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Perception and Interpretation of Advance Warning Signs on County Roads

March 1984

Iowa DOT Project HR-256
ERI Project 1641
ISU-ERI-Ames-84187

DEPARTMENTS OF CIVIL ENGINEERING,
SOCIOLOGY AND ANTHROPOLOGY, AND PSYCHOLOGY
ENGINEERING RESEARCH INSTITUTE
IOWA STATE UNIVERSITY, AMES

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report

College of Engineering
Iowa State University

DEPARTMENT OF TRANSPORTATION
IOWA

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Departments of Civil Engineering,
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EXECUTIVE SUMMARY

This research consisted of five laboratory experiments designed to address two objectives in an integrated analysis. The two research objectives were:

1. To discriminate between the symbol Stop Ahead warning sign and a small set of other signs (which included the word-legend Stop Ahead sign).

2. To analyze sign detection, recognizability, and processing characteristics by drivers.

A set of 16 signs was used in each of three experiments. A tachistoscope was used to display each sign image to a respondent for a brief interval in a controlled viewing experiment. The first experiment was designed to test detection of a sign in the driver's visual field; the second experiment was designed to test the driver's ability to recognize a given sign in the visual field; the third experiment was designed to test the speed and accuracy of a driver's response to each sign as a command to perform a driving action. The 16 signs each contained two different legend forms for the messages "Stop," "Do Not Enter," "Stop Ahead," "Signal Ahead," "Merge Left," "Merge Right," "Keep Right," and "Keep Left." Word-legend messages were detected better than symbol-only messages. Recognition accuracy was higher for "Stop" message signs than for the other types of messages. The speed and accuracy of driver responses to sign messages in the driver decision experiment were highly variable and depended upon sign legend type, sign message, and the action required. However, it is particularly

noteworthy that the word Stop Ahead and Signal Ahead signs produced more correct driver action decisions than did the symbol versions of these same signs.

A fourth experiment tested the meanings drivers associated with an eight-sign subset of the 16 signs used in the three experiments outlined previously. Semantic scale data revealed that word legend signs produced more consistent meaning associations than did symbol signs. Each of the previous three experiments utilized a different set of drivers, but all 112 participants in the first three experiments were tested on semantic scales.

A fifth experiment required all persons to select which (if any) signs they considered to be appropriate for use on two scale model county road intersections. One intersection was a "T" intersection of two paved roads with a vegetative sight restriction in one corner. The other intersection was a gravel county road intersecting a paved primary highway. This scale intersection experiment was conducted in a static display format and did not provide the respondent any sense of vehicle speed. A slight preference was shown for word-legend signs over symbol-legend signs for those drivers using advance warning signs. Drivers predominantly chose to place advance warning signs much closer to the intersection than the *Manual on Uniform Traffic Control Devices* suggests. However, several individuals did place advance warning signs at the *MUTCD* recommended location.

Social and behavioral variables, including length of driving experience, rural/urban experience, accident history, and other factors, were not found to exert any influence on the findings with the exception of differences based on the sex of the respondent. However, under detailed multivariate analysis the difference due to sex disappeared, indicating that it was merely a result of small sample size.

The conclusions are that word-legend Stop Ahead signs are more effective driver communication devices than symbol stop-ahead signs; that it is helpful to drivers to have a word plate supplementing the symbol sign if a symbol sign is used; and that the guidance in the MUTCD on the placement of advance warning signs should not supplant engineering judgment in providing proper sign communication at an intersection.

INTRODUCTION

Background

At county road intersections with signing control, advance warning signs frequently are needed to prepare drivers for traffic control devices such as Stop signs. Guidelines for installation of advance warning signs exist in the *Manual on Uniform Traffic Control Devices*. These guidelines are not all-inclusive, as individual circumstances on county highway systems demonstrate. Thus, engineering judgment is required in completely evaluating advance warning sign placement and subsequent installation. At some locations where the standard symbol-legend Stop Ahead (W3-1a) sign has been installed, drivers are not responding properly to the stop sign; the collisions that sometimes result represent a source of frustration for those attempting to communicate safety messages to drivers.

In our research, this question was addressed: Why does an intersection with a standard Stop Ahead sign and with advance warning signs installed on both sides of the road develop a history of collisions due to failure to obey the Stop sign? The intersection contained no unusual features. A possible reason was that the new symbol sign legend was less effective than the formerly used word sign legend. The results reported herein are directed toward this possibility.

The Problem

The problem researched can be stated most simply as a question: which is more effective as a communication device--the symbol legend Stop Ahead sign or the word legend Stop Ahead sign? Five more specific questions were postulated to organize the laboratory studies designed to test the basic question.

1. Is the symbol-legend Stop Ahead sign detected as fast as or faster than the word-legend Stop Ahead sign?
2. Is the symbol-legend Stop Ahead sign seen (or perceived) as accurately as the word-legend Stop Ahead sign?
3. Is the necessary advance warning message (to slow down or be prepared to stop) processed better with the symbol-legend Stop Ahead sign than with the word-legend Stop Ahead sign?
4. To what extent are any errors or misunderstandings in the interpretation of symbol-legend Stop Ahead signs (as compared to word-legend Stop Ahead signs) associated with fundamental brain perception and processing as opposed to willful thought processes that may be subjected to driver education and driver licensing efforts?
5. How do the social characteristics of drivers affect the communication of a Stop Ahead warning sign?

Research Objectives

1. To discriminate between the symbol Stop Ahead advance warning sign and a small set of other signs (that includes the word legend Stop Ahead sign).

Study of this discrimination consisted of three laboratory experiments. One was to define the detectability of each sign as a stimulus in a driver's visual field. A second was to define the degree to which a driver could recognize the sign in comparison to any other possible sign (as a measure of the degree to which a sign legend may be confused with another sign). A third was to define the rapidity with which sign information can be processed to make a basic driving decision associated with the sign.

2. To analyze sign detection, recognizability and processing characteristics by drivers.

This integral analysis was provided by having each respondent in the experiments directed toward Objective 1 participate in a scaling (attitude and preference) exercise on eight signs, followed by an exercise in which each respondent installed signs of his choosing on two scale-model intersections.

RESEARCH DESIGN

The experimental results that follow in this report document discrete steps taken to meet the research objectives. A brief explanation is necessary to state how these individual experiment steps form an integrated design.

During the format design of the sign images to be tested in the psychology laboratory experiments on detection, recognition and driver decision response, an apparent need emerged for some indication of the relationship of the test signs to the county highway system. Review of both the Manual on Uniform Traffic Control Devices commentary on sign design and installation and the basic principles of vision experimentation suggested that for statistical control purposes, four types of sign "action response," with two types of sign "message" within each action, and with both "word and symbol" based legend within each message, was needed. A sign set for visual processing testing included 16 signs listed in Table 1. A questionnaire, seeking estimates of the number of all such signs in place on the county highway system, estimates of driver response to each sign, and engineering perception of selected factors in the design and installation of warning signs, was mailed to all county engineering offices. The survey responses were used in final modifications to the psychology laboratory experiments.

Once the design of the psychology laboratory experiments on detection, recognition, and driver decision response was fixed, a sign perception (driver preference) test was designed using eight of the 16 signs listed in Table 1. The semantic scale experimental design was used

Table 1. Signs used in survey and psychology laboratory experiments.

Sign	Action	Message	Legend
Standard STOP	Stop	Stop	Symbol
Diamond STOP	Stop	Stop	Word
Ball DO NOT ENTER	Stop	Do not enter	Symbol
Word DO NOT ENTER	Stop	Do not enter	Word
Sym. Stop Ahead	Slow	Stop ahead	Symbol
Word STOP AHEAD	Slow	Stop ahead	Word
Sym. Signal Ahead	Slow	Signal ahead	Symbol
Word SIGNAL AHEAD	Slow	Signal ahead	Word
Sym. Merge Left	Go left	Merge left	Symbol
Word MERGE LEFT	Go left	Merge left	Word
Sym. Keep Left	Go left	Keep left	Symbol
Word KEEP LEFT	Go left	Keep left	Word
Sym. Merge Right	Go right	Merge right	Symbol
Word MERGE RIGHT	Go right	Merge right	Word
Sym. Keep Right	Go right	Keep right	Symbol
Word KEEP RIGHT	Go right	Keep right	Word

because several well-respected "human factors" researchers reporting studies of highway signing had used this technique. Signs requiring a "Stop" and signs requiring a "Slow" action were selected. The psychology laboratory experiments used a test respondent only once: therefore, each of the three experiments involved different persons. All respondents participating in any of the psychology laboratory experiments participated in the sign perception test using the semantic scale method. This provided a continuity across all persons tested.

Finally, upon completion of the semantic scale test, each respondent was asked to review scale models of two county road intersections and install any signing they might consider necessary. One intersection was a "T" intersection of two paved roads with a tree line sight obstruction in one quadrant. The other intersection was a gravel road crossing a paved primary highway ("+"). At each intersection model a set of signs (to scale) was provided including Stop signs, Yield signs, "T" intersection signs, Crossroad signs, Slow signs, both word and symbol signs for Stop Ahead and Yield Ahead, large arrow signs, and sharp turn signs. This provided information on each person's understanding of sign use to relate to detection, recognition, decision reaction, and perception of signs. This section, while not a detailed description of each experiment, is intended to emphasize the integrated nature of the experimentation and analysis.

MAILED SURVEY RESULTS

A questionnaire, seeking professional opinions of county engineers on several factors the research project staff considered relevant to the conduct of the research, was mailed to all 99 Iowa County Engineer offices. Eighty questionnaires were returned. Selected results related to the report objectives are presented here.

The number of standard octagonal stop signs installed on the county highway systems varied from 75 to 2000 per county, with a reported mean of 620. From 6 to 2000 word-legend Stop Ahead signs were reported. Symbol-legend Stop Ahead signs were reported to vary from 1 to 1200 per county. Stop Ahead advance warning signs as a proportion of the Stop signs reported in place varied from 10% to 100%. The split between word-legend and symbol-legend Stop Ahead signs varied from all word legend to all symbol legend, with wide variations between these extremes.

Each responding county engineer was asked to estimate the percentage of drivers who understood the intent and meaning of each of a set of signs. Estimates of understanding for stop signs varied from 9% to 100% with a mean of 97%. For Stop Ahead word-legend signs the estimates varied from 2% to 100% with a mean of 94%. For symbol-legend Stop Ahead signs, the estimate varied from 3% to 100% with a mean of 81%.

Each county engineer also was asked to estimate the proportion of drivers who understood the sign message and also obeyed it. Estimates of those obeying Stop signs ranged from 2% to 95% with a mean of 26%. Estimates of those obeying the instructions of a Stop Ahead sign ranged from 2% to 100% with a mean of 29% and 2% to 90% with a mean of 25% for word legend and symbol legend, respectively. Overall, county engineers provided an estimate of about 25% compliance with signing for a stop control intersection.

Responses to other questions displayed wider variation. A strong consensus was that, in attempting to improve driver response to signs apparently being ignored, two techniques were favored: (1) increase the size of sign, and (2) attach flags to the sign. In identifying factors in sign design perceived as important for effective driver communication, 41% considered sign shape as most important and 32% considered sign color the second most important factor.

Since each responding engineer was asked to provide only estimates in this survey for guidance in research design on this project, it is not appropriate to subject these data to detailed analysis. More precise data on this aspect of county highway system signing are available in Iowa Department of Transportation Project HR-262, "Signing on Very Low Volume Rural Roads."

THE LABORATORY EXPERIMENTS

The first three experiments conducted under Project HR-256 were designed to determine if fundamental differences exist in the perceptual operations that analyze the information presented in road signs. The pragmatic concern that initiated the project was whether the symbol-only or the word-only Stop Ahead advance warning sign more effectively communicated the intended message. Answering that question required that a wider sample of signs be studied and that distinctions be made between the perceptual operations involved in detecting, recognizing, and deciding what action is appropriate for each sign. To meet these objectives, a sample of 16 signs was studied, and three experiments were conducted. The first experiment tested for differences among the signs in simple detection of the presence versus absence of a sign. The second tested for differences in recognition of the signs once their presence was detected. The third measured differences in the speed and accuracy with which action decisions are made for the signs under study.

The Sample of Signs Studied

The sample included 15 regulation signs and an irregular diamond-shaped stop sign. The 16 signs included 4 signs that required the following 4 action decisions: Stop, Go Left, Go Right, and Slow Down. For each action decision, 2 signs presented the intended message in symbol format, and 2 signs presented the intended message in word format. Thus, the sample of signs permitted evaluation of the influence of (1) the action message, and (2) sign format on the separate perceptual operations of detecting, recognizing, and decision-making.

Experiment One: Detection

Thirty subjects served in the first experiment. The general procedure was to present each subject a series of pre- and post-marked tachistoscopic inputs and ask the subject, after each trial, whether the input on that trial 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 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 reached chance level in deciding whether each presentation was a blank or a road sign--that is, made no more than 16 correct sign/blank decisions out of the 32 presentations of the series. The performance criterion was that the subject perform at chance level on three successive series. When this criterion was met to assure that the subject felt certain that s/he was just guessing on each trial, three additional series were presented at the chance-level exposure duration to provide a more stable measure of the subject's ability to detect sign presence versus absence. 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.

Results

Results of Experiment One can be summarized briefly. The major finding was that signs presenting the stop message were detected with greater accuracy than were signs which presented Go Left, Go Right, or Slow Down messages. This is the most important result of Experiment One because it shows that the brain begins to extract the meaning of a sign message even at the very earliest stage of processing visual information. That is, even when the driver has no conscious awareness that a sign has been presented, the brain has already begun to analyze the message presented by the sign.

Three of the four stop-message signs (normal Stop sign, diamond Stop sign, symbol Do Not Enter sign, and word Do Not Enter sign) were bold red signs. Our initial hypothesis was that the important factor in detecting stop signs better than other signs was that they were the only bold red signs used. To test this hypothesis, we compared colorless Do Not Enter, Keep Right, and Keep Left signs and found that, even when color was eliminated from the comparison, detection of the Do Not Enter (i.e., Stop) sign was better than detection of the other two signs. The clear indication is that the meaning of the Stop sign, rather than its color, was the important factor in determining detectability.

Another important finding in Experiment One concerned sign format: signs that we categorized as word signs were detected more accurately than the signs we categorized as symbol signs. To pursue this finding, we categorized the signs three ways--words only, symbol only, and word-symbol combination signs--and tested differences among these three categories. The result was that words-only and word-symbol signs were detected more accurately than symbol signs.

To summarize briefly, then, Experiment One showed that even in the first and simplest perceptual operation of presence-absence detection, the brain is beginning to analyze the meaning of the sign, and that initial analysis proceeds better with word than symbol signs. These results are summarized in Table 2.

Experiment Two: Recognition

The same sample of signs was used in Experiment Two. The experiment was designed to determine if, 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. Thirty-six subjects served in the experiment.

The general procedure for the experiment was to present the subject a road sign tachistoscopically and then have the subject decide which of two signs (the presented sign and another sign) shown outside the tachistoscope in clear vision was the sign that had just been presented. Each trial began with the subject viewing the mask slide described previously, and the stimulus presentation was essentially an interruption in the 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 would be presented tachistoscopically and then paired with each of the other signs for the subject's forced choice of which sign had been presented tachistoscopically on that trial. The performance measure was the number of errors each subject made (out of 15 possible) for each sign.

Table 2. Experiment One: Detection (mean exposure duration = 24 msec).

1. Effect of message or required action on detection:		
	Stop	3.28/6.00 = 55% *
	Right	2.76/6.00 = 46%
	Left	2.66/6.00 = 44%
	Slow	2.73/6.00 = 46%
Words only (with sign color eliminated)		
	Do Not Enter	3.40/6.00 = 57%
	Keep Right	2.57/6.00 = 43%
	Keep Left	2.83/6.00 = 47%
2. Effect of sign format on detection:		
	Words	3.08/6.00 = 51%
	Symbols	2.63/6.00 = 44%
Trichotomy:	Words and Symbol	3.03/6.00 = 51.5%
	Words only	3.05/6.00 = 50.8%
	Symbol only	2.56/6.00 = 42.7%

*3.28/6.00 is an average of 3.28 correct detection responses of a possible 6.

The 36 subjects were assigned to 3 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 determined from Experiment One. In Experiment One, the mean exposure duration at which subjects met the criterion for chance level presence-absence detection was 24 milliseconds. The exposure durations used in Experiment Two were 1, 2, and 3 standard deviations above the Experiment One mean duration--i.e., 32, 41, and 49 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.

Results

Most simply stated, the results of Experiment Two showed that the perceptual operations performed in recognizing road signs differ considerably among signs. The message presented by the sign, the word versus symbol format of the sign, and exposure duration all interacted in determining the number of recognition errors; this complex interaction is presented graphically in Fig. 1. However, the findings of major pragmatic concern were clear in the data.

As expected, 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 milliseconds was not significant. The important indication here is that the perceptual operations of sign recognition are completed very rapidly, and the action decision for response (to a sign) triggered by those

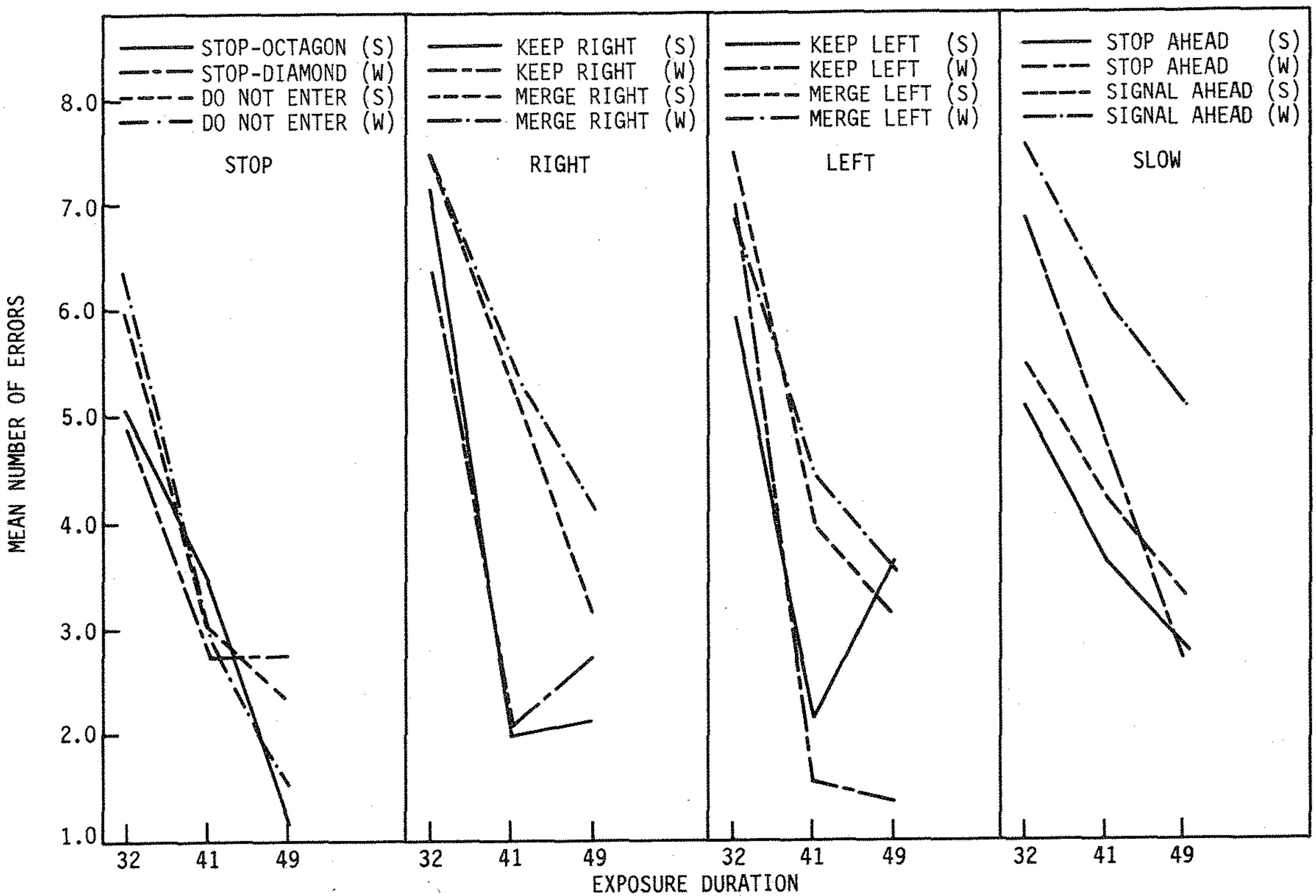

Fig. 1. Sign recognition errors.

perceptual operations occurs in a time period that is likely to be less than 50 milliseconds. A second finding of practical interest is 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 agrees with the Experiment One finding that stop message signs are detected better than the other signs studied.

These findings are, in general, evident in the data presented graphically in Fig. 1. Inspection of Fig. 1 also reveals informative differences in the patterns of error reductions for Stop, Go Right, Go Left, and Slow Down signs as exposure durations increased. For Stop message signs, errors declined in about the same pattern for Stop and Do Not Enter signs whether they were word or symbol signs. For Go Right and Go Left signs, similar patterns of error reduction were evident. As exposure duration increased, number of recognition errors decreased more rapidly for Keep Right (or Left) 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 instructed a driver to slow down. For Stop Ahead signs, fewer errors were made with word signs than with symbol 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 indication is that the word 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. For Signal Ahead signs, fewer recognition errors were made for symbol signs at all three exposure durations.

Experiment Three: Decision Reaction Times

Experiment Three was designed to measure the speed with which subjects decide on appropriate driver actions for various road signs once the signs are recognized. Forty-eight subjects served in the experiment. They were provided a response box that housed four response button switches. They 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 response decisions would be appropriate. The response decisions would be to stop, go right, go left, or slow down. They 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 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 to response buttons was counterbalanced across the four groups. The performance measure was each subject's mean response reaction time for each sign over 10 randomly ordered presentations of the 16 signs.

Results

The action required by the sign, the specific direction given by the sign (e.g., Stop versus Do Not Enter), and the word versus symbol format of the sign all interacted to determine the reaction time of subjects' responses. However, the findings of major pragmatic interest can be briefly summarized.

On the average, responses to Stop signs were faster than responses to signs that instruct the driver to slow down; responses to Go Right and Go Left signs were predictably longer and did not differ from each other. Perhaps of greater pragmatic interest was the effect of word versus symbol sign format. For both Go Right and Go Left signs, responses were faster for word than for symbol signs. For Stop signs, responses were equally fast for word and symbol signs. Finally, for both the Stop Ahead and Signal Ahead advance warning signs, decisions to slow down were faster for symbol signs than for word signs. These results, as well as evidence on how much subjects improved their performance over trials of the experiment, are summarized in Table 3.

The types of incorrect decisions made by subjects in Experiment Three were also very informative. The number of incorrect decisions varied widely across subjects. However, the total number of errors made in response to various signs permit certain general conclusions.

A large majority of the incorrect decisions were made in response to signs which required a Stop or Slow Down action. Of the responses to Stop signs, 13% were incorrect decisions to slow down (only 4% were decisions to turn right or left). Of the responses to signs that instructed the driver to slow down, 11% were incorrect decisions to stop; there was only one other incorrect decision in response to a Slow Down sign, and it was to turn left.

Closer scrutiny of these error responses was very informative. When the Stop Ahead and Signal Ahead signs were considered together, it was found that 78% of the incorrect Stop decisions were made to symbol signs and 22% of the errors were made to word signs. Ignoring

Table 3. Experiment Three: Decision reaction times (data are in milliseconds).

		Overall Mean	Trials: First Half	Trials: Second Half	Improvement
Stop	Word:	1042	1112	973	139
	Symbol:	1021	1080	962	118
Right	Word:	1188	1259	1117	142
	Symbol:	1254	1342	1166	176
Left	Word:	1209	1284	1133	151
	Symbol:	1294	1371	1217	154
Slow	Word:	1172	1229	1118	104
	Symbol:	1079	1140	1016	124

the symbol versus word format of the sign and considering Stop Ahead and Signal Ahead signs, it was found that 37% of the incorrect stop decisions were made in response to Stop Ahead signs and 63% of the errors came in response to Signal Ahead signs.

Consideration of incorrect decisions to slow down instead of stop were also informative. The large majority of these errors (91%) were made in response to Do Not Enter signs; 9% of the incorrect slow down decisions were made to Stop signs. For the Do Not Enter signs, errors were almost equally frequent for symbol (43%) and word (48%) signs. For the normal octagonal Stop sign, errors were few; only 2 "slow down" decisions and one "go left" decision were made. For the irregular diamond-shaped Stop sign, nine "slow down" decisions were incorrectly made.

CHARACTERISTICS OF THE SAMPLE

The nature of experimental research is such that standards of probability sampling are usually not met. The assumptions (that have been largely verified over time) on which experimentation is predicated essentially focus on the universality of the phenomena under examination. In the case of the laboratory research on the information processing of the brain under specific conditions, such assumptions are logical and can be extended to the research experiments conducted outside the psychology laboratory. It was necessary that the sample used for the experiments described in this section be comprised of the same individuals who had participated in the psychology laboratory experiments. For this reason, the extent to which this sample approximates that which would be found in a probability sample is unknown.

Such considerations notwithstanding, the resultant sample proved to be a representative and usable sample. Males comprised 55.88% (n = 57) of the sample while females comprised 44.11% (n = 45) of the total sample. This is a not-atypical sampling of the adult population, especially given the total sample size (as contrasted with modern probability samples). Of the participants, 97.8% (n = 45) possessed a valid driver's license while 2.2% (n = 1) did not. Note that some 60 of 112 respondents did not answer this item. Of those holding a valid license, 79.5% (n = 35) hold Iowa licenses, while all other states represented 15.9% (n = 7). Only 2.3% (n = 1) of the sample had less than 2 years' driving experience, while 54.5% (n = 24) had between 2 and 5 years of driving experience. Another 25.0% (n = 11) had between

6 and 11 years of driving experience. Smaller percentages of experience were reflected by 11 to 15 years of experience in 6.8% (n = 3), 16 to 20 years of experience in 4.5% (n = 2), and 21 to 40 years of driving experience in 6.8% (n = 3). A surprising 26.7% (n = 12) had experienced a collision while driving during the preceeding two years, while 73.3% (n = 33) reported no such events during the same interval.

As Table 4 shows, the preponderance of the sample lived in areas with populations ranging from 25,001 to 500,000 persons. Not surprisingly, the second largest group came from farm areas of fewer than 500 persons (reflecting 21.7% (n = 10)). The third largest group represented areas with populations greater than 100,000 persons. They reflected 19.6% (n = 9) of the sample. The balance of the sample was distributed in small and relatively even groups throughout the range of population sizes.

Of the drivers in the sample, the responses to the question as to what proportion of their driving time was spent on county (that is, outside city) roads was illuminating. Fully 55% (n = 19) responded that they drove less than 10% under such conditions. Two groups reported that such driving represented 11% to 25% and 26% to 40% of their driving (11.8% (n = 4)) in both instances. Table 5 portrays the entire range of responses.

In the next section, responses to the Semantic Differential Scale will be analyzed.

Table 4. Hometown population density.

Density	% of Respondents	No. of Respondents
Farm, <500	21.7%	(10)
501-1,000	2.2%	(1)
1,001-2,500	4.3%	(2)
2,501-5,000	4.3%	(2)
5,001-25,000	4.3%	(2)
25,001-50,000	37.0%	(17)
50,001-100,000	6.5%	(3)
100,000+	19.6%	(9)

No response identified = 56
n = 112

Table 5. Proportion of time spent driving on rural county roads.

% Driving	% of Respondents	No. of Respondents
0%-10%	55.9%	(19)
11%-25%	11.8%	(4)
26%-40%	11.8%	(4)
41%-60%	8.8%	(3)
61%-75%	2.9%	(1)
76%-90%	2.9%	(1)
91%-100%	5.9%	(2)

No response identified = 78
n = 112

SEMANTIC DIFFERENTIAL RESPONSES

Two versions of the Stop Ahead sign were used for examination using the semantic differential technique developed by Osgood, Succi, and Tannenbaum. One sign was the Stop Ahead in a symbolic version (diamond with black arrow pointing up with red octagon below) and the other was the Stop Ahead in a word version (diamond with black lettering reading "Stop Ahead"). The semantic differential technique assumes that there exists a structure to the meanings (semantic content) of elements in a perceived environment. 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. Respondents were asked to respond to a slide of each sign using a seven-point scale, although the scale gradations were transparent to the respondent. Further, the meanings of "Good" or "Bad" and the strengths of values between them were constructed by the respondent. What the respondent saw for each dimension of the semantic differential was as shown below:

Good_____:_____:_____:_____:_____:_____:_____: Bad

The respondent indicated a meaning response by placing a mark at the point on the scale dictated by the meaning derived by the individual dictated. It was found by Osgood et al., using exploratory factor analysis, that four dimensions of meaning were usually to be anticipated in empirical investigation. These dimensions were labeled Evaluative (judgments as to the meanings of worth found in the stimuli); Understandability (relating to the clarity of meaning intuited by the respondent); Potency (having to do with aspects of perceived strength or power in the symbolic meanings seen by the respondent in the stimuli); and finally, Activity (which refers to the vigor or robustness the symbolic meanings give off to the respondent). Thus, a low score on a scale item indicated a high degree of meaning attributed by the subject.

This technique, widely cited after a Human Factors article published by Dewar and Ells, was intended (in the words of Dewar and Ells) to address "...the need for relatively simple, inexpensive methods for the evaluation of traffic signs (and other types of sign messages)...." (p. 183). While the conclusion of Dewar and Ells was that "The semantic differential measure of meaning was found to be a valid index of the degree to which sign messages are understood," (p. 183) the technique was not assessed using a broad cross-section of sign materials. In fact, glance legibility was the specific focus of their research. Indeed, Dewar and Ells used only symbolic messages and went so far as to warn against the use of word-message signs. Further, the problem of comparability of data across semantic differential studies has been addressed only by Osgood et al. and then only to demonstrate that the technique has more than face validity. HR-256, then, may be seen as one of the first systematic examinations of the semantic differential across data-gathering conditions and symbol sets.

In Table 6, below-the-mean and mode scores for the Stop Ahead (word) and Stop Ahead (symbol) signs are reproduced where 4 is the midscale individual response. Note that the amount of variation is high enough that mean and mode scores frequently differ substantially.

Table 6. Mean and median scores for Stop Ahead (word and symbol) on semantic differential items.

	Word		Symbol	
	Mean	Median	Mean	Median
Good-Bad	5.64	5.90	4.97	5.50
Familiar-Unfamiliar	6.25	6.67	3.91	3.50
Active-Passive	5.13	5.41	4.70	4.93
Unpredictable-Predictable	5.74	6.15	4.63	4.94
Ugly-Beautiful	3.80	3.92	4.37	4.50
Meaningful-Meaningless	5.96	6.18	5.11	5.67
Slow-Fast	3.71	3.50	3.56	3.27
Strong-Weak	5.04	5.37	4.53	4.61
Worthless-Valuable	5.60	5.92	5.01	5.41
Important-Unimportant	6.00	6.17	5.23	5.63
Sharp-Dull	4.70	4.88	5.04	5.35
Simple-Complicated	5.71	6.01	4.46	4.77

It should be emphasized that the means for the semantic differential scores for individual items are interpreted such that a low mean indicates a high level of meaning (usually a positive or strength/power response). The mean scores for the Stop Ahead (symbol) sign were consistently more favorable than were the mean scores for the Stop Ahead (word) sign, with two exceptions. These two exceptions were for the continua Ugly-Beautiful and Sharp-Dull. Why the semantic content of the Stop Ahead (word) sign would be different along these continua was unclear. Also noteworthy is that the gap between the mean differences was sometimes dramatic. For the continuum Familiar-Unfamiliar, the two sign means were 6.25 (for the Stop Ahead (word) sign) and 3.91 (for the Stop Ahead (symbol) sign). Thus, the sample of respondents indicated that the symbol form of the Stop Ahead sign bore a substantially more familiar meaning to them than did the language counterpart of that advance warning sign. Finally, in many cases a rather large difference existed between the spread of mean versus median scores. This suggests that in many cases there existed some loadings on the seven-point scale of responses, which tended to destabilize the mean as an assessment of average response.

In Table 7, the responses for the Stop Ahead (word) sign, broken down by sex of the respondent, show that in the mean scores on eleven of twelve items, the males ascribed more positive meanings to the Stop Ahead (word) sign than did the female respondents. The sole exception was the Slow-Weak continuum, where females attributed more positive semantic meanings to the Stop Ahead (word) sign. Thus, the responses of the aggregated sample appear to be related to the sex of the respond-

Table 7. Mean scores for Stop Ahead (word) on semantic differential items by sex.

	Males	Females	Sample
Good-Bad	5.47	5.75	5.59
Familiar-Unfamiliar	6.15	6.33	6.23
Active-Passive	4.96	5.33	5.12
Unpredictable-Predictable	5.54	5.91	5.70
Ugly-Beautiful	3.73	3.77	3.75
Meaningful-Meaningless	5.80	6.08	5.93
Slow-Fast	3.70	3.53	3.62
Strong-Weak	4.89	5.15	5.00
Worthless-Valuable	5.42	5.73	5.55
Important-Unimportant	5.94	6.00	5.97
Sharp-Dull	4.49	4.93	4.68
Simple-Complicated	5.42	6.00	5.67

ent, for the pattern of these responses is clear. (In Table 8 the same contrast is presented for the Stop Ahead (symbol) sign.)

In Table 8, the responses become less clear-cut. Overall, males rated four items as having greater (and generally more positive) semantic meaning, while females rated eight items relating to the Stop Ahead (symbol) sign as having higher intrinsic meaning. An examination of specific items is interesting. For males, the items rated as having greater meaning for the Stop Ahead (symbol) sign were: Familiar-Unfamiliar; Active-Passive; Strong-Weak; and Worthless-Valuable. Thus, for males, the Stop Ahead (symbol) sign was considered toward the end of the meaning continua representing familiarity, activity, strength, and value. On all other items the males rated the Stop Ahead (symbol) as having less intrinsic meaning than did female respondents. Again, the size of the mean differences (see Ugly-Beautiful and Meaningful-Meaningless) were sometimes substantial.

The implications of these findings are not altogether clear. In a general sense, males rated the Stop Ahead (word) sign more positively in terms of intrinsic meaning than did females, while the females in the sample appeared to rate the Stop Ahead (symbol) sign more positively than the males in terms of intrinsic meaning. More importantly, there appears to be less specificity inherent in the meaning of the Stop Ahead (symbol) sign than in the Stop Ahead (word) sign. In short, the Stop Ahead (symbol) sign permits the individual more latitude to interpret or infuse the sign message with meanings, whereas the Stop Ahead (word) sign bears a specific and relatively unambiguous message. What we may never know is the extent to which these findings tend to reflect

Table 8. Mean scores for Stop Ahead (symbol) on semantic differential items by sex.

	Males	Females	Sample
Good-Bad	5.03	4.82	4.94
Familiar-Unfamiliar	3.85	3.97	3.91
Active-Passive	4.49	5.02	4.72
Unpredictable-Predictable	4.87	4.40	4.66
Ugly-Beautiful	4.63	3.93	4.32
Meaningful-Meaningless	5.43	4.66	5.09
Slow-Fast	3.75	3.40	3.59
Strong-Weak	4.45	4.62	4.52
Worthless-Valuable	5.24	4.62	4.97
Important-Unimportant	5.29	5.15	5.23
Sharp-Dull	5.10	4.82	4.98
Simple-Complicated	4.66	4.11	4.41

satisfaction with the specificity of the message as opposed to fondness for the meaning inherent in color, shape, boldness, and other variables.

In order to attempt to relate these findings to others generated in the human factors and transportation field, the results of the Dewar and Ells semantic differential study are next examined. In Table 9, a direct comparison is made between the data generated by Dewar and Ells and HR-256. (It is presumed that the Dewar and Ells Stop Ahead sign was, in fact, a symbol sign, although this was not clear from their writing.)

As Table 9 indicates, there did not exist a strong correlation between the findings generated by the data of Dewar and Ells and that of the current researchers. Generally, however, symbol signs were closer than Stop Ahead (word) signs to the scores reported (for the symbol sign) by Dewar and Ells. At best, the data do not support the conclusions of Dewar and Ells.

As indicated by Table 10, the underlying factors in the semantic differential tend to be highly intercorrelated.

Table 11 indicates that the Stop Ahead (symbol) sign underlying dimensions are also highly intercorrelated, but not nearly as strongly as those for the Stop Ahead (word) sign.

Analysis of the two sets of intercorrelation tables reveals that the factors underlying the word sign tend to be more consistently related than those for the symbol sign. The meaning of this appears to be that there are more factors that intervene to confound the meaning of the Stop Ahead (symbol) than the Stop Ahead (word) sign. Laboratory research on lexical elements suggests that detection of

Table 9. Stop Ahead sign scores for semantic differential dimensions by sex.

	Males				Females			
	Eval[a]	Und[b]	Pot[c]	Act[d]	Eval[a]	Und[b]	Pot[c]	Act[d]
Stop Ahead (DE)*	2.33	1.97	3.20	3.07	2.10	2.10	3.37	3.00
Stop Ahead (W)**	4.87	5.70	5.54	4.38	5.08	6.08	5.74	4.60
Stop Ahead (S)***	4.97	4.43	5.06	4.45	4.42	4.16	4.77	4.41

*Stop Ahead sign scores from Dewar and Ells study.

**Stop Ahead (word) sign scores from HR-256.

***Stop Ahead (symbol) signs scores from HR-256.

[a]Evaluative.

[b]Understandability.

[c]Potency.

[d]Activity.

Table 10. Correlation coefficients for semantic differential dimensions for Stop Ahead (word) sign.

	Eval	Pot	Act	Und
Evaluation	1.00	0.80	0.72	0.72
Potency	0.80	1.00	0.72	0.54
Activity	0.70	0.72	1.00	0.54
Understanding	0.57	0.54	0.54	1.00

Table 11. Correlation coefficients for semantic differential dimensions for Stop Ahead (symbol) sign.

	Eval	Pot	Act	Und
Evaluation	1.00	0.56	0.50	0.67
Potency	0.56	1.00	0.53	0.62
Activity	0.50	0.53	1.00	0.50
Understanding	0.67	0.62	0.50	1.00

such elements is faster for words than for non-words. Our research reported earlier found that for some kinds of signs (particularly warning signs) the word sign was superior to the symbol sign. The semantic differential scales suggest that the nature of meanings associated with symbols may be more involved, less clear-cut, and therefore more problematic than for word messages. More will be said of this later.

The next step in the analysis of the semantic differential data involved data reduction for specific semantic items. Two were selected as having the most critical bearing on sign meaning: Good-Bad and Simple-Complicated. The mode of analysis was to use the mean for the entire sample as a breaking point to divide the continuum of responses into a single dichotomous variable that could then be contrasted with independent variables. The goal, of course, was to detect the causal influence of social, sex, and age factors on the responses.

In the case of the Good-Bad variable, several factors were found to have <u>no</u> effect on meaning assessment differences. These include whether the subjects: (1) possessed a valid driver's license in Iowa or elsewhere; (2) had had any collision within the past two years; or (3) used Stop signs or Stop Ahead signs in the tabletop driving simulation. On the other hand, the Good-Bad semantic differential responses appeared to be related to whether the respondent used a word or symbol marker to sign the intersection on the first "T" intersection of the tabletop simulation of a real intersection. The following two tables demonstrate the relationships.

Table 12 presents an interesting contradiction. Fully 84.6% of the persons who rated the Stop Ahead (symbol) sign as having high meaning also opted to use a word message when signing the "T" intersection in the tabletop simulation. Also surprising was that only 36.6% of the subjects who rated the Stop Ahead (symbol) sign as having low meaning selected the symbol message when signing the "T" intersection. Thus, the data appears to generate an anomaly in that subjects inconsistently selected another message when signing a potentially dangerous "T" intersection. Table 13 indicates the parallel results for the Stop Ahead sign with a word message.

Table 13 continues to bear out the anomalous pattern. Only 77.1% of the subjects rating the Stop Ahead (word) sign as having high meaning also elected to use a word message while signing the "T" intersection, while 22.9% selected a symbol message. Again, two-thirds of the subjects who rated the Stop Ahead (word) sign as having low meaning subsequently selected a Stop Ahead warning message in the tabletop simulation bearing a word message.

These tables clearly demand interpretation. Several possibilities present themselves. The first is that the effect of the meaning assigned by *individual subjects may be very low, which is to say that the utili*tarian effect of meaning assignment by the individual may be very low where the message is serious or life-threatening. By way of explanation, it might be said that the individuals studied may have felt that both word and symbol messages presented were not good message conduits, but at the same time they recognized the need for such functional signing. A second explanation may be that the differences in

Table 12. Dichotomous Good-Bad item (symbol) from semantic differential relating to simulated "T" intersection.

Message	Used: Word	Used: Symbol	Total
High Meaning Stop Ahead (symbol)	84.6% (22)	15.4% (4)	100% (26)
Low Meaning Stop Ahead (symbol)	63.4% (45)	36.6% (26)	100% (71)

Table 13. Dichotomous Good-Bad item (word) from semantic differential relating to simulated "T" intersection.

Message	Used: Word	Used: Symbol	Total
High Meaning Stop Ahead (word)	77.1% (27)	22.9% (8)	100% (35)
Low Meaning Stop Ahead (word)	66.1% (37)	33.9% (19)	100% (56)

meaning assessment may reflect a relatively slight effect arising from conscious, logical deduction in driving response. Such findings may reflect a statistical artifact arising from small sample size. The authors reject the last reason because there exists clear evidence of patterns to responses rather than the random or drastically skewed variation often found in bad samples.

THE TABLETOP SIMULATION

The logic underlying the Tabletop Simulation was to create a model situation wherein respondents would locate the signing for two specific intersections in the manner they thought most appropriate. Two intersections were used because it was felt that situational differences might intervene (thus a "T" intersection as well as a gravel road approaching a state highway were used as the conditions for signing). Each respondent was provided with a tray containing all possible advance warning signs for such conditions. Holes in the model roadway at (simulated and proportional) 50-foot intervals provided some guidelines for placement. The possible range of signing placements was from 50 to 750 feet.

Results

Results are summarized in Figs. 2 and 3. Figure 2 presents a summary of the respondent's signing for the "T" intersection, while Fig. 3 presents the summary results for the "+" intersection. Generally, it can be said that drivers (at least in our sample) do want warning signs for potentially hazardous situations requiring driver action. In both cases an overwhelming proportion desired a stop sign at the crossing. In the case of the "T" intersection the sample was split as to whether the arrows should be used to warn of the necessity of left or right turn (55.4% used the arrows, 44.6% did not use the arrows). That distinction aside, however, the responses of the subjects to the two simulated signing exercises were remarkably similar.

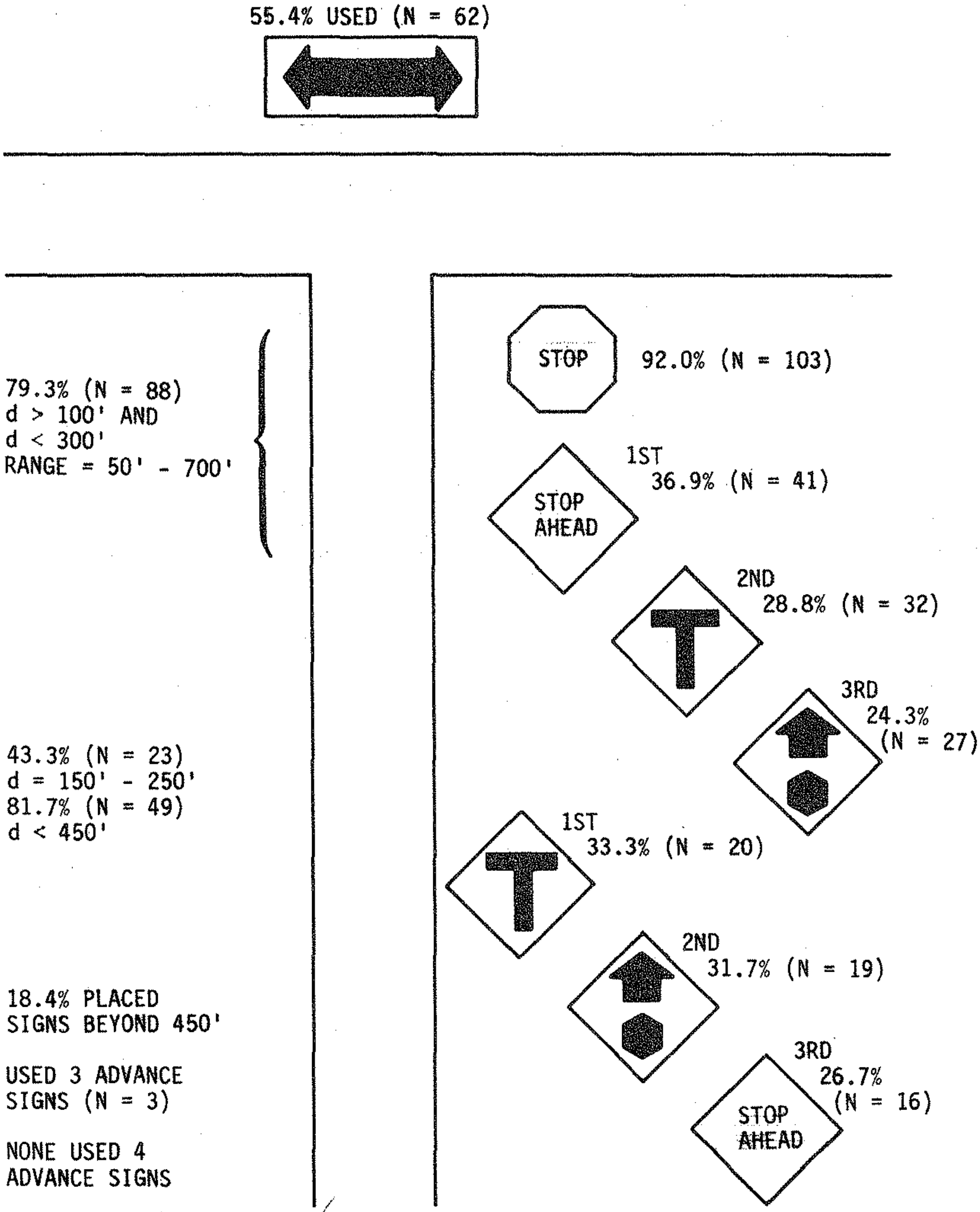

Fig. 2. Advance warning and stop sign placement for "T" intersection and total sample.

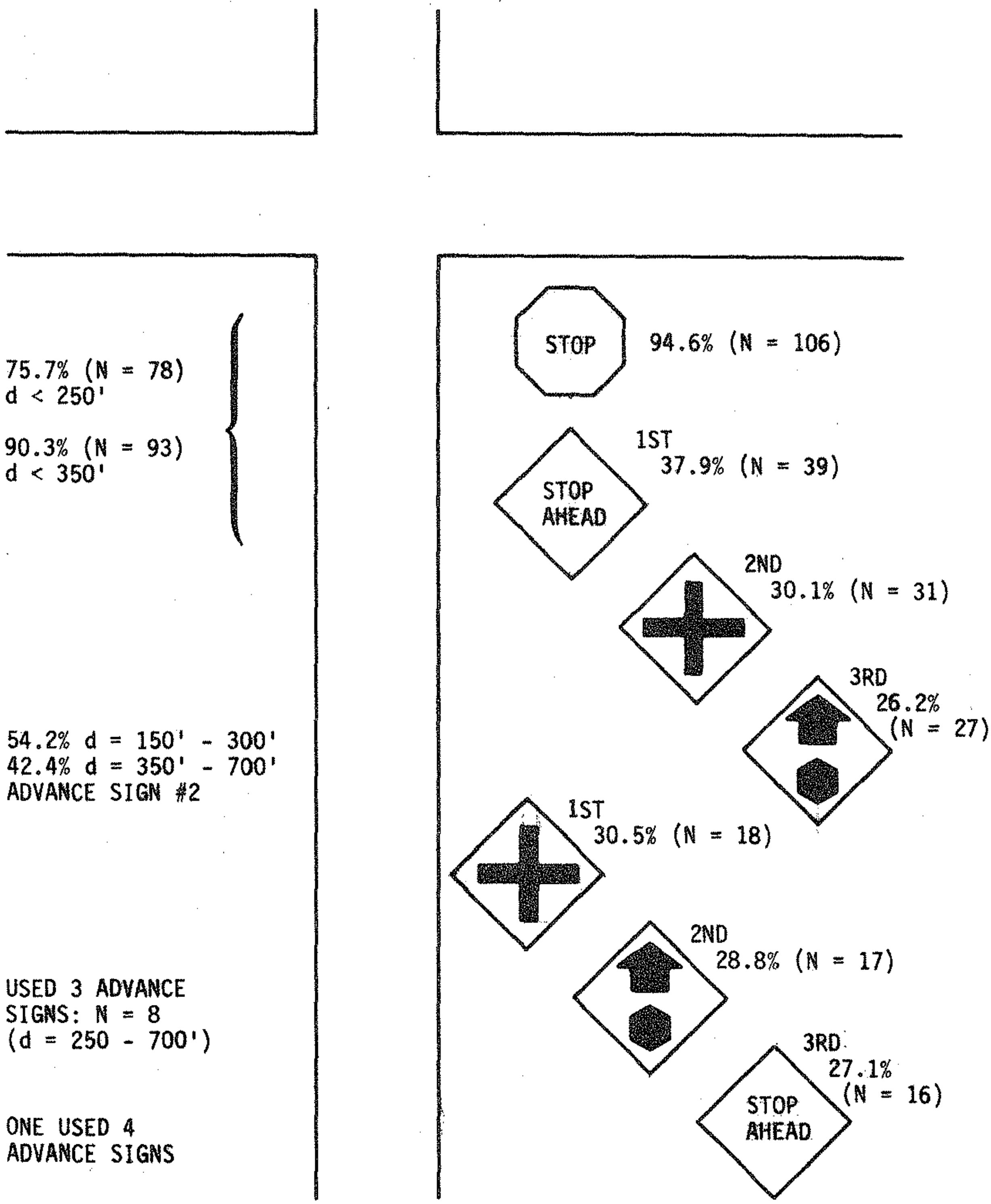

Fig. 3. Advance warning and stop sign placement for "+" intersection and total sample.

The "T" Intersection

Figure 2 may be best examined by beginning with the choices for the sign nearest the intersection--the Stop sign. Such a sign was placed there by 92.0% of the sample. A small percentage (7.1%) opted for a yield sign, leaving one person who felt that the intersection should have no traffic control at all at the juncture of roadways. At the same time, such unanimity did not exist regarding the arrows sign warning placed across the adjoining road. While 55.4% placed such a sign at that location, 44.6% did not use the sign (at least at that location, although some used it on the left side of the road across from the stop sign as an additional intersection marker).

Clearly the most interesting area to examine in this data relates to the placement of the next sign outward from the stop sign. In this case, most respondents again felt that at least one advance warning sign was needed to inform the driver adequately of the situation ahead. As Fig. 2 demonstrates, the most frequently selected sign was the Stop Ahead (word) sign (chosen by 36.9% of the sample). Next in popularity was the "T" intersection sign (with 28.8%), followed by the third choice, the Stop Ahead (symbol) sign (with 24.3% having selected this sign). It should be noted that the Stop Ahead (word) sign was also the first choice of the sample for the crossroad intersection at the same location (further discussion of this will ensue). The placement distances for this sign were also very interesting: in the case of the first sign placed after the stop sign, 79.3% placed the sign between 100 and 300 (simulated) feet from the intersection. This is obviously substantially closer than standard placement of this advance warning sign.

Moving to the second advance warning sign back from the "T" intersection, the first choice for this sign was the "T" intersection sign (with 33.3%) followed by the Stop Ahead (symbol) sign (with 31.7%) and the Stop Ahead (word) sign (with 26.7%). The distances at which these signs were placed also proved to be interesting: in the case of the second advance warning sign, some 43.3% placed their signs between 150 and 250 (simulated) feet, while 81.7% of the respondents placed their third sign at a point 450 feet or closer. Thus, only 18.4% placed their sign farther than 450 feet from the intersection. Note that persons who placed the second advance warning sign at 150 feet obviously must have placed the first advance warning sign between 50 and 150 feet.

Only three persons (out of a sample numbering 112) placed a third sign. No respondent placed more than three signs, although nothing prevented them from doing so.

The "+" Intersection

As in the case of the "T" intersection, the preponderance of respondents (94.6%) used a Stop sign at the "+" intersection. Again, as in the "T" intersection, the Stop Ahead (word) sign was the most popular choice (37.9%) for the first advance warning sign. The Crossroad (+) sign was the second most popular choice (30.1%), while the third most popular sign (26.2%) for this purpose was the Stop Ahead (symbol) sign. As for placement distance, respondents tended to place their first sign for the crossroad intersection even closer than for the simulated "T" intersection. A full 75.7% placed the first advance warning sign at a distance of 250 feet or less, while a point 350 feet from the intersection encompassed 90.3% of the signs placed by respondents.

In the case of the second advance warning sign, the first choice was the "+" sign, with 30.5% of the sample making this the preferred sign. The Stop Ahead (symbol) sign was a second choice (with 28.8%) and the Stop Ahead (word) was the third most popular sign used, with 27.1% placing it as the second advance warning sign. Again, the distances from the intersection tended to be very short, as 54.2% placed their signs 150 feet to 300 feet from the intersection. Bear in mind that this sign represents a third sign, as virtually all respondents will have placed a Stop sign as well as a first advance warning sign. The balance of the sample (42.4%) placed their second advance warning sign between 350 feet and 700 feet from the intersection.

SOCIAL AND BEHAVIORAL FACTORS

One goal of transportation research is to isolate the salient social or behavioral factors that help to explain specific phenomena. In the case of the simulated signing exercise carried out as a part of this research, a number of variables commonly held to be related to driving behavior were examined in order to help explain the use of signs in the simulation. These included the population of the respondent's home town and the approximate percentage of driving on county roads as opposed to city streets. In addition, variables included whether the respondent held a valid driver license, from which state that license was issued, the respondent's number of years of driving experience, and whether the respondent had experienced a driving accident in the previous two years. In the explanation of the respondents' proclivity toward advance warning signing, none of these factors were found to have an effect. In the placement of the first advance warning sign (nearest to the intersection), the respondent's sex appeared to be a very salient factor. For example, of those selecting the Stop Ahead (word) sign for the "T" intersection, 44.7% were male and 55.3% were female, while for those selecting the "T" intersection sign for that spot, 58.1% were male and 41.9% were female. As Table 14 demonstrates, this apparent relationship continued in the case of the crossroad intersection.

Table 14 shows an apparent pattern to the responses. When read from left to right, the table presents a picture of strikingly similar proportional differences.

Table 14. Sign selected for tabletop simulation and sex of respondent by intersection type.

Intersection Sex	"T" Male	"T" Female	Crossroad (+) Male	Crossroad (+) Female
1st Warning (Choice #1) (both Stop Ahead (word))	44.7%	55.3%	43.2%	56.8%
2nd Warning (Choice #1) ("T", + respectively)	52.6%	47.4%	55.6%	44.4%
1st Warning (Choice #2) ("T", + respectively)	58.1%	41.9%	60.0%	40.0%
2nd Warning (Choice #2) (both Sopt Ahead (symbol))	52.6%	44.4%	58.8%	41.2%

*Note that first and second warning signs refer to Figs. 2 and 3 (placement from intersection).

The discrepancy between male and female responses, although not great, would suggest that there may be a causal factor related to the sex of the respondent that would help to explain the choice of sign placement in the tabletop simulation. Unfortunately, such a simple solution breaks down under closer analysis. Using, for instance, only the respondents who placed a Stop Ahead (word) sign as the first advance warning sign, analyzing their choice for a second sign by sex of the respondent yields the finding that male and female respondents selecting any particular sign were almost equally divided. Such proved to be the case throughout. Whatever sex-related differences existed in the responses to the first advance warning sign choices (and they are consistent), the causation does not extend deeply enough through various levels of analysis that these differences explain, much less predict, behavior.

Analysis

A wealth of summary information is contained in Figs. 2 and 3. The results generated by the data are relatively consistent and enlightening.

First, the data suggests that drivers want advance warning signs. Clearly, the drivers in our sample feel that advance warning signs provide an added margin of safety when a potentially hazardous situation is approached.

Second, the signing of choice was essentially identical for both intersections. That is, the Stop Ahead (word) sign was the predominant choice for the closest advance warning sign for both intersection situations, while the two signs selected for the second sign from the intersection were variants of the same sign (the "T" intersection and the "+" intersection sign, respectively). This shows definite consistency of the respondents' preferences for such signing.

Third, drivers clearly preferred a Stop Ahead (word) sign closest to the intersection and a symbol sign descriptive of the potential hazard further out from the intersection. What this appears to suggest is that the driver priority for the ordering of such information (as seen in a driving approach) would be for general information in the form of a "T" intersection or "+" intersection sign, followed by specific information as to what driver action is required. In this situation the driver appears to be saying that the signs should inform as to (1) "here is what is ahead," and (2) "here is the action you will be required to take." Clearly, priority-setting was inherent in the act of signing the two intersections by the respondents. They may have used a word or a symbol advance warning sign, but in either case they were deciding what <u>kind</u> of information (as drivers) they needed first. In this case the data from this study do not permit firm conclusions as to the priority selection mechanism used by the sample of respondents. The data do permit us to assert, however, that such a system of priority setting does operate. Perhaps this particular point should be addressed in further research.

Fourth, a large enough number of respondents selected Stop Ahead (word) and Stop Ahead (symbol) signs singly or in combination with other signs to underscore the authors' findings in earlier research

(HR-230). The results are consistent with the earlier recommendation that where symbol signs are used for advance warning, they should be used with a supplemental word message for additional assurance of communication with those oriented to verbal or language messages rather than symbols.

RESEARCH SUMMARY

A questionnaire was developed to obtain preliminary research design input from Iowa County Engineers; 80 of 99 provided responses. These data were a useful supplement to, and in some cases a validation of, the general literature of human factors experimentation. Three separate experiments including 112 persons were conducted along the designs of experimental psychology to yield data on an individual's ability to detect different signs, the ability to recognize the message of a sign, and the speed and accuracy of making a driver-related decision from a sign message. A test of sign meanings was conducted using a respected sociological and psychological experimental method. Finally, an engineering scale model of two intersections was used to conduct a tabletop simulation of signing two intersections to obtain estimates of the respondents' abilities to interpret signing application. Interpretation of the resulting data, outlined in prior sections of this report, show correlated patterns among high-speed visual processing data, interpretive meanings, and simulation exercises in signing that suggest further research in signing communication needs to be conducted on several experimental levels to yield more reliable and detailed results.

CONCLUSIONS

The following three conclusions have been drawn from the reported research. These conclusions are based on combined experimental results as indicated in the brief explanatory comments incorporated with each conclusion.

1. A driver more accurately detects the presence of a word sign in his or her visual field than a symbol sign, as evidenced by the simple detection experiment; word-only sign legends were better detected than word-symbol combination legends, which were detected better than symbol-only signs; drivers associated more consistent meanings to word legend signs in the semantic scale test; and the drivers more often selected a word-legend sign if only one advance warning sign was placed in front of a Stop sign in the scale intersection simulations; the error rates in the driver action decision tests were lower for the word-legend Stop Ahead sign than for the symbol-legend Stop Ahead sign. It is concluded that if only a single advance warning sign is provided to drivers approaching a stop sign, it is preferable that it be either a word-legend sign or a symbol sign with a supplementary word plate. The data supporting this conclusion reinforce the findings of previous project HR-230.
2. Perceptual operations performed in recognizing various signs vary greatly, and accuracy in recognizing a sign increases with the length of time a person observes the sign. The

engineering practice of increasing sign size is likely to produce a psychological advantage, and any improvement in driver behavior may come from making the sign detectable at a greater distance, thereby increasing time for sign recognition. However, since the recognition rate apparently improves at a different rate for different sign messages and types of signs, it clearly remains an engineering judgment decision as to whether changing a sign size at a particular intersection will have a significant, positive effect in signing communication.

3. Decision reaction time (the driver's) is the result of a complex interaction among action required in response to the sign message, the type of sign message, and the message itself; signs communicating a requirement to stop produce faster driver decisions than the other types of messages tested, with signs communicating a requirement to slow (including the Stop Ahead signs) producing faster driver decisions than signs requiring a movement left or right. For both the Stop Ahead and Signal Ahead advance warning signs, decisions are made faster with symbol-legend signs, but such decisions are subject to much higher rates of misinterpretation than are word legends. Thus, the choice between either a symbol-legend Stop Ahead sign and a word-legend Stop Ahead sign remains a matter of engineering judgment regarding a driver's need to make driving decisions; however, laboratory tests on driver decision times suggest that word-legend Stop Ahead and Signal Ahead signs produce fewer incorrect decisions.

4. Results of respondent signing of two scale-model intersections indicate that drivers generally prefer advance warning signs to be significantly closer to the intersection than suggested in the guidelines of the Manual on Uniform Traffic Control Devices; thus, these data suggest that related signs such as a Stop sign and any advance warning sign for the intersection character (or announcing the presence of the Stop sign) are identified as one psychological (or decision) moment. No actual vehicle tests were made where respondents were traveling at highway speeds. This suggests, consistent with the principle of processing information to reduce uncertainty, that drivers may prefer these signs to be installed so that the driver can see all the associated signs and features at one instant during the approach to the intersection. The various ways the intersection was signed by different respondents clearly indicated that the application of advance warning signs to an intersection must be based on an engineering analysis of the site conditions and not the rigid application of dimensional criteria. These data indicate that drivers find the Manual on Uniform Traffic Control Devices guideline (to place an advance warning sign "about 750 feet in advance of the hazard or conditions" in rural areas) to be of little or no importance in signing communication. Therefore, if the horizontal alignment of the vertical alignment of the roadway or other visibility features suggest from an engineering analysis that advance

warning signs should be placed at a significantly different distance, the results of the engineering analysis should take precedence over the _Manual on Uniform Traffic Control Devices_.

FUTURE DIRECTIONS

From its inception, this research project was conducted on an interdisciplinary basis, using a research design consisting of a number of experiments with an integrated focus. However, as results emerged, their analysis took a direction that precluded examining several aspects of the data obtained. The research design focused only on meeting the original proposal objectives within allotted time and resources.

The research conducted under Project HR-256 has identified, for the first time, (1) differences in the basic perceptual operations of detecting, recognizing, and decision making for various road signs, and (2) links between those basic perceptual operations and the expressed preferences of a sample of the driving public in the ways they would place road signs to provide needed information to drivers at two types of rural intersections. In our view, the evidence summarized in this report clearly met the task order of the research contract. The remaining responsibility for meeting the task order is, however, to point out that at least some of the issues deserve further study as indicated by the present data.

In order to meet the task order of the contract, the complexity of the designs required for the experiments also provides valuable information that goes beyond both (a) the expressed purposes of the contract, and (b) the time period in which the task had to be met. The following questions could be addressed:

1. Once road signs are detected and the operations of perceptual recognition have begun, what factors cause recognition errors?

2. What relations exist between:

   a. High versus low decision reaction times and accuracy of those same subjects' placements of signs at roadway intersections?

   b. High versus low perceptual detection thresholds and those same subjects' placement of signs at roadway intersections?

   c. High versus low recognition accuracy and those same subjects' placement of signs at roadway intersections?

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TECHNICAL SUPPLEMENT

Data Analysis Summary Tables to Supplement

Detection Experiments, Recognition Experiments,

and Driver Decision Reaction Time Experiments

Analysis of Variance Summary: Experiment One - Detection.

Source	df	SS	MS	F	Prob.
Between subjects	29	53.99	1.86		
Action	3	29.55	9.85	6.24	0.0008
Action × S_s	87	137.33	1.58		
Direction/Action	4	13.82	3.46	2.23	0.07
S_s × Direction/Action	116	179.68	1.55		
Type	1	24.30	24.30	18.27	0.0002
Type × S_s	29	38.58	1.33		
Action × Type	3	9.35	3.12	2.24	0.09
Action × Type × S_s	87	121.28	1.39		
Type × Direction/Action	4	7.15	1.79	1.08	0.37
S_s × Type × Direction/Action	116	191.35	1.65		
Total	479				

S_s = Subjects

Direction/Action = Direction nested within Action

× = by

Analysis of Variance Summary: Experiment Two - Recognition.

Source	df	SS	MS	F	Prob.
Groups	2	1364.40	682.20	10.45	0.0003
S_s/Groups	33	2154.47	65.29		
Action	3	144.24	48.08	9.09	0.0001
Groups × Action	6	73.93	12.32	2.33	0.038
Action × S_s/Groups	99	523.45	5.29		
Direction/Action	4	214.03	53.51	15.38	0.0001
Groups × Direction/Action	8	83.39	10.42	3.00	0.004
S_s/Groups × Direction/Action	132	459.08	3.48		
Type	1	16.67	16.67	2.55	0.120
Groups × Type	2	0.84	0.42	0.06	0.938
Type × S_s/Groups	33	216.11	6.55		
Action × Type	3	57.35	19.12	5.43	0.002
Groups × Action × Type	6	28.05	4.68	1.33	0.252
Action × Type × S_s/Groups	99	348.47	3.52		
Type × Direction/Action	4	16.42	4.11	1.49	0.210
Type × Groups × Direction/Action	8	49.67	6.21	2.25	0.028
Type × S_s/Groups × Direction/Action	132	364.42	2.76		
Total	575				

S_s = Subjects

Direction/Action = Direction nested within Action

× = by

Experiment Two: Analysis Only for Slow Driver Action.

Source	df	SS	MS	F	Prob.
Between S_s	35	(667.687)			
	2	182.625	91.313	6.212	0.005
S_s	33	485.062	14.699		
Within S_s	(108)	(464.250)			
Direction	1	35.007	35.007	8.522	0.006
D × G	2	4.180	2.090	0.509	
D × S_s/G	33	135.563	4.108		
Type	1	70.840	70.840	20.720	0.000
T × G	2	7.097	3.549	1.038	0.367
T × S_s/G	33	112.813	3.419		
D × T	1	8.507	8.507	3.240	0.078
D × T × G	2	3.598	1.799	0.685	
D × T × S_s/G	33	86.646	2.626		
Total	143	1131.937			

G = Group

T = Type

D = Direction

S_s = Subjects

Experiment Two: Analysis Only for Move Left.

Source	df	SS	MS	F	Prob.
Between S_s	35	(1150.076)			
Groups	2	467.931	233.966	11.319	0.000
S_s	33	682.145	20.671		
Within S_s	(108)	(574.250)			
Direction	1	62.674	62.674	12.239	0.002
D × G	2	20.096	10.048	1.962	0.155
D × S_s/G	33	168.980	5.121		
Type	1	2.007	2.007	0.366	
T × G	2	8.847	4.424	0.807	
T × S_s/G	33	180.896	5.482		
D × T	1	4.340	4.340	1.396	0.244
D × T × G	2	28.848	14.424	4.641	0.017
D × T × S_s/G	33	102.563	3.108		
Total	143	1729.326			

G = Group

T = Type

D = Direction

S_s = Subjects

Experiment Two: Analysis Only for Move Right.

Source	df	SS	MS	F	Prob.
Between S_s	35	(1118.250)			
Groups	2	452.542	226.271	11.217	0.000
S/G	33	665.708	20.173		
Within S_s	(108)	(475.500)			
Direction	1	110.250	110.250	41.046	0.000
D × G	2	46.625	23.313	8.679	0.001
D × S_s/G	33	88.625	2.686		
Type	1	1.000	1.000	0.214	
T × G	2	9.375	4.688	1.004	0.379
T × S_s/G	33	154.125	4.670		
D × T	1	1.778	1.778	0.928	
D × T × G	2	0.513	0.257	0.134	
D × T × S_s/G	33	63.209	1.915		
Total	143	1593.750			

G = Groups

T = Type

D = Direction

S_s = Subjects

Experiment Two: Analysis Only for Stop.

Source	df	SS	MS	F	Prob.
Between S_s	35	(1174.743)			
Groups	2	330.264	165.132	6.453	0.005
S_s	33	844.479	25.590		
Within S_s	(108)	(333.258)			
Direction	1	4.340	4.340	2.141	0.150
D × G	2	13.514	6.757	3.333	0.047
D × S_s/G	33	66.896	2.027		
Type	1	0.007	0.007	0.002	
T × G	2	4.180	2.090	0.607	
T × S_s/G	33	113.563	3.441		
D × T	1	1.563	1.563	0.458	
D × T × G	2	16.542	8.271	0.103	
D × T × S_s/G	33	112.645	3.413		
Total	143	1507.993			

G = Groups

T = Type

D = Direction

S_s = Subjects

Error Choices: *Experiment Three* - Decision Reaction Times.

		Error Choice				
Action	Sign	Stop	Slow	Right	Left	Total
Stop	Stop (word)		2		1	3
	Stop (symbol)		9			9
	DNE (word)		58	5	14	77
	DNE (symbol)		53	1	17	71
Slow	Stop Ahead (word)	26				26
	Stop Ahead (symbol)	16				16
	Signal Ahead (word)	1				1
	Signal Ahead (symbol)	60				60
Right	Keep Right (word)		1			1
	Keep Right (symbol)				12	12
	Merge Right (word)		8		4	12
	Merge Right (symbol)		17		9	26
Left	Keep Left (word)	1	2	1		4
	Keep Left (symbol)	2	5	9		16
	Merge Left (word)	2		3		5
	Merge Left (symbol)	1	8	37		46
Totals		109	163	56	57	385

Summary

Error Choice

Action	Stop	Slow	Right	Left	Totals
Stop		122	6	32	162
Slow	103				103
Right		26		25	51
Left	6	15	50		71
Totals	109	163	56	57	385

Totals

Word = 129
Symbol - 256

Analysis of Variance Summary: Experiment Three - Decision Reaction Times.

Source	df	SS	MS	F	Prob.
Groups	3	4908056.16	1636018.7	1.91	0.142
S_s/G	44	37676705.82	856288.7		
Action	3	10854115.54	3618038.3	55.69	0.0001
Groups × Action	9	8893685.54	988187.3	15.21	0.0001
Action × S_s/G	132	8575294.51	64964.4		
Direction/Action	4	8082085.06	2020521.3	71.06	0.0001
Grps × Direction/ Action	12	354435.04	29536.3	1.04	0.416
S_s/G × Direction/ Action	171	4862109.03	28433.4		
Type	1	41903.39	41903.39	0.58	0.452
Groups × Type	3	1616064.60	538688.2	7.40	0.0004
Type × S_s/G	44	3204867.31	72837.9		
Action × Type	3	1928585.05	642861.7	20.18	0.0001
Groups × Action × Type	9	847454.45	94161.6	2.96	0.003
Action × Type × S_s/G	132	4204371.76	31851.3		
Type × Direction/ Action	4	282500.49	70625.1	3.72	0.006
Type × Groups × Di- rection/Action	12	175048.44	14587.4	0.77	0.682
Type × S_s/G × Direc- tion/Action	164	3112266.85	18977.2		
Half	1	7175297.61	7175297.61	75.36	0.0001
Groups × Half	3	329834.75	109944.9	1.15	0.338
Half × S_s/G	44	4189515.41	95216.3		
Action × Half	3	165984.73	55328.2	4.61	0.004
Action × Half × Groups	9	208153.81	23128.2	1.93	0.053
Action × Half × S_s/G	132	1584454.81	12003.4		
Half × Direction/ Action	4	388506.21	97126.6	8.13	0.0001
Half × Groups × Direction/Action	12	128899.27	10741.6	0.90	0.550
Half × S_s/G × Direc- tion/Action	170	2032023.23	11953.1		
Type × Half	1	0.0	0.0	0.0	1.00
Type × Half × Groups	3	37398.72	12466.2	1.17	0.333
Type × Half × S_s/G	44	469693.80	10674.9		
Action × Type × Half	3	66827.10	22275.7	2.53	0.059
Action × Type × Half/Groups	9	112125.89	12458.4	1.41	0.188
Action × Type × Half × S_s/G	131	115643.73	8821.7		
Type × Half × Di- rection/Action	4	55878.33	13969.6	1.08	0.367
Type × Half × Groups × Direc- tion/Action	12	83900.11	6991.7	0.54	0.885
Type × Half × S_s/G × Direction/ Action	159	2052220.01	12907.0		
Total	1494				

Data Analysis Summary Tables

to Supplement Sign Meaning Experiment

(Semantic Differential Scale)

and Scale-Model Intersection Signing Experiment

Scale reliability scores for semantic differential scales.*

	Alpha	Standardized Alpha
Stop Ahead (word)	.883	.886
Subscales:		
Evaluative	.625	.625
Potency	.742	.755
Activity	.659	.661
Understanding	.699	.701
Stop Ahead (symbol)	.926	.929
Subscales:		
Evaluative	.779	.780
Potency	.845	.844
Activity	.686	.688
Understanding	.730	.734

*n = 104.

Signs selected for "T" intersection in tabletop simulation (for first (closest) choice, second choice and third choice).

	Relative Percentage	No. of Cases
First Sign (closest)		
Stop Ahead (symbol)	24.3	27
Stop Ahead (word)	36.9	41
Yield Ahead (symbol)	2.7	3
Yield Ahead (word)	0.9	1
Arrow	6.3	7
"T"	28.8	32
Total		111
Second Sign		
Stop Ahead (symbol)	31.7	19
Stop Ahead (word)	26.7	16
Yield Ahead (symbol)	1.7	1
Yield Ahead (word)	5.0	3
Arrow	1.7	1
"T"	33.3	20
Total		60
Third Choice (farthest)		
Stop Ahead (symbol)	0.0	0
Stop Ahead (word)	33.3	1
Yield Ahead (symbol)	0.0	0
Yield Ahead (word)	0.0	0
Arrow	33.3	1
"T"	33.3	1
Total		3

Simulated sign placement distances for "T" intersection for choices one, two, and three.

Distance from Intersection (ft)	Number	Percentage
Sign #1 (closest)		
50'	8	7.2
100'	22	19.8
150'	24	21.6
200'	19	17.1
250'	11	9.9
300'	12	10.8
350'	4	3.6
400'	5	4.5
450'	2	1.8
600'	2	1.8
700'	2	1.8
Sign #2		
100'	3	5.0
150'	8	13.3
200'	10	16.7
250'	8	13.3
300	5	8.3
350'	2	3.3
400'	7	11.7
450'	6	10.0
550'	3	5.0
600'	1	1.7
650'	4	6.7
750'	3	5.0
Sign #3 (farthest)		
450'	1	33.3
600'	1	33.3
750'	1	33.3

Signs selected for "+" intersection in tabletop simulation for first choice (closest), second choice, and third choice.

	Number	Percentage
First Sign (closest)		
Stop Ahead (symbol)	27	26.2
Stop Ahead (word)	39	37.9
Yield Ahead (symbol)	2	1.9
Yield Ahead (word)	2	1.9
"+"	31	30.1
Slow	2	1.9
Second Sign		
Stop Ahead (symbol)	17	28.8
Stop Ahead (word)	16	27.1
Yield Ahead (symbol)	1	1.7
"+"	18	30.5
Slow	7	11.9
Third Sign (farthest)		
Stop Ahead (symbol)	1	12.5
Yield Ahead (word)	1	12.5
"+"	3	37.5
Slow	3	37.5

Simulated sign placement distances for "+" intersection for first choice, second choice, and third choice.

Distance	Number	Percentage
Sign #1 (closest)		
50'	8	7.8
100'	21	20.4
150'	26	25.2
200'	6	5.8
250'	17	16.5
300'	9	8.7
350'	6	5.8
400'	3	2.9
450'	2	1.9
500'	2	1.9
650'	2	1.9
700'	1	1.0
Sign #2		
100'	2	3.4
150'	9	15.3
200'	7	11.9
250'	9	15.3
300'	7	11.9
350'	5	8.5
400'	4	6.8
450'	4	6.8
500'	1	1.7
550'	3	5.1
600'	2	3.4
650'	4	6.8
700'	2	3.4
Sign #3 (farthest)		
250'	1	12.5
300'	2	25.0
550'	1	12.5
600'	2	25.0
650'	1	12.5
700'	1	12.5

Mean distances for sign placement by sex and intersection type.

	Male	Female
"T" Intersection		
Sign #1	92.08	97.05
Sign #2	225.69	125.75
"+" Intersection		
Sign #1	92.91	103.23
Sign #2	228.33	142.14

Summary Tables to Supplement

Analysis of County Office Survey

Stop signs in use, reported by mailed survey.

Stop Signs	No. of Counties	% of Responses
0-200	6	7
201-500	36	44
501-800	23	28
801-1500	14	17
1501 +	3	4
	82	100

Use of "Stop Ahead" signs as a proportion of Stop signs installed.

"Stop Ahead" Signs as Compared to Stop Signs in the County (%)	No. of Counties	% of Responses
0-10	1	1
11-20	6	7
21-30	4	4
31-40	15	19
41-50	9	11
51-60	3	4
61-70	9	11
71-80	8	10
81-90	3	4
91-100	15	19
101 +	8	10
	81	100

Percentage of installed "Stop Ahead" signs reported that are symbol-legend signs.

% of "Stop Ahead" Signs	No. of Counties	% of Responses
0	34	42
1-10	18	23
11-20	12	15
21-30	6	7
31-40	1	1
41-50	5	6
51-60	0	0
61-70	1	1
71-80	2	2
81-90	1	1
91-99	1	1
100	1	1
	82	100

Reported priority level for adding flashers to advance warning signs.

Priority	No. of Counties	% of Responses
Highest	12	16
Second highest	9	12
Third highest	7	10
No priority	19	26
n = 74		
Missing value = 6		

Reported priority level for changing a symbol advance warning sign to word-legend sign.

Priority	No. of Counties	% of Responses
Highest	5	7
Second highest	7	9
Third highest	6	8
No priority	36	48
n = 75		
Missing value = 5		

Reported priority level for moving a warning sign further back from the condition to which it applies.

Priority	No. of Counties	% of Responses
Highest	23	31
Second highest	9	12
Third highest	6	8
No priority	23	31
n = 74		
Missing value = 6		

Reported priority level for installing rumble strips at the condition to which the warning sign applies.

Priority	No. of Counties	% of Responses
Highest	12	16
Second highest	14	19
Third highest	9	12
No priority	20	27
n = 73		
Missing value = 7		

Reported priority level for installing rumble strips at the advance warning sign (or signs).

Priority	No. of Counties	% of Responses
Highest	8	11
Second highest	6	8
Third highest	4	5
No priority	40	53
n = 75		
Missing value = 5		

Reported priority level for installing a sign on the left side of the road, of the the same size and type as the warning sign installed on the right side of the road.

Priority	No. of Counties	% of Responses
Highest	10	14
Second highest	9	12
Third highest	4	5
No priority	27	37
n = 73		
Missing value = 7		

Reported priority level for installing larger than MUTCD recommended warning signs on both sides of the road.

Priority	No. of Counties	% of Responses
Highest	9	12
Second highest	9	12
Third highest	15	20
No priority	13	17
n = 75		
Missing value = 5		

Reported priority level for installing an advisory speed plate to the warning sign.

Priority	No. of Counties	% of Responses
Highest	3	4
Second highest	11	14
Third highest	13	17
No priority	19	25
n = 76		
Missing value = 4		

Reported priority level for installing a larger single warning sign on the right side of the road.

Priority	No. of Counties	% of Responses
Highest	19	25
Second highest	14	18
Third highest	14	18
No priority	12	16
n = 76		
Missing value = 4		

Reported priority level for adding flags to the warning sign (or signs).

Priority	No. of Counties	% of Responses
Highest	9	12
Second highest	18	24
Third highest	8	10
No priority	14	18
n = 76		
Missing value = 4		

Reported priority level for installing a word-legend supplementary plate to a symbol warning sign.

Priority	No. of Counties	% of Responses
Highest	14	19
Second highest	18	25
Third highest	14	19
No priority	7	10
n = 73		
Missing value = 7		

Reported priority level for installing a symbol supplementary plate to a word message warning sign.

Priority	No. of Counties	% of Responses
Highest	7	10
Second highest	7	10
Third highest	7	10
No priority	30	40
n = 74		
Missing value = 6		

Reported priority level for changing a word message warning sign to a symbol sign.

Priority	No. of Counties	% of Responses
Highest	1	25
Second highest	1	25
Third highest	1	25
No priority	0	0
n = 4		
Missing value = 76		

Reported importance level for sign shape as the characteristic determining sign effectiveness.

Importance	No. of Counties	% of Responses
Most	33	44
Second most	18	24
Third most	8	11
Least	2	3
n = 75		
Missing value = 5		

Reported importance for sign size as the characteristic determining sign effectiveness.

Importance	No. of Counties	% of Responses
Most	17	23
Second most	4	5
Third most	23	31
Least	1	1
n = 74		
Missing value = 6		

Reported importance for color of a sign as the characteristic determining sign effectiveness.

Importance	No. of Counties	% of Responses
Most	26	34
Second most	23	30
Third most	12	16
Least	2	3
n = 77		
Missing value = 3		

Reported importance for the openness of the background upon which a sign is viewed as the characteristic determining sign effectiveness.

Importance	No. of Counties	% of Responses
Most	10	14
Second most	8	11
Third most	11	15
Least	5	7
n = 72		
Missing value = 8		

Reported importance for the driver response required as the characteristic determining the sign effectiveness.

Importance	No. of Counties	% of Responses
Most	6	8
Second most	4	6
Third most	7	10
Least	17	24
n = 72		
Missing value = 8		

Reported importance for whether a sign message is presented by words or by a symbol as the characteristic determining the sign effectiveness.

Importance	No. of Counties	% of Responses
Most	5	7
Second most	5	7
Third most	4	6
Least	14	19
n = 72		
Missing value = 8		

Reported importance of repetition of sign message as the characteristic determining the sign effectiveness.

Importance	No. of Counties	% of Responses
Most	2	3
Second most	2	3
Third most	14	20
Least	30	44
n = 69		
Missing value = 11		

Reported importance of sign function as the characteristic determining sign effectiveness.

Importance	No. of Counties	% of Responses
Most	13	18
Second most	2	3
Third most	5	7
Least	21	29
n = 73		
Missing value = 7		