidly for Keep (Right or Left) signs than for Merge (Right or Left) signs, and there was little difference between word and symbol signs. Perhaps the most interesting pattern occurred for signs that instruct a driver to slow down. For Stop Ahead signs, fewer errors were made for symbol signs than for word signs when the exposure duration was 32 milliseconds but, when exposure duration was increased to 49 milliseconds, the number of errors for both word and symbol signs had reduced to about the same level. The implication is that the symbol version of the Stop Ahead sign can be more readily recognized if viewing time is extremely limited but, if sufficient viewing time is available, both word and symbol Stop Ahead signs can be recognized equally well. For Signal Ahead signs, fewer recognition errors were made for symbol signs at all three exposure durations.

We examined these data more closely to determine the types of confusions among signs that occur during percpetual analysis of the various signs. For the three groups of 12 subjects who were tested with 32, 41, and 49 millisecond presentations, we calculated the mean number of subjects who incorrectly chose, for each presented sign, each of the other 15 signs in recognition errors. We then calculated a 99% confidence interval about each of those means; signs for which the number of subjects making recognition errors exceeded that confidence interval were identified as signs producing either significantly larger or significantly smaller than average numbers of errors.

Table 1 summarizes the evidence for significantly high numbers of errors. The extreme left column identifies the 16 signs presented for identification. The top two rows of the table identify, for the 32, 41, and 49 millisecond test exposures, the message of the sign that was given in the error response. The numbers presented in the body of the table identify the specific sign that was given in an incorrect response.

At least three kinds of important information can be extracted from Table 1. First, one can identify the signs for which confusions were reciprocal - that is, signs which were confused with each other irrespective of which sign was the presented test sign and which sign was the

Table 1. Sign pairs producing high error rates.

		Error Choice Message											
		32 msec				41 msec				49 msec			
	Sign #	Stop	Right	Left	Slow	Stop	Right	Left	Slow	Stop	Right	Left	Slow
Stop Message	1	2				2				2			15
	2		9	8,11			5	12					
	3	1			13		6						
	4	2	9							2			
Right Message	5	1,2		12	16						6		
	6	2	10	7	14,16							12	
	9	1,3,4	6	11	13	1,3	5,6	7,11	13,16	1	6	11	13
	10	2	10	8	14,16	4		8,12	14		10		14
Left Message	7	2	10		13								
	8										5,6,9		13
	11	4	10	8	13	3,4	9		13		9	7,8	13,16
	12	3	19	7	13,15,16		10	7,8		2			13,14
Slow Message	13	3,4	5,6	7,8	14		6,9	7,8	15,16	1	6,9	11	
	14							7		4		7,8,11	
	15	2,3,4		11	13,14,16	2,3	6,9	7,8	13,14,16	3,4	6,9	8	13,14,16
	16	4					10	8,12					13,14

error choice. For 32 millisecond test presentations, the following signs were reciprocally confused.

Stop Ahead (Word) - Do Not Enter (Word)
Stop Ahead (Word) - Keep Left (Word + Symbol)
Merge Right (Word) - Do Not Enter (Word + Symbol)
Merge Right (Word) - Merge Right (Symbol)

When test exposures were 41 milliseconds, the following signs were reciprocally confused.

Merge Right (Word) - Merge Left (Word)
Merge Right (Symbol) - Merge Left (Symbol)
Stop Ahead (Word) - Merge Right (Word)
Stop Ahead (Word) - Signal Ahead (Word)

When test exposures were 49 milliseconds, the following signs were reciprocally confused.

Merge Right (Word) - Merge Left (Word)
Stop Ahead (Word) - Merge Right (Word)
Stop Ahead (Word) - Merge Left (Word)

The second important question that these findings address is: Which recognition errors are likely to produce incorrect driver actions and which ones are not likely to be dangerous? The question is answered, in part, by the reciprocal confusions between pairs of signs noted above. The Left-Right message signs provide a particularly useful example. For all three test exposures, signs which instruct a driver to either Merge or Keep Right or Left were reciprocally confused with each other, and the confusions occurred with both the word and symbol legend signs. In fact, the reciprocal confusions appear to identify Merge Right signs as particularly troublesome. Drivers appear to have particular difficulty in recognizing these signs; Merge Right signs were involved in seven of the eleven reciprocally confusing sign pairs noted above, and they were reciprocally confused with five different signs among which three different messages were presented. It is also important to notice that confusions involving Left-Right messages were not much affected by viewing time; increases from 32 to 41 to 49 millisecond exposures produced no systematic decrease in the number of these message confusions.

Some of the other signs were also frequently given in error responses, but these error choices are unlikely to produce dangerous driver actions. These error choices appear in the heavily outlined blocks in Table 1; they are errors among subgroups of signs which communicate essentially the same action message. For example, the standard octagonal Stop sign (MUTCD R1-1) was given in a number of error responses, but those responses were to other signs that instruct a driver to stop. These errors may indicate that, even when the driver is uncertain about which of several possible signs was shown, enough sign information has been extracted to communicate the Stop message, and the driver chooses the sign that presents that message most clearly.

The format of Table 2 duplicates that of Table 1 but summarizes the evidence on signs that prompted significantly <u>lower</u> than average numbers of error choices. These data indicate that Stop message signs were least frequently confused with signs presenting other action messages; the next-least-frequently confused signs were those that instruct a driver to Slow down and be cautious. The least frequently given error choices were the Signal Ahead symbol sign (MUTCD W3-3), the Signal Ahead word sign (MUTCD W3-3a), and the Merge Left word sign (MUTCD W9-2).

Table 2. Sign pairs producing low error rates.

		Error Choice Message											
		32 msec				41 msec				49 msec			
	Sign #	Stop	Right	Left	Slow	Stop	Right	Left	Slow	Stop	Right	Left	Slow
Stop Message	1	4	5,6,9	8,11,12	14,16	3,4	5	7,11					
	2	1	6,10	7	14,15,16		9	7,11			5,10	8,12	13,15,16
	3		10		15	1,4	9,10		13,15,16	4	5,10		16
	4	1		7,12		3		8,10	11	3			
Right Message	5	4	9	11	14	1,3,4	9,10	11	15		10		15
	6	3	5			1,2,3,4	10		14,15,16			11	16
	9							12					
	10						5		13		9		
Left Message	7				16	1,2	6,8	9,10	13,14,15,16			11,12	13
	8	3,4		12	15	2,4	5,9	11	13,15,16				
	11				16		5						
	12	2		11		2,3							
Slow Message	13			12	15	1,2					10		15
	14	1	5,9	8,12	15	3,4	5						
	15	1	6										
	16			7,11,12	13								

CONCLUSIONS

These data recommend the following conclusions.

1. Driver errors in recognizing signs once a sign is detected in the visual field are lower for signs requiring a stop action by the driver than those requiring a driver to either slow down or move laterally. This finding implies that failures to respond to Stop message signs are likely due to factors other than perceptual operations.

2. Errors in recognizing signs decrease sharply with very small increases above threshold presence/absence detection exposure durations. Errors in perceptual recognition operations are likely to occur within the first 50 milliseconds of viewing time after which recognition errors tend to level off.

3. The formats of some signs tend to produce many recognition errors with other sign messages (Merge Right) whereas other signs very infrequently occur in recognition errors (Signal Ahead).

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APPENDIX B: HIGHWAY SIGN MEANING AS AN INDICATOR OF PERCEPTUAL RESPONSE

HIGHWAY SIGN MEANING AS AN INDICATOR OF PERCEPTUAL RESPONSE

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ABSTRACT

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Semantic differential scaling has been used as a method of evaluating and assessing driver understanding and comprehension of traffic signs in the past. Litigation and other operational pressures on traffic engineering agencies have created an interest in finding a laboratory method to quickly and easily estimate driver performance in processing communication via signs. This paper reports research attempting to correlate the meanings assigned to signs through the semantic differential to quantitative measures of drivers' abilities to detect signs, to recognize signs once detected, and to react to signs in decision making once recognized.

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Significant correlations were most often found between meanings attributed to signs in semantic differential scales and the performance of drivers in recognizing signs. No semantic differential scales were found for any sign tested for which a significant correlation existed in detection, in recognition and in decision-reaction tests. It was concluded that semantic differential scaling has little or no relationship to perceptual response to highway signs by drivers.

INTRODUCTION

During the past decade, tort litigation has made agencies responsible for signing and traffic control of streets and highways very sensitive to the problem of traffic sign effectiveness and driver communication. While substantial discussion about this heightened sensitivity of state agencies has taken place, the authors' experience has been that local agencies are as much or more affected than state agencies. As engineering organizations have become more interested in examining the fundamental effectiveness of existing and proposed signs, or new applications of existing signs, a concern has arisen as to how testing and evaluation of signs should be carried out.

The typical engineering approach has been to create a "prototype" and make a "pilot plant" installation. The design of a sign and test installation on a limited portion of the street and highway system that is suggested by this philosophy has become quite risky due to the threat of tort litigation over accidents during testing. Thus, concerns over potential safety hazards inherent in full scale sign testing as well as the potential financial loss during subsequent litigation has increased interest in the laboratory testing of signs.

The Manual on Uniform Traffic Control Devices [1] identifies the generally accepted five basic requirements of an effective traffic control device. They are: (a) Fulfill a need, (b) Command attention, (c) Convey a clear, simple meaning, (d) Command respect of road users, and (e) Give adequate time for proper response.

Engineering studies can determine whether the need for traffic control devices exists, and we are therefore not concerned with the first requirement in seeking effective laboratory testing of signs. Traffic enforcement and the judicial process are the primary mechanisms by which road users develop respect for traffic control devices, and we are thus not concerned with a laboratory method to test respect for traffic control devices. However, it would seem that if laboratory experiments can be conducted which measure differences among signs related to commanding attention, conveying a clear and simple meaning, and giving adequate time for proper response, then much can be learned about the effectiveness of a sign without the necessity of using prototype field testing.

A technique suggested as providing a simple, inexpensive method for evaluating traffic signs is that of the semantic differential [2]. The semantic differential technique developed by Osgood, Succi, and Tannenbaum assumes that there exists an underlying structure to the meanings (semantic context) assigned to elements in a perceived environment [3]. Osgood, et al., wrote that these underlying or subconscious structures of meanings may be studied by means of a scaling technique similar to a questionnaire. While Osgood, et al., used exploratory factor analysis to find four dimensions of meaning among the set of scales by which the respondents rated a test item, Nunnally has defined analysis validity for each scale [4]. Since factor analysis of semantic scales is only a qualitative or arguable assessment of the interaction of scale responses, we have chosen for this analysis of a portion of our research data set to follow Nunnally and examine each scale separately.

If semantic differential scales of perceived meaning of signs are to be useful in addressing, via laboratory tests, the three basic sign requirements of interest identified above, then it should be possible to demonstrate some relationship between semantic scales and quantitative tests designed to measure responses to these very sign requirements. This paper reports one of a number of analyses performed in the course of a research project funded by the Iowa Department of Transportation Highway Division and demonstrates that caution must be exercised in attempting to extrapolate perceived highway sign meaning into driver response.

EXPERIMENTATION

Three laboratory experiments were designed to test driver responses to a set of sixteen signs. The fundamental focus of the research was to examine differences between "word legend" and "symbol legend" Stop Ahead warning signs. However, in order to test the significance and sensitivity of any experimentally determined differences between these signs, it was necessary to incorporate a larger sign set into the design. The total sign set consisted of the 16 signs shown in Fig. 1.

Respondents who participated in the experiments described in the following sections were volunteers from undergraduate courses as well as faculty and administrative staff at Iowa State University. Faculty and staff members (16 of 108 persons) ranged from late 30s to early 60s in age. All participants had to possess a valid driver's license.

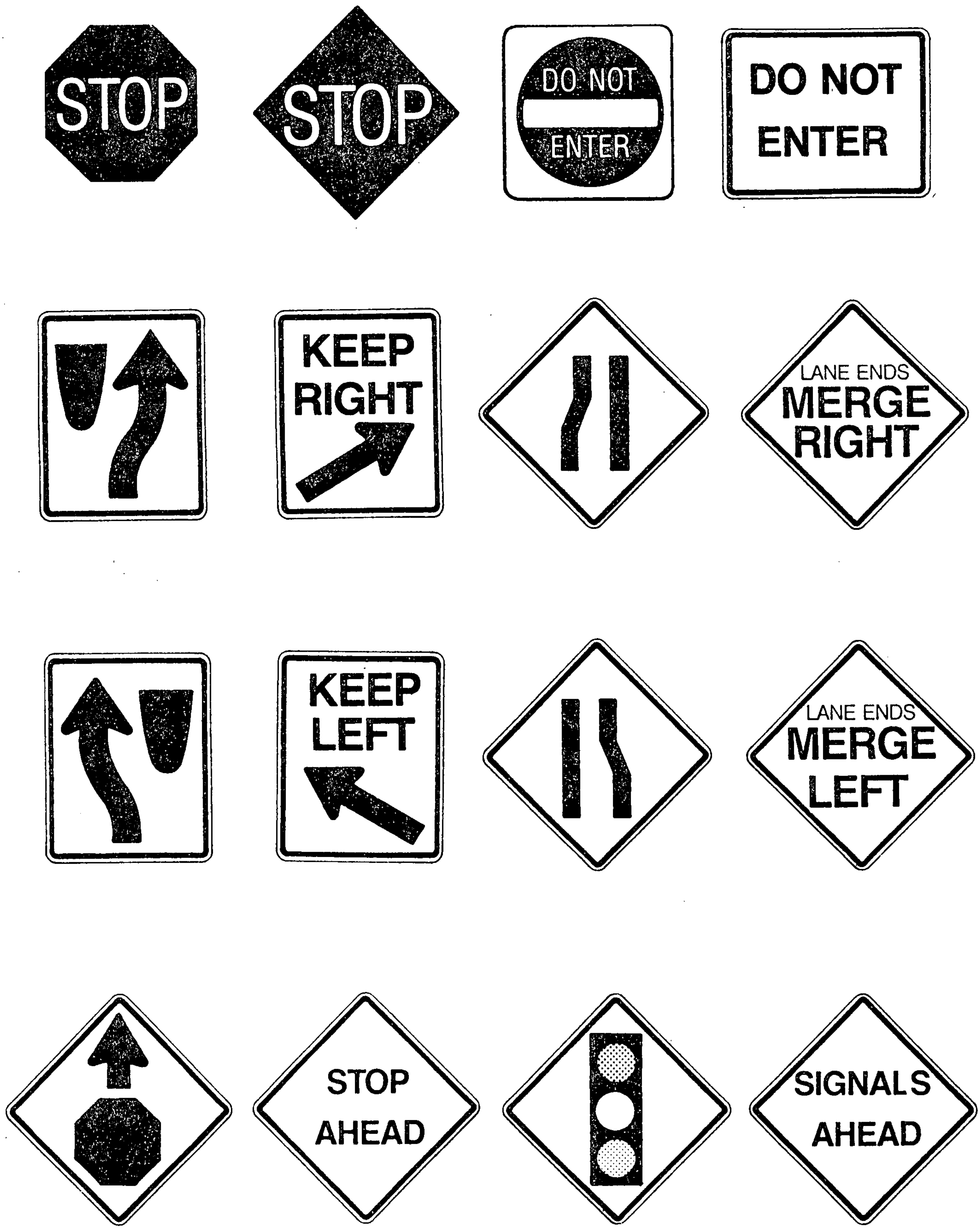

Fig. 1. Matrix of signs for detection, recognition, and reaction experiments.

Because the design of the experiments and the testing equipment made potential differences in visual acuity among subjects an irrelevant consideration, no measurement of visual acuity was conducted. Age was not asked of the respondents since a measure of driving experience was obtained (found not to be a significant influence on performance in any of our analyses).

Experiment One: Detection

A detection experiment was conducted first. Each of 30 persons was presented a series of pre- and post-masked tachistoscopic inputs and asked, after each trial, whether the input was a road sign or a blank flash. Subjects began each trial viewing a mask slide consisting of randomly assembled pieces of various road signs, and the test input for each trial was essentially a brief interruption in the viewing of the mask slide. Each series of trials included presentations of the 16 signs listed above and 16 blank presentations in a random order. For each subject, the first series of trials began with 110 millisecond presentations that were clearly visible to the subject. On succeeding series of trials, exposure durations were reduced until the subject performed at no better than chance level in deciding whether each presentation was a blank or a road sign. That is, the performance criterion was that each person make no more than 16 correct sign/blank decisions out of a series of 32 consecutive presentations. The criterion of acceptable consistency for a given subject was performance at or below chance level on three consecutive sequences of 32 presentations. Once this criterion was met, three additional series of 32 presentations each were administered to the subject and recorded along with the results of the previous three series.

For each sign, then, the measure submitted to statistical evaluation was the number of times the sign was correctly detected over the six series at chance-level exposure duration. For the analysis reported here the probability of correct detection was correlated with semantic differential scale results. The mean chance-level exposure duration for all 30 subjects was 24 milliseconds.

Experiment Two: Recognition

The same sample of 16 signs was used in a second experiment designed to test for differences in recognizability among signs. The experiment was designed to determine whether, after a sign's presence is detected, differences exist in the perceptual operations involved in the recognition process that make the driver aware of the sign. A total of 36 subjects participated in the experiment.

The general procedure was to present the subject a road sign tachistoscopically and then have the subject decide which of two signs (the just-presented sign and another sign randomly selected from the set) shown outside the tachistoscope in clear vision was the sign that had just been presented. Each trial began with the subject viewing the previously described mask slide; as in the preceding detection experiment, stimulus presentation was essentially an interruption of the subject's viewing of the mask. The experiment required 240 trials for each subject. This permitted 15 test trials for each sign; that is, 15 trials on which a given sign was presented tachistoscopically and then paired with each of the other signs for the subject's forced choice identification of which sign had been presented tachistoscopically on that trial. The performance measure was the number of errors, of a possible 15, that each subject made. For the analysis reported here the probability of correct recognition was correlated with the semantic differential scale results.

The 36 subjects were assigned to three groups of 12 subjects each. This made it possible to evaluate the effect of viewing time on sign recognition. A different exposure duration was used for each group. Exposure durations were based on the results of Experiment One (Detection). Recognition experiment exposure times for groups 1, 2, and 3 were 32, 41 and 49 milliseconds respectively. These exposure durations were, respectively, one, two, and three standard deviations above the mean exposure duration for chance-level presence-absence detection in Experiment One (24 milliseconds). This manipulation permitted observation of the influence of sign message and sign format on reducing recognition errors as time increased for completion of the recognition process.

Experiment Three: Decision Reaction Times

This experiment was designed to measure the speed with which subjects could decide on appropriate driver actions for various road signs once the signs were recognized. Forty-eight subjects participated in the experiment. Each subject was provided a response box that housed four response button switches. Respondents were seated in front of a screen onto which road sign slides were projected. At the beginning of the experiment, they were told that road signs would be projected onto the screen and that, for each sign, one of four action decisions would be appropriate. The response decisions would be to stop, to go right, to go left, or to slow down. The subjects were asked to indicate, by pressing the appropriate response button as rapidly as possible, what driver action they would take in response to each of the projected signs.

Proper experimental control required that the assignment of the four response buttons to the four decision actions be varied across subjects. Accordingly, the 48 subjects were assigned to four groups of 12 subjects each, and assignment of decision actions was counterbalanced across the four groups. As positioned from left to right, the response buttons indicated the following action decisions for the four groups of subjects.

Group 1: Stop, Left, Right, Slow

Group 2: Slow, Stop, Left, Right

Group 3: Right, Slow, Stop, Left

Group 4: Left, Right, Slow, Stop

The performance measure was each subject's mean response reaction time for each sign over 10 randomly ordered presentations of each of the 16 signs. As might be expected, the reversal of decision associated with button position for "go left" and "go right" for Group 3 produced such aberrant values that the results from Group 3 were deleted for this reported analysis.

Semantic Differential Tests

Each subject in the detection, recognition and decision-reaction experiments was instructed to go to another laboratory to complete a second test. There they were administered the semantic differential scale. Not all subjects did so and the exclusion of subjects in Experiment Three with reversed left-right response buttons (Group 3) provided 27 subjects from Experiment One, 35 subjects from Experiment Two and 23 subjects from Experiment Three who completed the semantic differential and whose performance could be correlated across the experiments.

In order to limit the time required in the semantic differential test and minimize subject resistance, the authors decided to utilize only a portion of the complete set of 16 signs. Since the contract focus of the research revolved around the differences between the word and the symbol Stop Ahead signs both of those were included. Driver behavior using the STOP sign as a "slow" rather than a "stop" driver action was also an issue in the research question so it was determined that the set of signs to be tested would be the four "slow down" driver action signs and the four "stop" driver action signs.

Twelve seven-point scales were created for each subject to mark in response to each of the eight signs. The extreme ends of each scale were identified with the following pairs of descriptors: Good to Bad; Familiar to Unfamiliar; Active to Passive; Predictable to Unpredictable; Beautiful to Ugly; Meaningful to Meaningless; Fast to Slow; Strong to Weak; Valuable to Worthless; Important to Unimportant; Sharp to Dull;

Simple to Complex. These descriptors were selected after consulting original work by Osgood, et al. [3] and considering the application previously made by Dewar and Ells [2].

A random number generator was used to select two different sequences of the eight signs to produce a "slide set A" and a "slide set B" to be displayed to respondents. Trial measurements indicated that no more than one person would be expected to be waiting while a subject was participating in the semantic scale test. A random number generator was used to select the order in which the scales were placed on the answer sheet with the same answer sheet being used for all signs viewed and all subjects. Each subject was seated in a room with subdued lighting and shown slides of the previously described signs one through eight. Each subject was allowed to study each sign as long as he or she wished, but the instructions given at the beginning of the test informed each subject that each scale was to be marked with the first impression about the sign. A randomized order to the scales also included a randomization of the "positive" or the "negative" descriptor as the left end of the scale. The positive end of the scale was given a weight of seven and the negative end was given a weight of one in the data reduction.

RESULTS

Each semantic differential scale response to each sign scaled by the respondent was correlated with that respondent's performance on that sign in the detection, recognition and decision-reaction experiments using Pearson correlations as an indicator of whether semantic differential scaling can serve as an estimator of driver perception performance in highway signing. Table 1 shows correlations between performance in the laboratory test of simple presence-absence detection of signs and semantic differential responses for all semantic differential scales. In the examination of Table 1, two notations require clarification. "Perf Same" refers to the correlation between semantic differential responses and presence-absence detection in the lab study when sign format (word versus symbol) was the same in both tasks; "Perf Opp" refers to the correlation between performances in the two tasks when sign message was the same but sign formats (word versus symbol) were opposites in the two tasks.

Considered by sign type, Table 1 clearly shows that the Stop Ahead (word) sign generated the largest number of statistically significant correlations (a total of seven) between semantic scale items and detection performance. Four of the correlations were produced by "Perf Same" conditions, and three occurred under "Perf Opp" conditions. All correlations were positive in direction. The Signal Ahead (symbol) and the Do Not Enter (word) signs produced the next highest number of significant correlations (five). The Signal Ahead (symbol) sign produced positive correlations whereas the Do Not Enter (word) sign produced negative correlations. The only other sign to produce a significant correlation was the Signal Ahead (word) sign. The semantic differential scales most frequently correlating with detection performance were (in decending order of frequency) Active-Passive and Predictable-Unpredictable,

Table 1. Semantic differential scale correlations with detection experiment results by sign shown.

	Signal Ahead (Sym)	Signal Ahead (Word)	Stop Ahead (Sym)	Stop Ahead (Word)	Do Not Enter (Sym)	Do Not Enter (Word)	Stop (Oct)	Stop (Diam)
Good - Bad								
Perf Same	--	--	--	+0.39	--	--	--	--
Perf Opp	--	--	--	+0.52	--	--	--	--
Familiar - UNF								
Perf Same	--	--	--	--	--	-0.40	--	--
Perf Opp	--	--	--	--	--	--	--	--
Active - Passive								
Perf Same	+0.40	--	--	+0.37	--	-0.52	--	--
Perf Opp	--	--	--	+0.54	--	-0.52	--	--
Pred - Unpred								
Perf Same	+0.41	--	--	+0.42	--	-0.37	--	--
Perf Opp	+0.50	--	--	--	--	--	--	--
Beautiful - Ugly								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Mean'ful - Mean'less								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Fast - Slow								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	+0.44	--	--	--	--
Strong - Weak								
Perf Same	--	--	--	--	--	-0.48	--	--
Perf Opp	--	--	--	--	--	--	--	--
Val - Worthless								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	+0.40	--	--	--	--
Imp - Unimp								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Sharp - Dull								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	+0.55	--	--	--	--	--	--	--
Simple - Complex								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	+0.43	+0.46	--	--	--	--	--	--

"--" = Not significant at 0.05 or better level.

Perf Same = detection, recognition or decision-reaction performance on sign with same lexical status to legend as the one scaled.

Perf Opp = detection, recognition or decision-reaction performance on sign with opposite lexical status in legend as the one scaled.

32ms and 49ms = milliseconds exposure duration in tachiostoscopic presentation during recognition experiment, etc.

followed by Simple-Complex, Familiar-Unfamiliar, Fast-Slow, Strong-Weak, Valuable-Worthless, and Sharp-Dull.

Consideration of sameness versus difference in sign format for the two tasks (i.e., Perf Same and Perf Opp) shows consistent relations between tasks for only three signs and three semantic differential scales. The Stop Ahead (word) sign correlated positively, for both matching and mismatching sign formats, with the Good-Bad and the Active-Passive scales. Similarly, the Signal Ahead (symbol) sign correlated positively with the Predictable-Unpredictable scale for both sign format arrangements. On the other hand, the Do Not Enter (word) sign correlated negatively, for matching and mismatching sign formats, with the Active-Passive semantic scale. The meaning of this pattern is unclear. One interpretation might be that both the Signal Ahead (symbol) and Stop Ahead (word) signs are common, but seen so infrequently that they still command attention. At the same time, the Do Not Enter (word) sign may well be seen as a sign in which the expected action for a given sign placement is unclear. As Table 1 shows, the distribution of the remaining correlations between the two tasks was not at all systematic.

Table 2 presents correlations between sign recognition in the lab when exposures were 32 milliseconds and performance on semantic differential scales. Note that only four correlations were statistically significant. Two of these were for one sign and one semantic scale; recognition of the Stop Ahead (word) sign correlated negatively with performance on the Predictable-Unpredictable semantic scale when sign formats matched and when they mismatched for the two tasks. Considering the potential number of correlations in this series of comparsions,

Table 2. Semantic differential scale correlations with 32ms recognition experiment results by sign shown.

	Signal Ahead (Sym)	Signal Ahead (Word)	Stop Ahead (Sym)	Stop Ahead (Word)	Do Not Enter (Sym)	Do Not Enter (Word)	Stop (Oct)	Stop (Diam)
Good - Bad								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Familiar - UNF								
Perf Same	--	--	--	--	--	--	-0.57	--
Perf Opp	--	--	--	--	--	--	--	--
Active - Passive								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Pred - Unpred								
Perf Same	--	--	--	-0.67	--	--	--	--
Perf Opp	--	--	--	-0.57	--	--	--	--
Beautiful - Ugly								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Mean'ful - Mean'less								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Fast - Slow								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Strong - Weak								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Val - Worthless								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Imp - Unimp								
Perf Same	+0.69	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Sharp - Dull								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Simple - Complex								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--

"--" = Not significant at 0.05 or better level.

Perf Same = detection, recognition or decision-reaction performance on sign with same lexical status to legend as the one scaled.

Perf Opp = detection, recognition or decision-reaction performance on sign with opposite lexical status in legend as the one scaled.

32ms and 49ms = milliseconds exposure duration in tachiostoscopic presentation during recognition experiment, etc.

very little comparability between perceptual recognition and semantic differential responses is suggested by these findings.

Table 3 shows the pattern of correlations between sign recognitions at 49 millisecond exposures and responses to the semantic differential. For this longer exposure duration in the recognition test, more than twice as many statistically significant correlations with semantic differential performance were observed. Most striking was the number of positive correlations between recognition of the Stop Ahead (symbol) sign and semantic scale responses; for six of ten semantic differential scales, at least one correlation with recognition was found. All but one correlation was for the "Perf Same" condition. The semantic scales correlating with recognition of 49 millisecond sign presentations were: Beautiful-Ugly, Strong-Weak, Valuable-Worthless, Sharp-Dull and Simple-Complex. Only one other sign, the Do Not Enter (symbol) sign generated more than one statistically significant correlation.

In Table 4, the reaction-decision experiment, a different pattern of responses was generated. First, rather than clustering on signs as in Tables 1-3, the correlations tended to group about one semantic differential dimension--Active-Passive. Note that three of the five correlations were where "Perf Opp" conditions were met. Once again the Do Not Enter (word) sign generated statistically significant correlations and again they were negative in direction.

Finally, it should be pointed out that there were extremely few statistically significant correlations where 192 calculations per table were carried out. In Table 1 there were 18 statistically significant correlations (9.37%), while in Table 2 only four of the correlations

Table 3. Semantic differential scale correlations with 49ms recognition experiment results by sign shown.

	Signal Ahead (Sym)	Signal Ahead (Word)	Stop Ahead (Sym)	Stop Ahead (Word)	Do Not Enter (Sym)	Do Not Enter (Word)	Stop (Oct)	Stop (Diam)
Good - Bad								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Familiar - UNF								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Active - Passive								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Pred - Unpred								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Beautiful - Ugly								
Perf Same	--	--	+0.61	--	--	--	--	--
Perf Opp	--	--	--	--	+0.70	--	--	--
Mean'ful - Mean'less								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Fast - Slow								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	-0.73	--
Strong - Weak								
Perf Same	--	--	+0.69	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Val - Worthless								
Perf Same	--	--	+0.63	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Imp - Unimp								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	+0.68	--	--	--
Sharp - Dull								
Perf Same	--	--	+0.61	--	--	--	--	--
Perf Opp	--	-0.87	--	--	--	--	--	--
Simple - Complex								
Perf Same	--	--	+0.66	--	--	--	--	--
Perf Opp	--	--	+0.60	--	--	--	--	--

"--" = Not significant at 0.05 or better level.

Perf Same = detection, recognition or decision-reaction performance on sign with same lexical status to legend as the one scaled.

Perf Opp = detection, recognition or decision-reaction performance on sign with opposite lexical status in legend as the one scaled.

32ms and 49ms = milliseconds exposure duration in tachiostoscopic presentation during recognition experiment, etc.

Table 4. Semantic differential scale correlations with decision reaction results by sign shown.

	Signal Ahead (Sym)	Signal Ahead (Word)	Stop Ahead (Sym)	Stop Ahead (Word)	Do Not Enter (Sym)	Do Not Enter (Word)	Stop (Oct)	Stop (Diam)
Good - Bad								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Familiar - UNF								
Perf Same	--	--	--	--	--	-0.55	--	--
Perf Opp	--	--	--	--	--	-0.55	--	--
Active - Passive								
Perf Same	--	--	--	--	--	-0.61	--	--
Perf Opp	--	--	+0.36	+0.44	--	-0.49	--	-0.43
Pred - Unpred								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	+0.42	--	--	--	--	--	--	--
Beautiful - Ugly								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Mean'ful - Mean'less								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Fast - Slow								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Strong - Weak								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Val - Worthless								
Perf Same	--	--	--	--	--	-0.58	--	--
Perf Opp	--	--	--	--	--	-0.45	--	--
Imp - Unimp								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Sharp - Dull								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--
Simple - Complex								
Perf Same	--	--	--	--	--	--	--	--
Perf Opp	--	--	--	--	--	--	--	--

"--" = Not significant at 0.05 or better level.

Perf Same = detection, recognition or decision-reaction performance on sign with same lexical status to legend as the one scaled.

Perf Opp = detection, recognition or decision-reaction performance on sign with opposite lexical status in legend as the one scaled.

32ms and 49ms = milliseconds exposure duration in tachiostoscopic presentation during recognition experiment, etc.

were significant (2.08%). In Table 3, ten of 192 possible correlations were significant (5.20%), and in Table 4 there were again ten statistically significant correlations (5.20%). Thus, the data show, for these sets of comparisons between semantic differential responses the tests of sign detection, recognition, and action decision latencies in the laboratory, an average 5.46% of the possible correlations were statistically significant.

At the same time, the only meaningful patterns of significant correlations were found in relation to the signs bearing the following legends:

Stop Ahead (symbol)

Signal Ahead (symbol)

Stop Ahead (word)

Do Not Enter (word)

Given that the purpose of our research was to examine formats of the stop ahead warning to motorists, we found this pattern of findings interesting but puzzling. One possible interpretation of these results might be that all four signs are not seen with great frequency and are likely not thought about when seen. Unlike standard Stop Signs which have been so frequently seen that they may have become functionally invisible, these signs may still bear sufficient "freshness" that they engender responses and meaning attribution. At the same time, the semantic differential scales generating substantial patterns of correlations (three or more significant correlations) included only the following:

Active-Passive

Predictable-Unpredictable

Why these two meaning dimensions would produce these patterns of correlations is also unclear. Given the above comments regarding the frequency of sign usage, it may well be that these less frequently seen signs generated in respondents feelings of both certainty or uncertainty as well as the vitality or robustness of message contained.

CONCLUSIONS

The basic hypothesis of this research was that tests of perceptual detection, recognition, and action decision latency would correlate with measures of perceived meaning of signs (i.e., that the ability to see and recognize signs in very short time durations was somehow related to semantic differential measures of stored meaning). Data that we will report elsewhere clearly show that sign detection, recognition, and action decision latency are all clearly related to sign meaning. However, for this report, we computed a total of 1152 correlations between laboratory tests of perception and 12 semantic differential meaning scales and so few were found to be significant that it is clear that semantic differential measures of attributed meanings of a sign are not systematically related to laboratory tests of the ability to detect, recognize, and decide on driver actions.

The clear suggestion of these findings is that the semantic differential, as an adjunct and verification device for laboratory detection/recognition research is of questionable reliability and validity.

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