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VARIABLE MESSAGE SIGNAGE CONTENT: SURVEY TEST OF MEANING AND SIMULATION TEST OF USABILITY

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Successful communication with motorists concerning the preseance and constraints of the roadway ahead is critical for improving safety and traffic flow in work zones. The content of messages presented on static and variable message signs (VMSs) is especially important given that drivers must detect, comprehend, and translate signage information while being preoccupied to some degree with the task of driving their vehicle.

A survey study was conducted as a preliminary investigation into the information content of VMSs and other real time motorist information displays used in road work zones. Four VMSs were used in the survey. The subject pool consisted of 75 volunteers (approximate mean age=45 years) who stopped at a rest area on Interstate 35W (Northbound) just South of Rush City, Minnesota. Two questions were asked about each sign concerning meaning and delay of journey. Results showed that drivers could understand the content of a message, but could not always predict the consequences of the information. Variations of three signs from this study were adapted for use in the simulation experiment.

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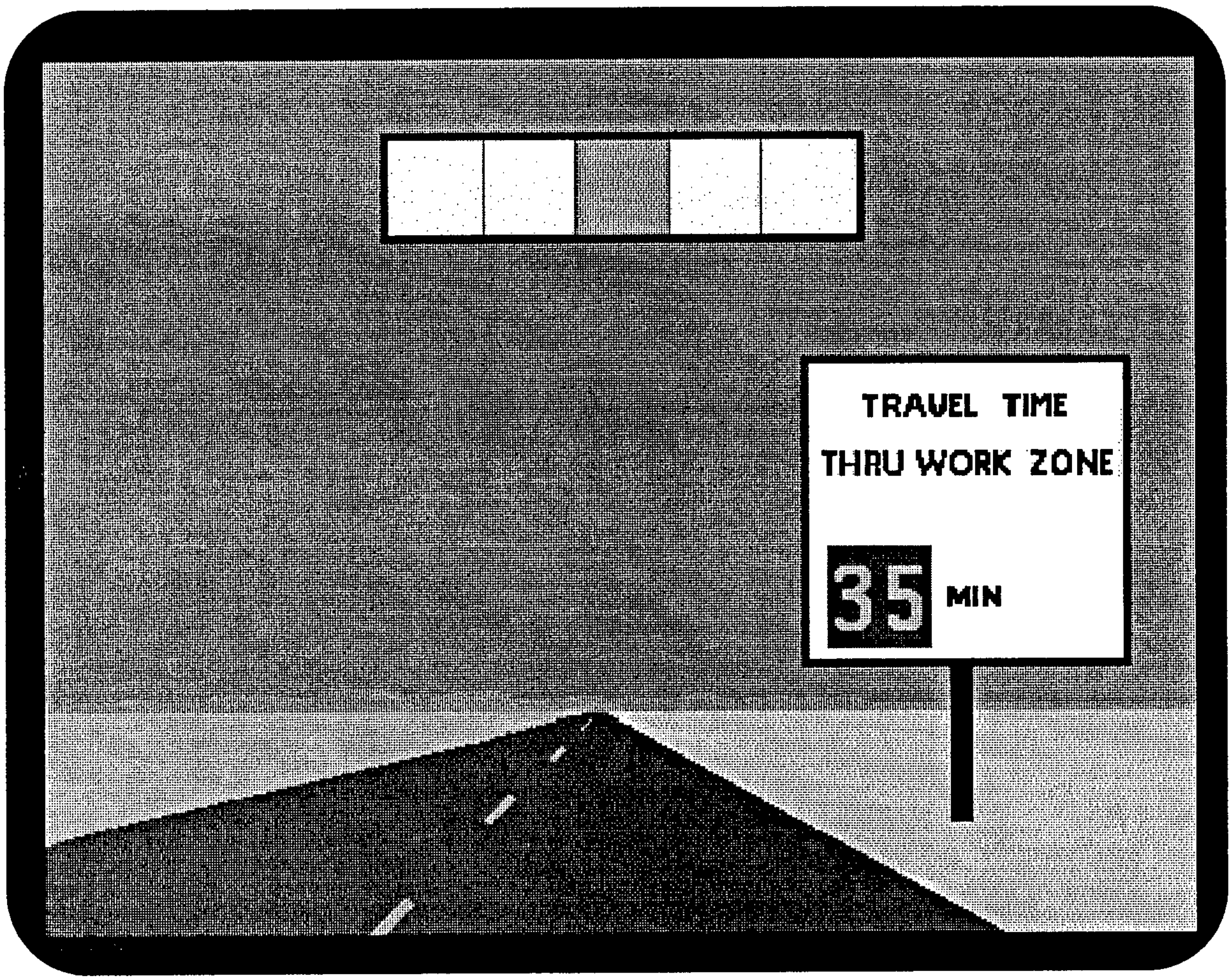
SURVEY TEST OF MEANING AND SIMULATION TEST OF USABILITY

Final Report



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VARIABLE MESSAGE SIGNAGE CONTENT:
SURVEY TEST OF MEANING AND SIMULATION TEST OF USABILITY

Final Report

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Developing the capability to evaluate variable (changeable) message signs in virtual environments was made possible only through the collaboration and personal efforts of many individuals. All of the project personnel listed below contributed to this research as well as key members of the Intelligent Work Zone Partnership (3M Company, Minnesota Department of Transportation, and the University of Minnesota). P.A. Hancock and S.T. Chrysler wrote the original proposals to the Center for Transportation Studies, that eventually led to funding for this project, and they helped design the survey study. M. Vercruyssen was the principal investigator for the reported research. R. Newell, D. May, S. Garber, and P. Siegfried from 3M provided initial concepts for developing the sign content first employed in pilot testing. J. Wright from Minnesota Guidestar and M. Nookala, G. Thompson, and D. Pickett from Mn/DOT encouraged early development of this project and provided suggestions for the number of characters restriction placed on the prototypes tested in this research. W. Knecht provided important perception and optical flow information to this research. A. Briggs, the initial research assistant on this project, conducted data collection and initial analyses of the survey study. G. Williams did final analyses and preliminary writing on the survey study and constructed the VMSs for the simulation study. D. Wagner, the student project director, conducted the literature review, data collection and analyses for the simulation experiment, and assisted in the development of this technical report. Mark Coyle provided computer programming for the simulation experiment. O. Olofinboba was technical coordinator and chief engineer for the simulation experiment. J. Duley assisted in survey data collection. R. Stephens advised equipment construction of the signs used in the virtual environment. Materials and supplies were provided by Psy-Med Associates in support of the project and personnel. This research is also reported in Wagner, Vercruyssen, and Hancock (in press).

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ABSTRACT

Successful communication with motorists concerning the presence and constraints of the roadway ahead is critical for improving safety and traffic flow in work zones. The content of messages presented on static and variable message signs (VMSs) is especially important given that drivers must detect, comprehend, and translate signage information while being preoccupied to some degree with the task of driving their vehicle.

A **survey study** was conducted as a preliminary investigation into the information content of VMSs and other real time motorist information displays used in road work zones. Four VMSs were used in the survey. The subject pool consisted of 75 volunteers (approximate mean age= 45 years) who stopped at a rest area on Interstate 35W (Northbound) just South of Rush City, Minnesota. Two questions were asked about each sign concerning meaning and delay of journey. Results showed that drivers could understand the content of a message, but could not always predict the consequences of the information. Variations of three signs from this study were adapted for use in the simulation experiment.

A **simulation experiment** was conducted to test a prototype dual-task system and to assess the effect of message type, display type, content, and repeated exposure to the signs on message comprehension and translation. A total of 20 participants (mean age = 25 yrs) viewed a computer simulation of a section of road leading up to a work zone site that had VMSs along the road side. Signs were of two message types (speed vs. time signs), three display types (two inexpensive, one with full text wrap-around and one with partial wrap-around, and one expensive matrix of three lines by eight characters flashed twice), two similar message versions, and a complete repeat for reliability in a 2x3x2x2 repeated measures design. The primary task required attending to a grid line in the rearview mirror and remembering which signal had appeared. The concurrent, secondary task was reading the message content of VMSs that were optically expanding at a rate comparable to traveling at 70 mph (111 kph). Questions regarding the grid line signal and sign comprehension and interpretation followed. The results demonstrated the ability of this methodology to evaluate VMS content and to identify useful phrases. Message type significantly affected comprehension of sign content and translation of the consequences of the information conveyed but display type did not influence responses to time or speed signs. This suggests a potential for substantial savings from the increased use of inexpensive displays instead of full-matrix units. Future research should involve assessment of the validity of computer simulation in addition to testing behavioral responses to message content either with a follow up or on-road and/or driving simulation experiment.

EXECUTIVE SUMMARY

The goal of this research was to develop a methodology for evaluating proposed information to be displayed on variable (changeable) message signs (VMSs) in work (construction) zones. Two activities were undertaken: a survey study and a driving simulation experiment.

Survey Study. Four realistic signs were included in a survey of drivers to determine their ability to understand and translate the consequences of sample signage contents. The subject pool consisted of 75 willing participants who voluntarily stopped at a rest area on I-35W (northbound) south of Rush City, MN. Two questions were asked about each sign: one about meaning and one about the effect the signage information would have on journey time. It was found that drivers may understand the content of a message, but that does not necessarily mean they can predict the consequences of the information, and vice versa. The survey provided valuable information and highlighted issues for sign content testing prior to display.

Simulation Experiment. To assess the correctness of interpretation of meaning and comprehension of the consequences of the information on VMSs, 20 participants viewed a computer simulation of a stretch of highway leading up to a work zone site. This simulation produced optically expanding static signs and variable message signs of various display types. Two tasks were performed simultaneiously: The primary task required attending to a grid in the rearview mirror and remembering which signal had appeared on it. The secondary task involved answering questions about the message content of variable message signs that expressed time or speed related information. The type of message displayed significantly affected the accuracy of interpretation of speed signs and the comprehension of consequences for the time signs. For speed signs, even those that shared a common meaning resulted in different interpretations. The type of VMS display did not appear to influence responses for either time or speed signs. The dual-task procedure developed in this research showed promise for identifying appropriate VMS content in an efficient and cost effective manner.

INTRODUCTION

Traditional highway signage is relatively consistent and unchanging over time. The message is displayed in such a fashion that passing drivers are able to comprehend content and act appropriately. Unfortunately, the driving environment is not static and changes can take place over several temporal ranges -- years, months, days, and even momentary. Traditional, static signage is able to cope with some of the former ranges but cannot deal with the daily or hourly changes in conditions. This situation is insufficiently flexible for future highways as envisaged by intelligent transport systems (ITS). In response to these concerns, a number of different strategies have been proposed for more dynamic information presentation. These include in-vehicle information services. However, one problem with such innovations is, what happens to drivers not equipped with such capabilities? An intermediary proposition is to develop driver information signs that can vary their content in real time in response to local conditions and changes. These are variously known as changeable message signs (CMSs) or variable message signs (VMSs). Nowhere is such capability needed more than in work zones where operational conditions frequently change on a daily basis and can even alter according to momentary requirements.

Highway work zone-related fatalities in the United States increased from 489 to 782 (60%) between 1982 and 1989 (Merwin, 1991). In Minnesota, long winters mean less time than most states for road construction and repair. Moreover, it is during the summer months that more people travel the state's highways. When demands of the traveling public approach the demands of road construction, the competition for transit access makes safety a primary concern, both safety of the construction workers and safety of motorists. In the past five years there have been approximately 14,000 reported work zone accidents in Minnesota and these have resulted in more than 6,000 injuries and some 60 fatalities -- in 1994, one worker and 12 motorists died in work zone accidents (Denn, 1995, p. 2). In short, work zones can be dangerous places. While many issues must be considered for improving safety in work zones, successful communication of traffic signs with motorists is critical. For this reason, in recent years, there has been a rapid development of advanced traffic management systems, in particular programmable and fixed-bar VMSs. In order to maximize the effectiveness of these signs in modifying drivers' behavior, optimal message content and wording must be identified. Given the limited length and duration of most displays, including signage and in-vehicle equipment, messages must nearly always be abbreviated or truncated. While the designers of these messages understand their notation, the messages are not always understood as intended by drivers.

The Minnesota Department of Transportation (Mn/DOT) has made a major investment in VMS hardware and software systems. All too often, message design is based not on human factors or text comprehension principles, but solely on the programmer's opinion of what should work. Variable message signs can be used to provide pertinent real-time information. However, the choice of message should be empirically demonstrated as appropriate, given that drivers must detect, comprehend, and translate signage information while being occupied to some degree with the primary task of controlling the vehicle. The goal of the present research was to develop a dual-task methodology that could manipulate difficulty levels of the primary task (driving) in order to assess the appropriateness of VMS content, especially for those signs used in work zones, and to initiate development of procedures for recommending messages that effectively communicate the intended information. This project gathered information about VMS detection and comprehension from three sources: a review of literature, a road sign survey study, and a driving simulator experiment.

REVIEW OF LITERATURE

With the help of librarians at the Minnesota Department of Transportation (MNDOT), many references were acquired by word searches using computer data bases including: Transportation Research Information Service, Pals (Minnesota State University System), Engineering Index, National Technical Information Service. Search key words included: variable (changeable) message, human factors; speed (velocity) and advisory (warning). Still other citations were obtained via cross-referencing of obtained articles and recommendations from various research colleagues. The most current information was obtained from proceedings of recent ITS America Conferences and ITS World Congresses.

One possible cause of work zone related accidents is the high speeds and variability of speeds of vehicles entering the zone. Reduction in speeds and variability of speeds entering into the work zone with informative, real-time speed advisories may be one solution. Increasing the number of motorists detouring and reducing congestion through appropriate travel time information, may be another solution. The purpose of this literature review, therefore, was to obtain articles describing appropriate message content for variable message signs that could be used in work zones. While there are certain advantages to variable message sign technology (e.g., Balke & Ullman, 1992) and attention has been paid to evaluation of variable message sign systems (e.g., Cooper, Sawyer, & Rutley, 1992; Fournier et al., 1992; Sawyer, 1990), most research has not typically focused on systematic manipulation of verbiage found on VMSs. The following is a brief summary of general, relevant research on traffic signage (see Wagner, Vercruyssen, & Hancock, in press, for additional information).

Work Zone Traffic Signs in General. Paniati (1989) evaluated sign symbols used in work zones for viewer preference, legibility, and comprehension. Odgen, Womack, and Mounce (1990) provided motorists with a questionnaire that assessed comprehension and opinion of typical static signs implemented in work zones. Benekohal and Wang (1993) studied speed distributions in the highway work zone.

Speed Advisory Information. Lane and Pfau (1975) used speed advisories in reduced visibility with variable message advisories without reference to verbiage. Sheppard (1993) looked at the timing and spacing of signals in a real-time speed advisory system. Benekohal (1992) addressed speed reduction techniques including drone radar, strobe lights, police presence and placement of variable message signs with respect to work zones. Rutley, Hodge, and Lines (1983) studied speed advisories on VMSs in a motorway system in Great Britain using combined numerical and pictorial information.

Travel Time Information. Stamatiadis and Taylor (1993) assessed the efficiency of a recursive adaptive algorithm in predicting travel times. Ullman, Dudek, and Balke (1994) surveyed diversion decisions of motorists to corridor attribute messages such as time saved. Wenger, Spyridakis, Haselkorn, Barfield, and Conquest (1990) were concerned with reduction of congestion and thus systematically varied the semantic and syntactic information on VMSs that provided information about cause of congestion and alternative routes.

International Projects Implementing VMSs. The use of real time motorist information VMSs increased dramatically in the 1970s in France, Germany, Italy, Japan, the Netherlands, the United Kingdom, and the United States. Typical ergonomics problems to be addressed included: "What type of information do drivers need? What are the best ways to present the information? Where should the information be located? What are the best ways to present the information?" (see Dudek, 1979; cited in Dewar, 1989, p. 75).

Papageorgiou, Gower, Messmer, and Morin (1994) looked at control strategies for management of VMSs. Bonsall (1994) used a route choice computer simulation to study response to VMS message content as part of the QUO VADIS project in the UK. Cummings and Fournier (1994) provided a general review of the use of VMSs throughout Europe and evaluations of various systems that have been implemented. Lauer and McDonald (1994) summarized research on urban traffic management that used VMSs as part of the European DRIVE project. METACOR is a mathematical model used for simulating traffic flow that will eventually be used for testing VMSs control (Haj salem et al., 1994). Tarry, Jensen, and MacKenzie (1994) discussed evaluation strategies used to assess VMS systems as part of the European QUO VADIS project. Bolelli, Tognoni, and Cominetti (1994) addressed the issue of conflicting information among VMS systems and other traffic management systems in Italy. Caubet, Pejoan, Adham, and Nicolas (1994) presented concerns of message type, structure and vocabulary found on VMSs in France.

Important Lessons. Dr. Brien Benson (head of a cooperative effort of the Institute of Public Policy at George Mason University, Center for Transportation Research, and the ITS Research Center of Excellence (RCE) at Virginia Polytechnic Institute and State University) has been conducting research on "Assessment of Motorist Attitudes Towards Variable Message Sign Content in Northern Virginia" to determine how well VMSs communicate relevant traffic information to motorists via measures of public perception of VMSs. Preliminary reports from this project examine the content of VMSs giving friendly reminders of "Drive Safely" to more practical warnings like "Congestion Ahead" or "Accident Ahead." Focus groups articulated that VMS messages are often inaccurate, especially when announcing that congestion exists where it does not and vice versa. Often inaccurate traffic information, like displaying the incorrect current date or time, result from not updating VMS content often enough. Displaying incorrect information seriously compromises public confidence in and attention to VMSs. Benson makes two suggestions -- (1) display a phone number for reporting inaccurate VMS messages and (2) show the time when currently displayed traffic information was first posted -- and advocates the use of public opinion to form the most practical solutions for improving the efficiency of traffic management systems (Staff writers, 1995). Other issues being investigated include the location of VMSs, uses of VMSs for other than traffic information and control, alternative sources of information other than VMSs, and the public's willingness to pay for traffic information.

Dewar (1989) wrote a classic review on traffic signs that addressed 10 topics: (1) introduction (philosophy and implementation and classification of traffic signs), (2) criteria for traffic sign design, (3) road user factors (age, eye movements, attention and overload, learning and memory, and stimulus-response compatibility), (4) sign design factors (word message content, codes, and symbols), (5) changeable message signs and real time motorist information, (6) environmental factors (illumination, weather, sign placement and conspicuity, and roadway geometry), (7) problems with traffic signs (compliance with traffic signs), (8) evaluating traffic signs, (9) relationship with other traffic control devices, and (10) future research needs.

Dudek (1979) wrote a classic review on changeable message signs to manage traffic in conditions of recurring problems (e.g., peak period congestion), non-recurring problems (e.g., accidents, construction), environmental problems (e.g., fog, ice), and special operational problems (e.g., tunnels, drawbridges, contraflow lanes).

The choice of words used in the message is important. For instance, a message for heavy traffic density could include terms like "very congested," "traffic jam," "extra delay," "stop-and-go traffic," or vague terms like "heavy traffic," "delay," or "congested," that should be avoided (Dudek, 1979). It is important for traffic engineers (and everyone involved in the traffic management system) to understand public perception of messages displayed. For example, Dudek et al. (1978) determined that the public interprets "major accident" as being at least a 20-minute delay and "minor accident" as being not more than a 15-minute delay. Travel times must be reasonably accurate or not used. Information on time saved by taking an alternative route seems to be no more effective than time delay information (Dewar, 1989). Also, to avoid confusion for drivers traveling across many regions, phrasing should be standardized (e.g., avoid using local names or sponsor names for highways instead of their state or federal identification; consistently use only one of the ring-road terms like beltways, bypasses, loops, or circles; use consistently one term for the parallel business roads called service roads, access roads, frontage roads, and feeder streets.

Message length on VMSs should be limited to the information capabilities of the drivers. Dudek (1979) has suggested an eight-word message, with no more than four elements (e.g., "accident ahead, 4 km, avoid delay, use route 14"). Allow one second per short word and two seconds per unit of information, whichever is longer, and limit text to two lines of not more than 20 characters (Dudek et al., 1978). Drivers prefer information on location and length of congestion (e.g., "heavy congestion next 5 km") and do not find useful information about travel time or delay time (e.g., Dudek, Messer, & Jones, 1971; Heatherington, Worrall, & Hoff, 1970).

Dual-task Method (i.e., driving and sign reading). Some examples of secondary tasks that have been implemented in studies of driving behavior are reading and repeating random digits located on a dashboard display (Wierwille, Gutmann, Hicks, & Muto, 1977; Wierwille & Gutmann, 1978), detecting changes in consecutive 8-digit numbers (Brown, 1962), detecting an odd-even-odd sequence in an audibly-presented succession of numbers (Brown, 1965), and listening to 10 letters and remembering which letter was repeated twice (Brown, 1965). Divided attention issues in driving have been well documented by Ivan Brown (e.g., Brown, 1962, 1965, 1978; Brown & Poulton, 1961; Brown, Simmonds, & Tickner, 1967; Brown, Tickner, & Simmonds, 1966), Walter Wierwille (e.g., Hicks & Wierwille, 1979; Wierwille & Gutmann, 1978; Wierwille & Williges, 1980; Wierwille, Gutmann, Hicks, & Muto, 1977) and others (e.g., Damos, 1991; Farber & Gallagher, 1972; Hancock, Wulf, Thom, & Fassnacht, 1990; Kahneman, Ben-Ishai, & Lotan, 1973; Schlegel, 1993; Wildervanck, Mulder, & Michon, 1978).

ROAD SIGN SURVEY

Drivers are bombarded with excessive information from road signs in the environment, including both traffic control devices and, to a greater extent, advertising signs. To avoid information overload, drivers selectively attend to a small amount of relevant information around them and selectively ignore a great deal of information considered to be irrelevant. Unfortunately, messages on many important traffic control signs are partially or completely missed. The purpose of this study was to investigate road sign comprehension and preferences by the driving public. It was hoped that the survey results would show that most drivers interpret at least one of the signs with the same meaning and that the drivers would consistently rank the signs according to usefulness of information.

Survey Method

Survey Participants

The participants were volunteers recruited at the rest area on Interstate 35W northbound, just south of Rush City. Participants were asked to participate in a study that aimed to help design better road signs. The sample consisted of 75 volunteers: 49 males, and 26 females. Age ranged from 16 to 66+ years, with 73.3% of the sample being aged between 25 and 65 years. Summary details about the participants is shown in Table 1. The majority of the respondents were Minnesota residents.

Before the interviewer proceeded with the survey the participant was required to sign a consent form (Appendix A). The volunteers that completed the survey were offered a Minnesota road map as a reward.

Table 1. Summary of Participant and Vehicle Demographics.

	Frequency	*Percent*
Age		
16-25 years	**10**	**13.3**
25-45 years	**31**	**41.3**
46-65 years	**24**	**32**
66- older	**10**	**13.3**
Total	**75**	**100**
Sex		
Male	**49**	**65.3**
Female	**26**	**34.7**
Total	**75**	**100**
Vehicle		
Unknown	**2**	**2.7**
Passenger Car	**45**	**60**
Van	**12**	**16**
Heavy Commercial	**1**	**1.3**
Light Truck	**12**	**16**
RV	**2**	**2.7**
Bus	**0**	**0**
Motorcycle	**1**	**1.3**
Total	**75**	**100**

Apparatus

The survey packet. Each interviewer was provided with a packet that contained the following:

1. Brief driver profiles.
2. Set of signs prepared in a counterbalanced order across interviewer.
3. The list of questions to be asked about each road sign.
4. A list of potential answers to the question.

The sign packets. Each volunteer was given a packet of signs. Preceding each electronic message sign a sheet presenting two static diamond signs was given (see Appendix B). The diamond shape static signs presented the following information:

ROAD CONSTRUCTION AHEAD
ROAD CONSTRUCTION 10 MILES

The electronic signs were presented on rectangles, rendered on 8.5 x 11 inch sheets of paper (see Appendix B). The road signs presented the following messages:

Sign 1 CURRENT DELAY / 20 MINUTES
Sign 2 CURRENT BACKUP / 1 MILE
Sign 3 CURRENT TRAVEL TIME / THROUGH CONSTRUCTION / 50 MINUTES
Sign 4 CURRENT SPEED / 30 MPH

Survey Procedure

The survey was conducted during a Friday afternoon in August, 1993. Experimenters from the Human Factors Research Laboratory, 3M Company, and the Minnesota Department of Transportation asked drivers to interpret examples of four variable message signs. The survey was administered at a rest area on Interstate 35W northbound, just south of Rush City, MN, and the content of the messages referred to the possibility of a road construction zone occurring ahead.

Drivers were informed by the interviewers that the signs were electronic, or changing signs, but a real-time aspect was not intentionally stressed. Drivers were asked the same question about each of the signs, "What does this sign mean to you?". The final question asked the drivers, "Which of the four signs do you think gives the most useful information?" It was expected that the results from the survey would show that drivers all interpret at least one of the signs with the same meaning, and that the drivers show a preference to one of the signs as providing the most useful information.

Participants were initially asked a few questions in order to complete the driver profile. This profile included gender; age; where the participant lived; and the type of vehicle s/he was driving. Responses to these questions were optional.

Each participant was handed a packet of signs. Instructions were given by the interviewer for the participant to turn the page to the first electronic sign. The interviewer asked an open ended question: "What does this sign mean to you?" The interviewer had been provided with a list of nine possible answers that had been generated by researchers prior to the survey. The list of answers was not exhaustive but provided the interviewers with a guide to the possible answers that could be received. The list also indicated if a follow up question should be posed in order to elicit further meaning from the response. Interviewers recorded the responses of the drivers to the questions by taking written notes. The interviewer then posed a second question, "How will the construction affect the arrival time at your destination?" This was an optional question, such that if the participant did not have an opinion they were not forced to give an answer. After the second question participants were asked to turn the page to the next set of static signs and electronic signs and the questions were asked again. This procedure continued until the participant had commented on all four electronic signs. The participant was then presented with a sheet showing all the electronic signs, and asked the following questions, "If there were a traffic problem, which sign provides you with the most useful information? and Why?" After completion of this question the participant was thanked by the interviewer and given a Minnesota road map.

Treatment of Data

Initially the responses to the first question were coded according to the original list of nine predicted responses. It became obvious that this list did not contain all the responses given, and therefore a second list of coded responses was constructed. This list contained 18 possible responses (Appendix C). Each response to the first question was coded according to the second list.

Survey Results

Answers to questions in the survey are presented in the order they were asked. The survey is presented in Appendix D.

What does this sign mean to you?

A summary of responses to question one is shown in Table 2.

Table 2. Summary of Responses to the Question: "What does this sign mean to you?"

	Number of different responses	Number of answers that received 10% or more of the responses	Answer that received highest number of responses
Sign 1	16	3	25% It will take me x minutes to reach the end of the construction
Sign 2	13	4	21% Traffic will be stopped for x miles
Sign 3	12	2	69% It will take me x minutes to reach the end of the construction
Sign 4	10	2	61% The speed limit throughout the construction zone is x mph.

Sign 1 and sign 2 (Current delay, and Current backup, respectively) received the largest number of different responses, 16 and 13 respectively. Three or more of the answers received over 10% of the responses suggesting that there was low consensus in explaining what these two signs meant. The opposite was true for sign 3 and sign 4 (Current travel time, and Current traffic speed). Sign 3 received 69% of the responses for one particular answer and sign 4 received 61%. Sign 3 received 12 different responses and sign 4 received 10. For these two signs fewer of the answers received more than 10% of the responses, which is a consequence of receiving such high consistency for one answer. Figure 1 illustrates the responses for the three most popular answers for each of the signs which further shows how sign 3 and sign 4 gathered a large number of responses for one answer, unlike sign 1 and sign 2, thus a certain level of consistency in meaning among respondents.

How will the construction affect the arrival time at your destination?

The interviewer asked a question inquiring as to how the construction would affect the participant's arrival time at their destination. A response was not always gained to this question, in some instances a reply such as, the arrival time was unimportant because as the respondent was on vacation, prevented a more numerical answer being acquired. Those that responded with a time value have been analyzed, while those that responded with "late" or something similar have been ignored. Table 3 contains a summary of results for this question.

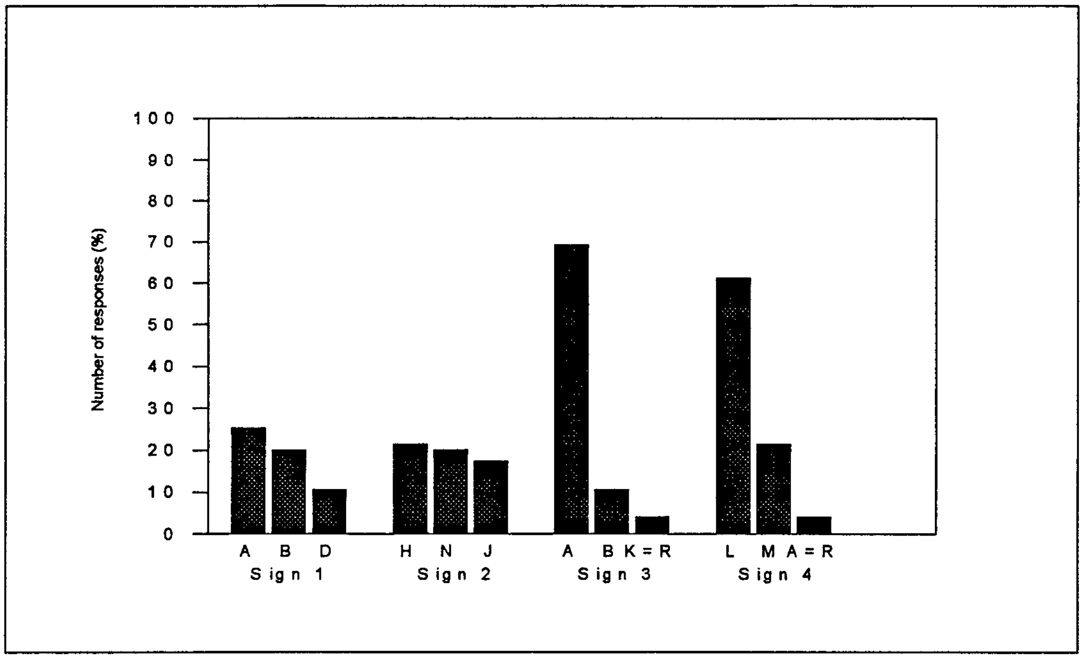

Figure 1. The most popular responses to the question: What does this sign mean to you? Response codes are defined in Appendix C. For instance, Code A is "It will take me ____ minutes to reach the end of the construction." Code L is "The speed limit through the construction zone is ____ mph.

Table 3. Summary of Responses to the Question: "How will the construction affect the arrival time at your destination?"

	Number of respondents out of 75	Mean time affecting travel time	sd	Number of respondents that were +/- 5 minutes of mean of affected travel time
Sign 1	54	20.8	9.51	43
Sign 2	21	28.2	17.56	6
Sign 3	45	47	17.39	15
Sign 4	39	27.3	19.22	5

Sign 1 achieved the greatest response to this question by receiving 54 out of a possible 75 responses. Sign 3 and sign 4 both received more than a 50% response rate, while sign 2 received less than a third. The affect on travel time estimations for sign 1 and sign 3 reflects the times that were presented on the signs, i.e., 20 minutes and 50 minutes, by producing means of 20.8 (sd =9.5) and 47 (sd=17.4), respectively. The actual mean values cannot be compared across signs as it was not the intent of the signs to convey the same information, however a measure of consistency has been crudely achieved by considering consistency to be a participants estimate being within five minutes of the mean time. The level of consistency achieved for each sign is illustrated in Figure 2. Sign 1 provides high consistency with 79.6% of the participant's estimating an affected travel time within five minutes of 20.8 minutes. Sign 2 has the second highest consistency, with 33.3%. The ratio of five minutes to the mean time for sign 2 is greater than for sign 1 and may be responsible for some of the difference in the consistency between the two signs, however as the consistency for sign 1 is more than twice that for sign 2 it is assumed that sign 1 provides greater consistency.

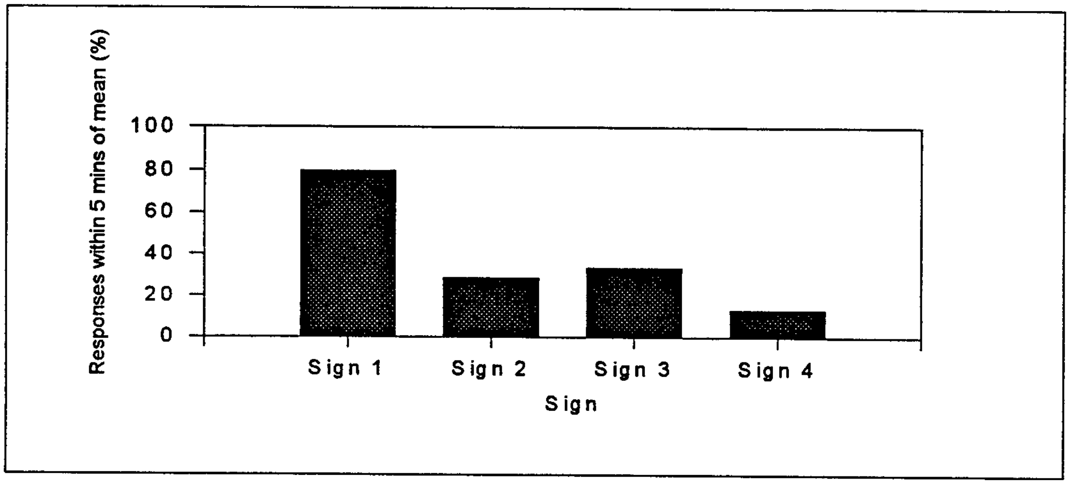

Figure 2. Consistency achieved among participants in estimating the effect of construction on travel time. A consistent response was one where the participant estimated the time within five minutes of the calculated mean across all the respondents estimates.

Figure 3 illustrates the responses achieved from both the questions. The meaning of the signs presents the percentage of respondents that chose the most popular answer for question one, and is therefore based on a sample of 75. The estimated travel time values are representative for those participants that responded to the second question. The trend suggests that drivers may be able to verbalize what they think a sign means, but may not be able to interpret the consequences of it, and vice versa. This is apparent for sign 3 and sign 4, which achieve a high level of consistency for understanding the meaning of the sign, but low for estimating travel time affects, whereas sign 1 has the opposite results. Within participant, or internal consistency, therefore, further supports this trend. For the sign that read CURRENT DELAY 20 MINUTES, approximately 50% of the responses were ambiguous or meaningless and, consequently, could not be scored. Of the half that could be analyzed approximately 50% responses were consistent with initial interpretation of the message on the sign and 50% were not. For the sign that read TRAVEL TIME THROUGH CONSTRUCTION 50 MINUTES, approximately 45% of the responses were ambiguous or meaningless and could not be scored either. Of the responses that could be analyzed approximately 35% responses were consistent with initial interpretation and 65% were not.

While TRAVEL TIME THROUGH CONSTRUCTION was least ambiguous and most preferred, participants, by and large, were not very effective at extrapolating the information to answer the valid, follow-up question. In a more natural setting the answer to that question would be integral to making a route diversion decision. The results for CURRENT DELAY 20 MINUTES, that ranked third for sign usefulness, were more consistent with the variability found in its interpretation.

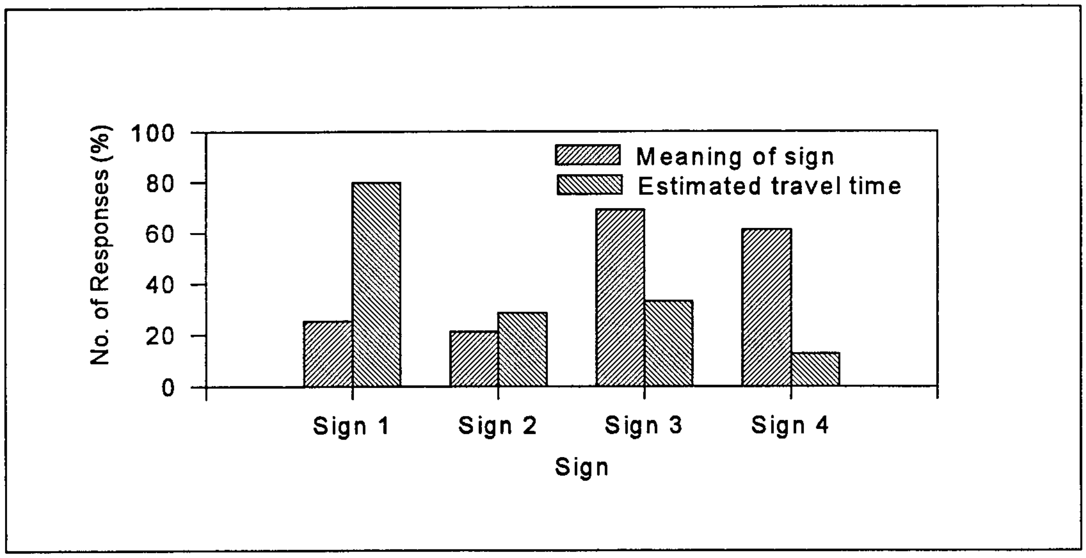

Figure 3. Consistency of sign meaning and estimate of travel time for each sign.

If there were a traffic problem, which sign provides you with the most useful information?

The final question asked which sign was preferred. The most popular answer was sign 3 (48.5 %). Signs 1 and 4 produced similar results, 21.9 % and 22.6 % respectively. Sign 2 received the same number of votes as the no preference option, two votes (2.66%).

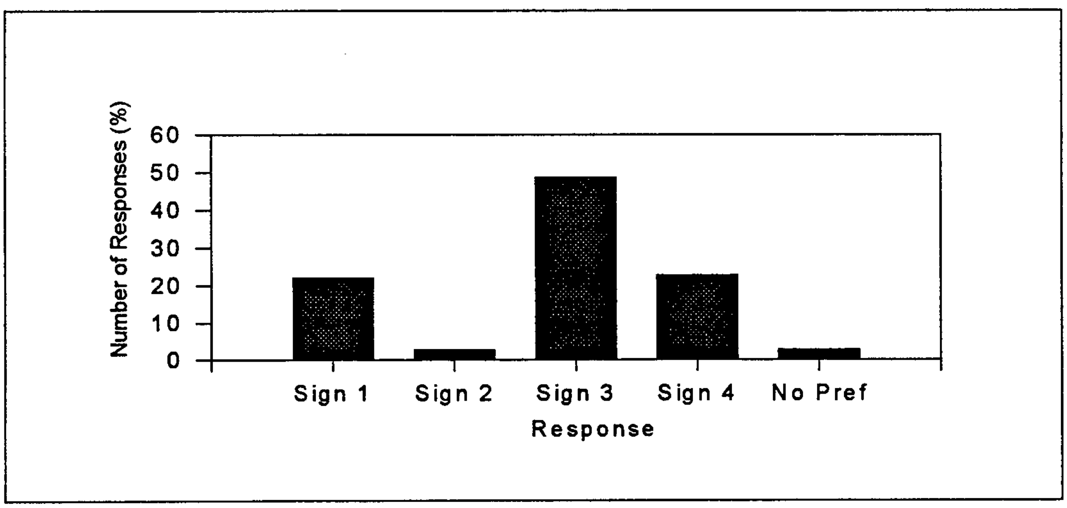

Figure 4. Selection of the sign displaying the most useful information.

Survey Discussion

The information that a driver gathers from VMSs may initially appear obvious and easily interpretable, but this assumption is not always correct. This survey set out as a pilot study to gather information about the interpretability of VMSs in road construction zones by the driving public. The aim was not to determine whether one specific sign was superior to another, but what type of information was interpreted consistently by the driving public. The questions posed have provided information about two types of consistency: consistency in the meaning of the message and consistency in the interpretation of the consequence of the sign.

Answers from question 1 suggest that the more explicit the information is, the easier it is to gain a consistent interpretation of the meaning. The sign that produced the most consistent interpretation was sign 3 - Current travel time through construction 50 minutes - this was interpreted as, "It will take me x minutes to reach the end of the construction." Incidentally this sign also contained the most words in its presentation. This fact was actually commented on by some of the drivers when deciding which road sign they most preferred. While sign 3 was a clear winner of the question "What does this sign mean to you?," it was a runner up for the consistency in travel time question. Only 33.3 % of the responses were within 5 minutes of the mean estimated time.

The interpretation of sign 1 (Current Delay 20 minutes) produced low consistency in response to question 1. Only 25% of the responses interpreted it in the same way: It will take me x minutes to reach the end of the construction zone. This finding is inconsistent with Dudek (1992) who reports that drivers typically interpret delay in minutes to mean relative to their normal travel time, i.e., it will take x minutes longer than usual. However, in contrast to the mixed interpretations for meaning, when drivers were asked how their journey time would be affected, sign 1 produced the most number of responses from the drivers. A total of 50 out of 75 drivers provided an answer to this question, within the responses a consistency of 79.6% was achieved. To a traffic engineer the term delay refers to the amount of time traffic is stopped before it can move again, thus a delay of twenty minutes could in fact lead to a lengthening of travel time by much more than twenty minutes. This finding strongly suggests that drivers interpret "delay" differently from traffic engineers as nearly 80% of the responses were between 15 and 25 minutes. If the term delay was used as the driving public interpret it to be, then from the results of this survey the word should be used when a conveyance of additional travel time information is required. It would be useful to clear up the discrepancy in the meaning of this word for use in traffic signs. If it could be agreed upon to be the provider of travel time information then it could convey the meaning that sign 3 does in a fewer number of words and consequently require less distraction from the task of driving. If the word, "delay," is to be used a decision must be made to educate the public about the meaning of road signs or the traffic engineers must alter their understanding of the word to conform with that of the public.

Information provided by the sign "Current travel speed 30 mph" achieved good consistency in defining the meaning of the sign. Some 61 % of the participants interpreted the sign to mean: The speed LIMIT through the construction zone is x mph. It was not the intent of the sign to provide regulatory information only advisory, however it was interpreted as such. This highlights the fact that whilst sign 4 did achieve a degree of consistency in its meaningfulness, the meaningful interpretation by the drivers was different from the intended one. When participants were asked to explain how this would affect travel time to the final destination only 39 provided a response, and the consistency for the responses was weak. only 12.8.% (5 drivers of the 39 that had responded) of the drivers provided a response that was within 5 minutes of the mean estimated time. The resultant effect of sign 4 suggests it may contribute to eliciting a certain driving behavior in the construction zone ,i.e. , a speed limit of 30 mph, but it provides little knowledge for a driver to estimate how his/her journey time is to be affected.

The least favored sign was, Current backup 1 mile. This sign may have had problems in a consensus being formed as it was dependent upon a participant understanding the term backup. The information presented provides no information as to where the backup starts and stops in the construction zone. The message provides no details as to how this occurrence is going to affect the travelers journey -- it is a statement of a fact. The second question, related to the consequence of a '1 mile backup' on journey time, produced low results: only 21 participants hazarded a guess at interpreting the message.

It needs to be determined who is being served by the sign: the transportation engineers who want to achieve a certain driving behavior in the zone, or drivers for determining how they might deal with traffic situations, whether it be to wait patiently in a line of traffic, or to attempt an alternate route. It is possible to provide each type of information, but the degree of consistent success is dependent upon a number of factors that have become apparent from the results of this survey.

The number of words used in a sign could influence the consistency of understanding. In this survey drivers were under no time constraints to complete the questions. For example, Sign 3 contains seven words which were read at the participant's leisure. In a real driving situation the driver will be traveling at high speed past the sign. A tradeoff between the number of words to provide a consistent understanding and the number of words that can be comprehended in the time taken to drive past the sign might need consideration.

Messages were not constructed to provide participants with regulatory information yet it apparently was achieved. The sign that included a speed value managed to convey in its information that it was a speed limit. It could be questioned as to whether the drivers interpreted the whole sign when expressing its meaning, or focused on the speed, therefore ignoring the component that showed "traffic speed through construction ..." In most driving environments a speed usually refers to a speed limit and is presented in isolation on a speed sign, in this instance it was portrayed with other information that appears to have been ignored. The power of stereotyped behavior and expectations may have been the cause of this result.

When asked a question about journey time, participants seemed to seek a time value in the message sign, hence the high number of responses to that question for sign 1 and sign 3. Consistency for these responses could be attributed to a misinterpretation of the presented information. The interpretation for the 'delay' sign needs to be investigated, currently the likelihood of a 20 minute delay sign expressing an extended travel time of 20 minutes is very slim, yet this is the expectation of the driving public regardless of what they say the word delay means.

The survey was completed as a preliminary study into drivers' interpretation of variable message signs in road construction zone environments. The results have shown that there is little consensus from the driving population between the meaningful interpretation of a sign and the consequence of the information it is providing on the drivers' journey. Further research is required to identify what type of traffic information can be presented on variable message signs to achieve a consensus in meaningful interpretation.

SIMULATION EXPERIMENT

Introduction

The dramatic increase in highway work zone-related fatalities in recent years (Merwin, 1991) is a serious concern requiring immediate attention. While many issues must be considered for improving safety in work zones, successful communication of traffic signs with motorist is critical. In response to such needs, a variety of traffic management systems have been design and implemented in the United States and in Europe. In the United States, for example, Information for Motorists (INFORM) has been created to improve throughput along a highway corridor in New York. Variable (changeable) Message Signs (VMSs) provide traffic congestion and transit delay information that allow drivers to make appropriate route diversions and other navigational decisions (Smith, 1992). This signage system is also capable of delivering congestion warnings and speed advisories (Bolte, 1984). In Germany the Aichelberg Congestion Warning System was designed to optimize flow of traffic and reduce the number of rear-end collisions. Regardless of the type of traffic management systems, certain fundamental human factors issues must be addressed (e.g., Hancock & Parasuraman, 1992)

One common element of these systems is a reliance on the technology of programmable and fixed-bar VMSs. Variable message signage is an improvement over conventional static road signs especially because of its capability of providing real-time traffic information for regulations, diversions, and traffic state descriptors for any type of road. The freedom to express more informative messages is, however, constrained by the limitations of the human information processing system and possible interpretations of sign meaning. Thus, an abundance of human factors questions must be addressed when designing the message content for VMS systems (e.g., Dudek, 1978, 1984, 1991, 1992).

Optimizing throughput of traffic in the work zone, through the implementation of VMS systems, may be a starting point in the reduction of the hazards for both the motorists and construction workers in work areas. This may be accomplished with signage that successfully reroutes traffic prior to the work zone and reduces speed and variability of traffic entering into the work zone.

Consequently, important at this time is research addressing human factors issues regarding message content of two types of signs typically implemented in the work zone. The first VMS is placed prior to the work zone and the final point of diversion. Its contents provide sufficient information for the driver to make a decision whether or not to avoid the work zone. The second VMS is typically placed before the work zone. It functions to reduce the speed and variability of traffic entering into the work zone.

Arguably when motorists approach a traffic incident, such as road construction, they are most concerned with the immediate effects on their travel time. They need to know whether diversion from the incident is most prudent. How then should this information be presented? Should time be expressed in terms of delay, added travel time, extra travel time, or total travel time? While some messages may prove ambiguous in interpretation, still others require additional mental calculations; neither of which are conducive for effective communication of information.

Travel time is problematic because it can be easily discredited and motorists must mentally calculate additional travel time (Dudek, 1992). Heathington, Worrall, and Hof (1970) studied motorist preference for traffic descriptors for levels of traffic congestion. "EXTRA DELAY-10 TO 20 MINUTES/NEXT 3 MILES" (ranked 5th) and "TRAVEL TIME 15-25 MINUTES/NEXT 3 MILES," (ranked 6th) were preferred least as descriptors for heavy congestion. Similarly, Beers (1974) found delay time ranked 4th and travel time 6th in a list of preferred traffic descriptors. It should be noted that the absolute ranking of travel time and delay in these two studies is not as important as their ranking relative to each other. These incident descriptors were outranked by information such as cause of congestion, traffic speed, or lane closure; information that most likely would be included in most intelligent work zone systems in addition to delay or travel time information. What does emerge from these two studies is a preference for delay information over travel time.

Huchingson and Dudek (1979) addressed interpretation of the sign "DELAY X MINUTES." The most popular interpretation expressed delay as extra travel time relative to normal travel time. This survey was, however, possibly biased towards the most popular interpretation. Of the five possible interpretations, the two most popular had the same meaning expressed in a slightly different manner. Thus, delay being synonymous with additional travel time was represented more often than the other interpretations. The next two most popular interpretations, delay being equivalent to total travel time, were not as similar in meaning. In addition to travel time information, each of these interpretations included traffic state information that could not be gleaned from the information provided by the sign.

Most of the literature reviewed support the use of delay information. Delay was considered unambiguous and most useful relative to travel time information. It should be noted, however, that travel time, in these contexts, referred to the total amount of time to traverse the work zone. It may prove beneficial to express travel time in terms of additional or extra time to travel through the work zone. Furthermore, due to possible survey bias, in addition to the results of the pilot survey, it still remains questionable whether delay is more or less ambiguous to motorists than travel time information.

Traffic speed signs pose a variety of human factors questions for any intelligent highway system. Should these signs be speed advisories or real-time updates of traffic speed at various points in the work zone? Once this issue has been settled, a consensus of appropriate verbiage must be achieved. Numerous articles have employed or made reference to the message content of speed advisory signs, including "Max SPEED 45 MPH" and "SLOW TO 45 MPH" (Hanscom, 1982) or "MAINTAIN 15 IN FOG" (Wagner, 1978) or "SLOW DOWN X" (Helliar-Symons & Wheeler, 1984). Yet, some advisory systems such as the Aichelberg Congestion Warning System in Germany (Bolte, 1984) and the motorway system in England (Rutley, 1992) do not include any wording on their speed advisory signs. Still others advise adding pictorial information in addition to the advised speed (Rutley, 1992). In general, however, there tends to be an unreliable response of motorists to speed advisories in work zones (Vecellio & Culpepper, 1984).

Richards, Wunderlich, Dudek, and Brackett (1985) and Richards and Dudek (1986) explored the effectiveness of four different types of speed controls in the work zone: flagging, law enforcement, variable message signs, and lane width reduction. VMSs were divided into two categories, those with wording such as "DETOUR AHEAD" or "ROAD WORK AHEAD" plus a speed advisory such as "35 MPH" or "SLOW 45 MPH" and those VMSs that contained speed advisory only. VMSs, however, produced only "modest" speed reduction at urban arterial and freeway sites. Branner (1990) manipulated the content of speed signs. Speed advisory signs that read "IT'S THE LAW, SPEED LIMIT 40 PAST CREW" in addition to "WORK ZONE SPEED LIMIT," resulted in greatest reduction of speed and variability of traffic speeds prior to the work zone. It should be noted that the speeds were still averaging 8 mph above the speed posted on the sign.

Significant speed reductions have occurred at the entrance of a work zone when a speed monitoring display, coupled with radar, displayed both the work zone speed and the speed of a given car entering the work zone (McCoy, Bonneson, & Kollbaum, 1995). Radar has also been employed to trigger a warning message on VMSs when a motorist's speed is in excess of the traffic speed of the work zone (Garber & Patel, 1995). In the present study, messages on VMSs included "HIGH SPEED SLOW DOWN," and "REDUCE

SPEED IN WORK ZONE." The first two signs proved most effective in reducing traffic speeds in a work zone.

From reviewing the literature it is apparent that more experimental manipulation of message content of both speed advisory signs and incident descriptor signs is greatly needed in addition to the design and implementation of more valid testing procedures. Answers regarding usefulness of information and interpretation of message still remain elusive. Thus while the pilot survey assessed consistency of interpretation of traffic signs, a simulation experiment is needed to assess the correctness of interpretation and comprehension of the consequences of the information on the signs. Ideal would be use of more ecologically valid environments replete with dual tasks, controlled exposure times, and simulated travel. Therefore, the purpose of this experiment was to test a prototype dual-task (divided attention) methodology and to assess the effect of message type, display type, content, and repeated exposure to VMSs on message comprehension and translation.

Simulation Experiment Method

Participants

Twenty articipants (10 males and 10 females) were recruited from a sign-up sheet in the Psychology Department at the University of Minnesota. Average age for male, female and both were 25.4, 24.6, 25.0, respectively. Average number of years driving with a license for male, female and both were 9.3, 7.3, and 8.3 respectively. All but 5 of 20 participants had either 20/20 vision or corrected approximately to 20/20 for the experiment. Participants were paid $5.00 for their time.

Task

Participants viewed a computer simulation of travel down a section of road leading up to a work zone (see Figure t). On the side of the road was a series of optically expanding static signs and VMSs. Two tasks were performed simultaneiously: monitoring activity in a rearview mirrir and remembering content on passing VMSs.

Primary Task. Presented to the driver, in the location of the in-car center rear-view mirror, was a grid line that was divided into five, adjacent, white squares (see Figure 5). Each square was either inactive, active, or active with a signal. When a square was inactive, it consisted of a single, white square. When the square was active, the white square was switched to a yellow square. When the square was active with a signal, the white square was replaced with a yellow square with a signal inside. The signal consisted of a black letter (either A, B, C, D, or E, depending on that of the five squares in the grid line was active). In order to create a Gestalt grouping effect and to add more ecological validity, a rearview mirror shaped box enclosed the grid line. This box was not significantly larger than the grid line it enclosed. A single, training trial preceded the experimental trials. For the practice trial, during the eight seconds the letters on the VMSs were visible on the opposite side of the road, one of the five squares in the grid line became either active, or active with a signal, in a random manner at a rate of one square per second (i.e., exposure time = one second; inter-activation interval =0 second). In other words, the period over that the grid line was active consisted of eight, one second intervals. During two, randomly selected intervals throughout this period, two squares were active with their respective signals (one segment per interval with random selection, without replacement, among squares A through E). The other six intervals consisted of randomly selected squares that were active with no signal (one segment per interval with random selection, with replacement, among squares A through E). For the experimental trials the overall format was the same as above with the exception that a square with a signal randomly occurred only once during one the first six intervals. The other seven intervals, including the last two intervals, had randomly selected squares that were active with no signal (one segment per interval with random selection, with replacement, among squares A through E). It should be noted that the random number generator used for both practice and experimental trials generated pseudo-random numbers employing linear congruential 48 bit integer arithmetic. Following activation of the grid line, participants were asked which signal or signals appeared on the grid line. They had six possible choices (one of which never occurred and thus acted as an additional complication) and filled their answers out on multiple choice answer sheet, later to be read by an optical character reader.

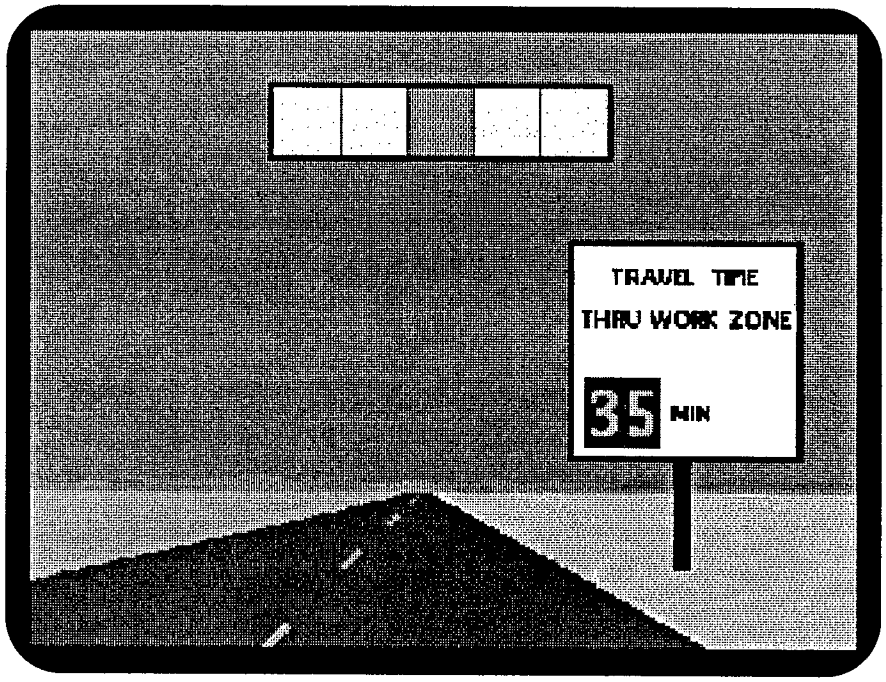

Figure 5. Sample of optically expanding (111kph/70 mph) hybrid variable message sign on right of roadway with rear-view mirror grid line primary task.

Secondary Task. A Silicon Graphics IRIS-class mini-computer and a 50 cm (20-inch) SVGA monitor were used to simulate travel along a section of road leading up to, but not including, a work zone (frame speed $\geq$ 20 frames/second). Static and variable message signs, that occupied the right side of the road, were produced on Designer's Workbench. This allowed continuous expansion of the visual angle of the sign to be correlated with simulated forward movement. A display time of eight seconds was chosen as a maximum readability time for the VMSs, since the average VMS used by the Minnesota Department of Transportation (MNDOT) has 40 cm (16 inch) letters with a readability rate of 6.1 meter/cm (50 feet/inch). It was assumed that the average speed of traffic on a rural highway is 111 kph (70 mph). Hence, readability time was approximately eight seconds. Questions preceding VMSs were used to assess comprehension and interpretation of message content. In response to Time Signs, participants were asked to determine how late they would be for work. Answers were in multiple choice format with nine time choices ranging from 5-50 minutes, incremented with 5 minute intervals. In response to Speed Signs, participants were asked to determine what type of sign it was. Answers, once again, were in multiple choice format with three possible responses, namely, that the sign was a regulatory, advisor, or an update of speed of traffic ahead.

Miscellaneous. An auditory signal warned participants of the continuation of each driving sequence. The speedometer appeared in the lower left corner of the monitor and always read 60 mph. This value was chosen, despite above calculations of readability at 111 kph (70 mph), so mental calculations of time to get through the work zone could be easily calculated.

Design

Time Signs. This experiment employed two 2x3x2x2 repeated measures ANOVA designs with 24 conditions: one for Time Signs and one for Speed Signs. Time Signs were either Transit or Delay Signs. Transit Signs described the total travel time through the work zone. Delay Signs described the additional time required to travel through the work zone. The two types of Time Signs were then presented with three types of variable message signs: wrap-around black lettering (against white background) with green variable numeric digits (against black background) in the center of the signs (Display Type 1); nonwrap-around with black lettering (against white background) preceding green numeric digits (against black background) in the lower left portion of the sign (Display Type 2); sequential with all green lettering: two sequences with a sequencing rate of 2 seconds/sequence, three lines per sequence, and a maximum of eight characters per line (Display Type 3). Each of the three display types for both Transit and Delay Signs were further divided into two choices or examples. Each example was further divided into one of two times. Trial 1 was the first time the sign was seen by the participant. Trial 2 was the second time the sign was seen by the participant. Thus 12 Time signs were presented twice for a total of 24 cells (see Table 4 and Appendix I).

Table 4. Time Sign Design.

	TIME SIGNS																							
Type	Transit												Delay											
Display	D1				D2				D3				D1				D2				D3			
Choice	C1		C2		C1		C2		C1		C2		C1		C2		C1		C2		C1		C2	
Trial	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2

Note: (D)isplay, (C)hoice, (T)rial

Speed Signs. Speed Signs were of two types: Personal or Ahead Signs. Personal Signs provided the advised speeds for entrance into the work zone. Ahead Signs supplied average speeds of traffic at the beginning of the work zone. The two types of Speed Signs were then presented with three types of variable message signs that were identical to those used for the Time Signs (see description of three displays above). Each of the three display types for both personal and ahead signs were further divided into two choices or examples. Each choice was further divided into two trials. Once again, Trial 1 was the first time the sign was seen by the participant. Trial 2 was the second time the sign was seen by the participant. Thus 12 Time signs were presented twice for a total of 24 cells (see Table 5 and Appendix I).

Table 5. Speed Sign Design.

	SPEED SIGNS																							
Type	Personal												Ahead											
Display	D1				D2				D3				D1				D2				D3			
Choice	C1		C2		C1		C2		C1		C2		C1		C2		C1		C2		C1		C2	
Trial	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2

Note : (D)isplay, (C)hoice, and (T)rial

The experiment consisted of 25 passes up to, but not including, the work zone (one practice, 24 experimental). Each pass consisted of two static construction signs followed by a Time Sign and a Speed Sign. Twelve combinations of both signs were randomly produced with a random number table. These twelve combinations were randomly sequenced for the first twelve passes of an order. The mirror opposite of this order was used for the last 12 passes. The same twelve combinations of Time and Speed Signs were used for both conditions.

Procedure

On a monitor participants viewed a computer simulation of a section of road leading up to a construction zone. After a moment driving in the simulator, a static sign, CONSTRUCTION AHEAD, approached (loomed up) on the right side of the roadway. After another segment of road had been traveled, a second static message sign, CONSTRUCTION NEXT 10 MILES, appeared and passed on the right side of the road. Participants were instructed to pay attention to the message on each of these signs and be prepared to answer questions about the third and fourth sign in the sequence (participants were instructed beforehand as to the nature of the two types of signs and the questions they would be asked regarding both the primary and the secondary task). After another segment of road had been traveled, a VMS emerged from the horizon and passed on the right side of the road. This sign was a Time Sign. At approximately the same time the VMS was readable the grid line became active. Once the Time Sign passed out of view eight seconds after becoming visible, the screen paused for 15 seconds. Two questions regarding the Time Sign and the grid line were presented to the participant. Following the pause, an auditory signal occurred and the simulation continued. After another segment of road had been traversed, a variable message sign approached on the right side of the road. This sign was a Speed Sign. At approximately the same time the variable message sign was readable the grid line once again became activated. Once the Speed Sign passed out of view, the screen paused (15 seconds). Two questions regarding the Speed Sign and the grid line were presented to the participant. After the pause and auditory signal occurred, another trial began. The entire scenario was repeated 25 times with one practice pass and 24 experimental passes.

Instructions To Participants. Hello! On the behalf of the Human Factors Research Laboratory at the University of Minnesota we would like to thank you for participating in this experiment. Before we begin, I would like you to read and sign an informed consent form. (See Appendices E-G for consent form information.)

On the monitor before you will be presented a computer simulation of a section of roadway leading up to, but not including, a work zone. As you travel down the road you will see a sequence of four signs on the right side of the road. Please pay attention to the message on each of these signs and be prepared to answer questions about the third and forth sign in the sequence. The third sign will, in general, tell you information about time and how it relates to the construction site. You will be asked this question (show the question and answer sheet) in response to the message on the Time Sign. The fourth sign will tell you information, in general, about speed and how it relates to the construction site. You will be asked this question (show the question and answer sheet) in response to the message on the Speed Sign. Please pay attention to all the information you receive on the signs in addition to the speed you are traveling. This information will always appear on the bottom left part of the screen.

In addition to answering questions about the message content of the Time and Speed Signs, you will have another task to perform. As you will soon see, a grid line, consisting of five white squares will always be located where you would expect your in-car rearview mirror. At some point, single sections of this grid line will start to light up, i.e., some white squares will turn yellow. On occasion, a signal, i.e., a letter in the alphabet, will appear in one of the yellow squares. This can happen more than once. Your task will be to remember which signal(s) appeared on the grid line (show question and answer sheet).

In summary, each time the screen pauses, you will be given the questions regarding the signal(s) on the grid line and the message on the road sign just seen. At this point you will fill in you answer on the multiple choice answer sheet. For the question on the grid line, fill in the oval that corresponds to the letter of the signal. For the question on the sign's message, fill in the oval that has the number inside it that corresponds to the number on the question sheet. You will hear a "beep" from the computer at which time you should finish the questions and look up at the screen again.

After you have seen all four signs along the stretch of road leading to the construction site and answered the corresponding questions, the same procedure will be repeated 24 more times. Each section of road leading up to the construction zone will have different messages and different display types for the third and forth sign in the sequences, in addition to different signals on the grid line.

Do you have any questions? We will go through a practice trial so you can become more familiar with the grid line task. Unlike actual testing, all four signs will be identical for the practice trial and you will not have to answer any questions about these signs.

Treatment of Data

A 5-way repeated measure ANOVA was run on dichotomous correct and incorrect responses to both Time and Speed Signs with CATMOD (from SAS Version 6.08; see also Lunney, 1968) conducted a significant and relevant contrasts.

Simulation Experiment Results

Primary Task

Participants performed with a high level of accuracy, the mean number incorrect responses 2.3 out of a possible 48 (s.d. = 2.1; range 0 to 7). Occasional errors did not appear systematic. Near perfect performance by most participants made further analyses of the primary task data unwarranted.

Secondary Task

Test-Retest Reliability. For Speed Signs no differences were found between first and second presentation, regardless of factors, except for a spurious four-way interaction of type by display by choice by time ($F_{2,36}=4.03$; $p=.0246$; Greenhouse-Geiser corrected $p=.0293$). However, for Time Signs the effect of a 4-way interaction of type by choice by time by condition ($F_{1,18}=17.92$; $p=.0005$) revealed that participants were significantly more accurate on trial 2 than trial 1 ($F_{1,18}=20.19$; $p=.0003$), likely due to the better understanding of the task at hand obtained from a complete reviewing of all signs in the experiment. Henceforth, all analyses are based only on trial 2 data, considering trial 1 data as practice.

Check of Counterbalance. Although none of the interactions were significant for Time Sign trial 2 data, i.e., no simple effects emerged, a main effect of type was found ($F_{1,18}=18.24$; $p=.0005$). Counterbalances were then collapsed and a three-way repeated measures ANOVA was conducted. Once again only the main effect of type was significant ($F_{1,19}= 18.18$; $p=.0004$) with participants responding with greater accuracy on Delay signs than Transit signs (mean percent correct 95.0 and 46.7, respectively). A repeated measures ANOVA with the single factor of type using percent error from six responses for each type showed a main effect of type ($F_{1,19}=18.8$; $p=.0004$) with a mean percent correct for Delay and Transit signs of 95.0 and 46.7, respectively. (Please see Figure 6). Polygons, rather than histograms, are used to better illustrate potential interaction and trends in the data.

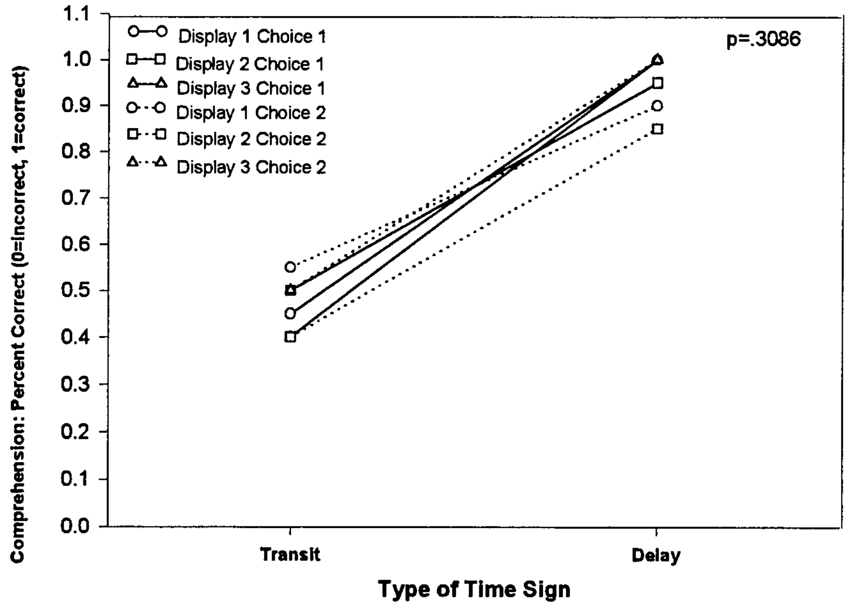

Figure 6. Percent correct on comprehension of Time Signs as a three-way interaction of type, display, and choice.

For Speed Sign trial 2 data, main effect of type ($F1,18= 14.98$; $p=.0011$) and choice ($F1,18= 36.73$; $p=.0001$) were found. Counterbalances were then collapsed and a three-way repeated measures ANOVA was conducted. Once again main effects of type ($F1,19= 15.55$; $p=.0009$; Chi-squared=16.36; $p=.0001$) and choice ($F1,19= 38.00$; $p=.0001$; Chi-squared=40.00; $p<.00005$) were significant with participants responding with great accuracy to Update over Advisory signs (mean percent correct 65.8 and 30.8, respectively) and choice 2 over choice 1 (mean percent correct 65.0 and 31.7, respectively). In addition, a two-way interaction of type by choice ($F1,19= 4.41$; $p=.0493$; Chi-squared=4.64; $p=.0312$) was significant (see Figure 7). Figure 8 provides interpretation of percent correct as a function of display, choice, and type of speed sign.

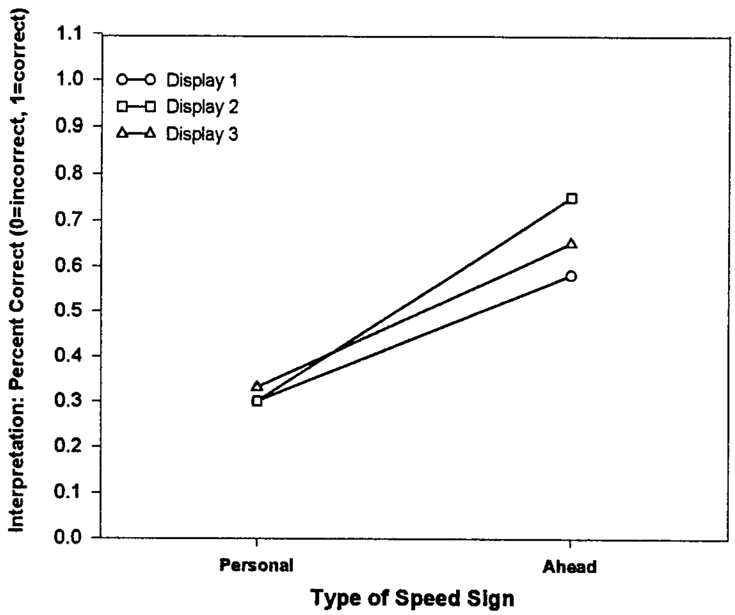

Figure 7. Percent correct on interpretation of Speed Signs as a two-way interaction of type and display.

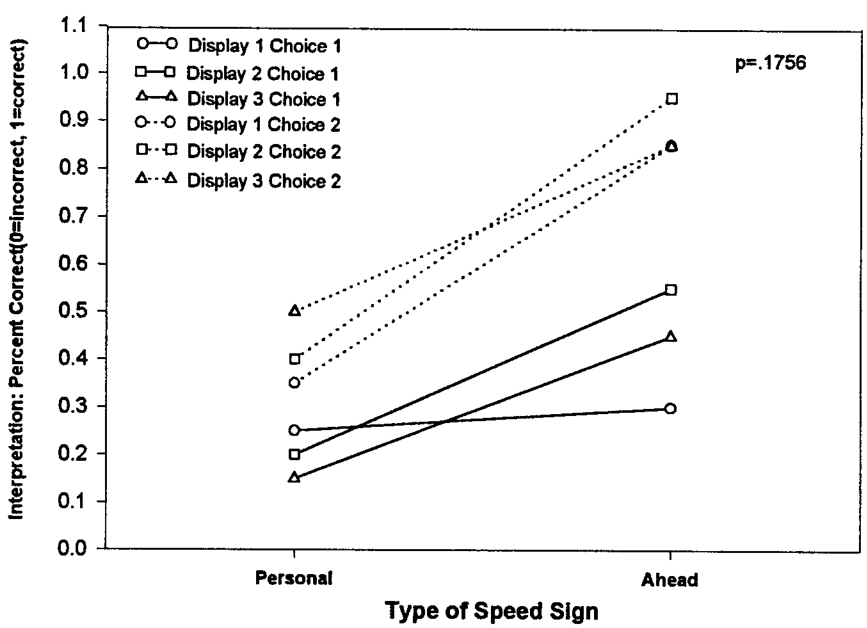

Figure 8. Percent correct on interpretation of Speed Signs as a three-way interaction of type, display, and choice.

Simulation Experiment Discussion

The goal of this experiment was to develop a technology that could be employed to study the comprehension and interpretation of the content of variable message signs. Variable message signs provide real-time information to motorists and allow considerable flexibility in the type of information conveyed independently or in concert with existing technology found in intelligent highway systems. While much research, to date, has focused on physical and perceptual aspects of these signs, e.g., readability, considerably less attention has been given to other, more functional aspects of signage, like comprehension and interpretation. In some situations, message ambiguities may lead to slight confusion and irritation. However, in more extreme cases, misunderstandings could be fatal. Unfortunately, work zones tend to be a typical backdrop for such occasions, due to the size and variability of the speed of incoming traffic and the vulnerability of construction workers within the zone. Thoughtful experimentation of VMS message content might help reduce the number of tragedies.

The dual task methodology employed in this experiment provides a means for testing message content in a more ecologically feasible manner. Participants viewed a computer simulation of a stretch of road leading up to, but not including a work zone. For the primary task, participants had to pay attention to and remember the signals that occurred along the grid line in the rear view mirror. This task was designed to loosely capture the level of attention resources required to monitor the lane position of traffic in the rearview mirror. The concurrent, secondary task involved viewing an approaching (optically expanding) variable message sign and answering a question based on individual interpretation and comprehension. Variable message signs presented information about time or speed and how these factors related to the work zone. Three different types of displays were also tested. The main findings follow.

Primary Task

During experimental trials, only one signal occurred with each approach of a variable message sign. This task proved quite simple, with near ceiling levels of performance. As a result, an accuracy trade-off between the primary and secondary task was not assessed. Future research should involve systematic manipulation of the level of difficulty of this task, through increasing the number of signals to remember and the speed at which the signals are presented. It is important that the primary task loads sufficiently on the information processing capabilities of the driver such that resources for performing the secondary task are appropriately taxed.

Secondary Task

Time Signs. Transit Time Signs conveyed the time necessary to traverse the work zone, while Delay Signs provided the additional amount of time to traverse the work zone. In order to respond correctly, participants had to determine the number of minutes they would be late for work. In the former situation, one needed to mentally calculate the amount of time it would have taken to travel along the same stretch of road, without the work zone and subtract this from the total amount of time to traverse the work zone. Given the time constraints on reading, comprehending and interpreting traffic signs, this was not a trivial task. It was expected, therefore, that some people would perform less accurately on these types of signs compared with the type that did not require mental calculation. So while drivers may be consistently accurate with their interpretation of transit signs and even show preference for the information they convey, as found in the survey study, the ability to glean the most useful information from this type of sign, namely its effect on travel time, seemed to be lacking. Furthermore, while the survey study suggests that delay information is ambiguous in interpretation, both the pilot survey and the simulation experiment suggest that people still are able to correctly comprehend how the delay will affect their travel. Another interesting question lies in the message content of the two choices. Delay Time Signs were further divided into those that expressed additional time to travel the work zone, either in terms of extra time or delay. In the survey study, people's diverse interpretations of meaning of delay indicated a high level of message ambiguity, even though most were able to comprehend how their travel time would be affected. In addition to further testing comprehension of the consequences of delay, the simulation experiment tried to determine whether additional time could be expressed in a seemingly less ambiguous manner using the words "extra time." Both choices rendered high level of accuracy in responses and did not differ significantly from each other. Finally, the different display types of variable message signs did not appear to differ significantly in their effect on a person's comprehension of the consequences of messages expressing time information.

Speed Signs. When drivers were asked to interpret Speed Signs used in this experiment as regulatory, advisory, or an update of the speed of traffic ahead, they generally misinterpreted the Personal Speed signs more often than Ahead Speed Signs. People also tended to correctly interpret choice #2 signs more often than choice #1. This trend was further complicated by an interaction between the type and choice of speed signs. This interaction was due, largely, to a consistently high level of accuracy on choice #2 Ahead Speed Signs. These signs were most likely correctly interpreted as update signs due to the unambiguous use of either the verb "moving," the adjective "ahead," or both. Choice #1 Ahead Speed Signs, on the other hand, used the words speed in conjunction with the word traffic; the referent of traffic being either the person reading the sign or the cars ahead. Furthermore, the word speed is quite often seen in the context of regulatory or advisory speed signs. This combination could have led to misinterpretation of a choice #1 Ahead Speed Sign as one or the other. Personal Speed Signs resulted in the greatest number of misinterpretations. The messages on these signs, as is often the case of advisory signs, were phrased as commands, contrary to what their name implies. Consequently, it is not terribly surprising that participants tended to misinterpreted them. Finally, the different types of variable message sign displays did not appear to differ significantly in their effect on a person's ability to interpret messages expressing speed information.

Findings of the present experiment indicate that the type of message on VMSs does affect comprehension and interpretation. How interpretation of VMSs influences driving behavior is a topic of investigation beyond the scope of this study, though of equal significance. If the sign expresses time, motorists are more likely to glean relevant information when the message expresses additional amount of time to travel through the work zone, as opposed to the total amount of time. This information may have the effect of increasing the number of detours taken before the work zone; thus reducing some of the congestion preceding the work zone. If the sign expressed speed, messages in command form were likely to be interpreted as speed advisories, whereas speed signs that use the action verb "moving" are more likely to be correctly interpreted as describing the speed of traffic ahead. The type of variable message sign did not appear to significantly influence sign interpretation or comprehension of consequences. This suggests that the cost of constructing variable message signs might be reduced by creating hybrid signs that provide pertinent real time information.

CONCLUSION

The goal of this research was to develop a methodology for assessing the effectiveness of word usage on variable message signs used in work zones. A survey was conducted as a preliminary investigation into the information content of VMSs for construction/repair zones. It was found that a driver may understand the content of a message, but it does not necessarily mean s/he can predict the consequences of the information, and vice versa. This preliminary investigation provided valuable information in highlighting some issues that need to be addressed. A computer simulation experiment was conducted, using dual tasks, to assess the correctness of interpretation of meaning and comprehension of the consequences of the information on variable message signs. Although participants performed with high levels of accuracy on the primary task, in general, the type of message found on the variable message signs significantly influenced the accuracy of interpretation of speed signs and the comprehension of consequences for the time signs. Even speed signs that shared a common meaning resulted in different interpretations. The type of VMS display did not appear to directly influence responses for either time or speed signs, thereby suggesting substantial cost savings might occur from using static signs with variable speed and time information rather than expensive full-matrix VMSs.

The computer-assisted methodology employed by this research provides a means of assessing message content by having visual expansion of VMSs, consistent readability times, and varied display types in a divided attention task. Further, it provides opportunity to manipulate attentional demands of test participants in video projection environments without expensive simulators.

Each summer in Minnesota there are more than 500 transportation construction projects affecting traffic flow. There are over 15,000 state, city, county, and industry workers on Minnesota highways improving the transportation system (Denn, 1995). While these projects may temporarily inconvenience travelers, they provide long term benefits for everyone using the highways. To make work zones safer, Mn/DOT has improved work zone safety procedures and technologies, enhanced worker training, supported new legislation that doubles fines for speeding in work zones, increased the presence of law enforcement in work zones, and launched a new campaign that educates and heightens public awareness about work zone safety (for more information on the work zone safety campaign phone 612.296.8705). The present VMS research is another example of attempts to improve safety in work zones and throughout the Minnesota transportation system. Targeting workers, motorists, and transportation researchers, Mn/DOT is trying to reduce the incidence of work zone accidents.

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APPENDIX A.

Road Sign Survey Consent Form

Road Sign Survey Consent Form 20 August 1993

The Minnesota Department of Transportation, 3M and the University of Minnesota are working together to design better road signs. In this short survey, you will be asked a few questions about your background, which are optional. Then we will show you four different traffic signs and ask you a couple of questions about each of them. The entire survey should take less than 10 minutes of your time.

Your signature below indicates that you have read and understood this form and have agreed to participate. You have the right to discontinue your participation at any time -- even if you sign.

______________________________ Your Signature

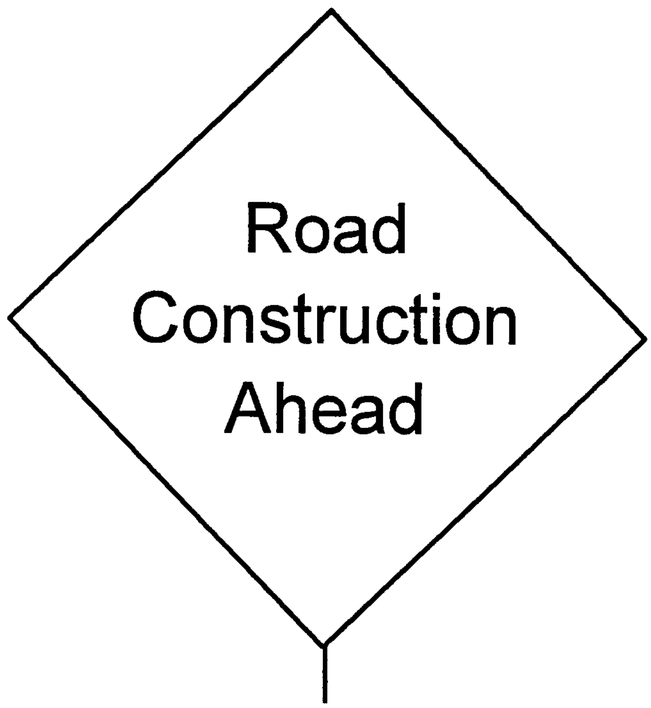
_______________ Date

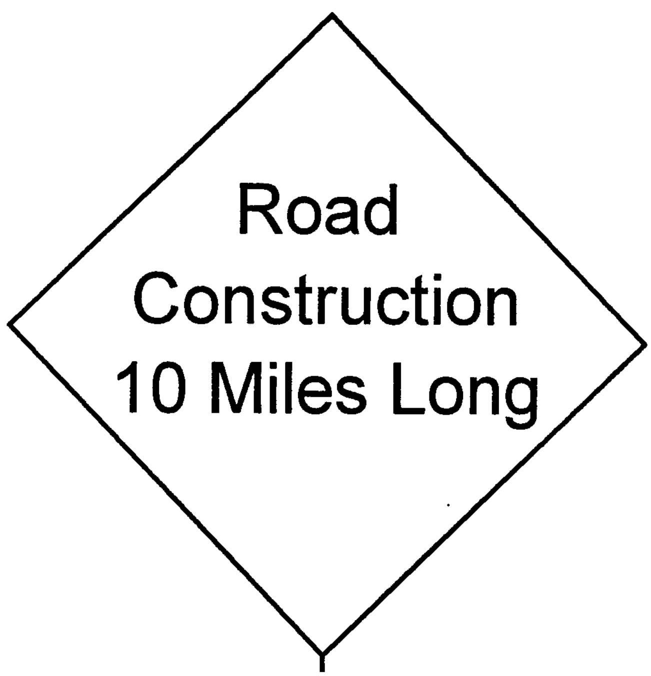
______________________________ Researcher's Initials

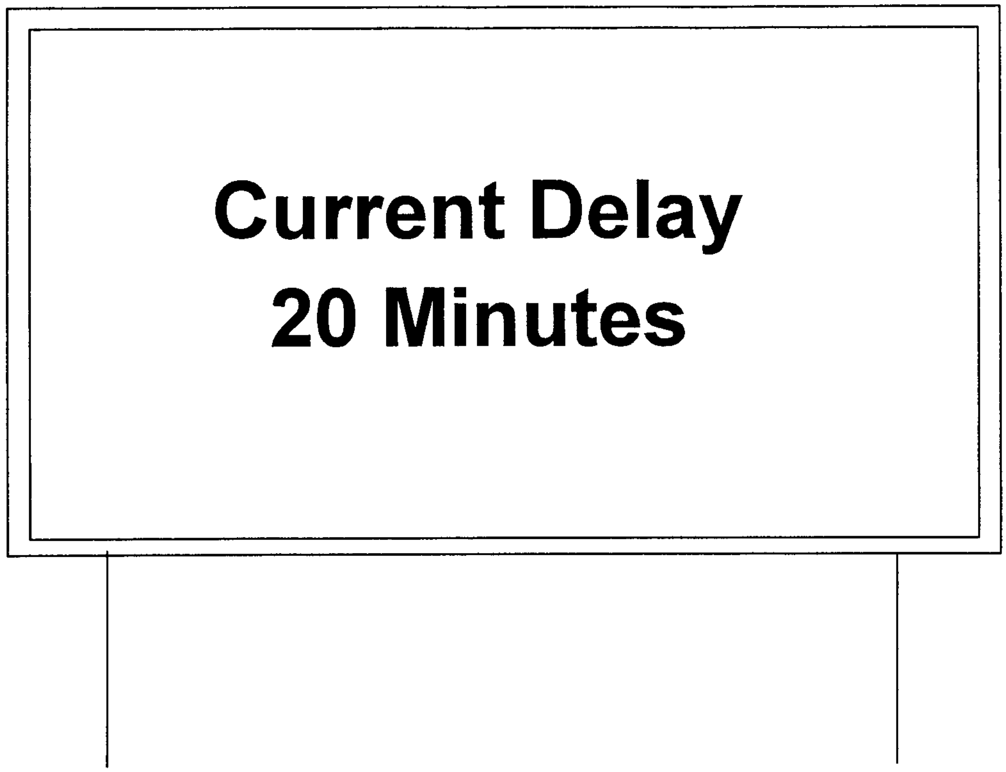
_______________ Date

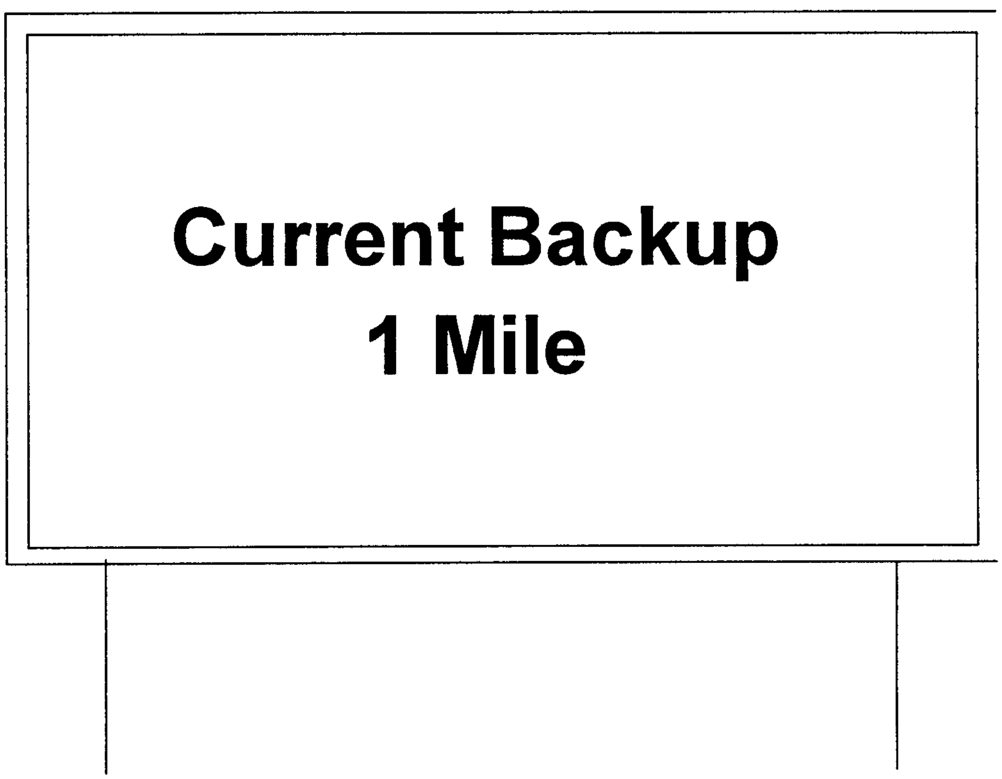
APPENDIX B.

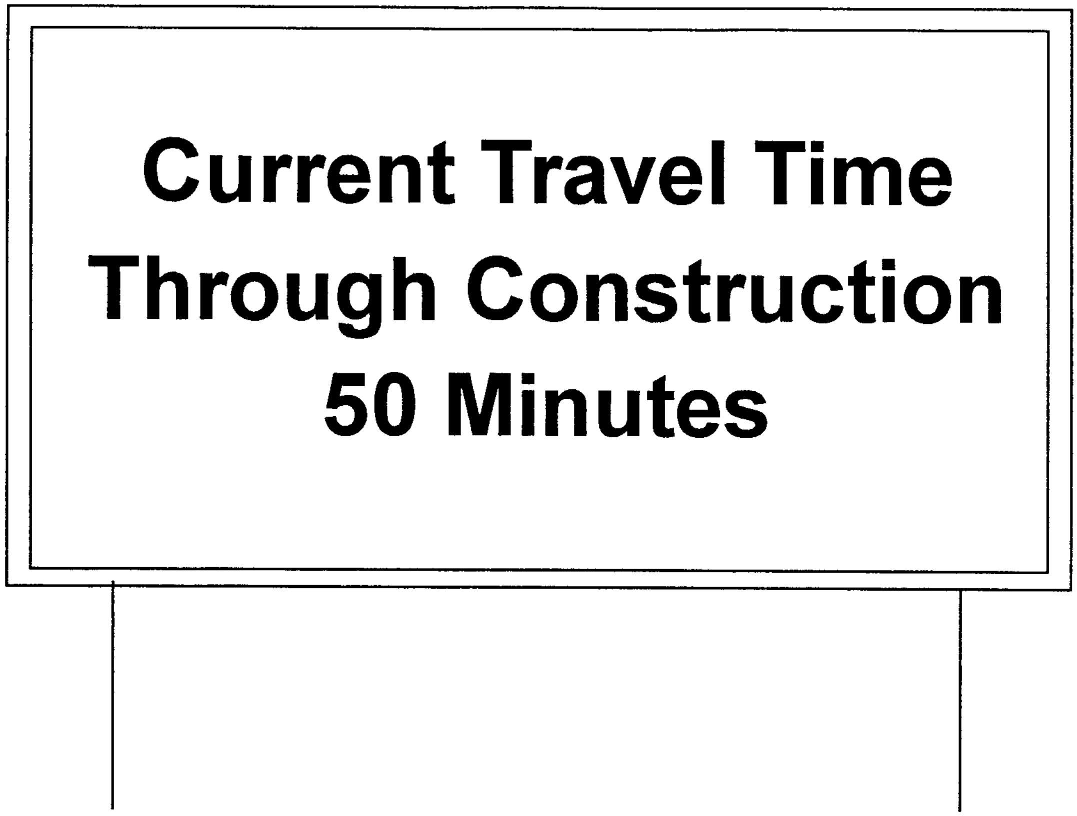
Signs Used in Road Sign Survey Study

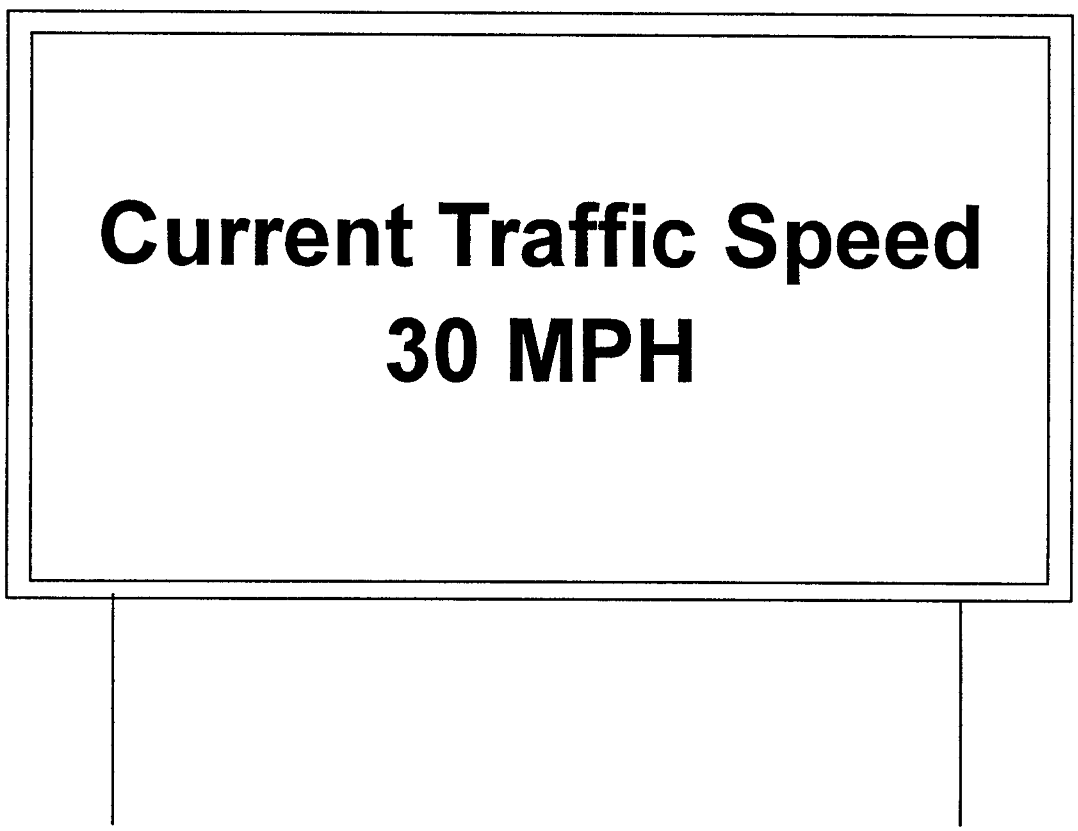





Current Delay
20 Minutes


Current Backup
1 Mile


Current Travel Time
Through Construction
50 Minutes


Current Traffic Speed
30 MPH

APPENDIX C.

Codes to Score Open-Ended Responses

The following list of codes were used to score the open ended responses.

A It will take me ___ minutes to reach the end of the construction.
B It will take me ____ minutes longer to make my trip (no further explication).
C It will take me ____ minutes longer to make my trip, relative to no construction (at estimated 65 mph).
D It will take me ____ minutes longer to make my trip, relative to construction, with light traffic traveling through (at estimated 55 mph).
E I will be stopped (or waiting) for ____ minutes.
F I will be stopped for ____ minutes.
G I will be in slow traffic for ____ minutes.
H Traffic will be stopped for ____ miles.
I Traffic be stop-and-go for ____ miles.
J Traffic will be slow for ____ miles.
K Meaningless response, e.g., go slow, be late, be stuck in traffic.
L The speed LIMIT through the construction zone is ____ mph.
M Traffic is moving at ____ mph.
N Backup (stopped / stop-and-go traffic) is before construction.
O Repeated word in sign : Delay; Backup or answered "in a line of traffic", interviewer was unable to get driver to explain.
P Driver responded only that he or she would take an alternate route.
Q No idea - too confusing - don't know.
R Other

APPENDIX D.

Road Sign Survey Study Questionnaire

Researcher ___ Participant#___ Order: (Optional) ______ Consent form signed ______

Background questions:

What is your age? 16 - 25 25 - 45 45 - 65 65 - older
What is your sex? M F
Where do you live? ________________________________, ______
(City) (State)
What type of vehicle are you driving? passenger car van heavy commercial light truck RV bus

Assume that you are getting back on 35 heading north. Shortly after you enter the highway, you see the following road signs: {show 1st sign page}

Road Construction Ahead
Road Construction Next 10 miles

A short time later you see the following electronic sign: {show 1st sign}

Q1: What does this sign mean to you?
- A. It will take me _____ minutes to reach the end of the construction.
- B. It will take me _____ minutes longer to make my trip.
  - **[In that case, will it take you more minutes longer compared to:**
    - i. the situation in which there is no construction?
    - ii. the situation in which there is construction but light traffic?
  - **{Skip over question 2, to next sign.}]**
- C. I will be stopped for _____ minutes.
- D. I will be in stop-and-go traffic for _____ minutes.
- E. I will be in slow traffic for _____ minutes.
  - [In that case, What does "slow" mean to you? Speed = _____ mph.]
- F. Traffic will be stopped for _____ miles.
- G. Traffic will be stop-and-go for _____ miles.
- H. Traffic will be slow for _____ miles.
  - [In that case, What does "slow" mean to you? Speed = _____ mph.]
- I. I must go ________ mph.
- J. Other:

Q2: How will the construction affect the arrival time at your destination?
Additional ____ min hours

Let's say that the next day you see this instead: {show next / 2nd sign}

Q1: What does this sign mean to you?

A. It will take me _____ minutes to reach the end of the construction.

B. It will take me _____ minutes longer to make my trip.

[In that case, will it take you more minutes longer compared to:

i. the situation in which there is no construction?

ii. the situation in which there is construction but light traffic?

{Skip over question 2, to next sign.}]

C. I will be stopped for _____ minutes.

D. I will be in stop-and-go traffic for _____ minutes.

E. I will be in slow traffic for _____ minutes.

[In that case, What does "slow" mean to you? Speed = _____ mph.]

F. Traffic will be stopped for _____ miles.

G. Traffic will be stop-and-go for _____ miles.

H. Traffic will be slow for _____ miles.

[In that case, What does "slow" mean to you? Speed = _____ mph.]

I. I must go ________ mph.

J. Other:

Q2: How will the construction affect the arrival time at your destination?

Additional ____ min hours

What if you had seen this sign? {show 3rd sign}

Q1: What does this sign mean to you?

A. It will take me _____ minutes to reach the end of the construction.

B. It will take me _____ minutes longer to make my trip.

[In that case, will it take you more minutes longer compared to:

i. the situation in which there is no construction?

ii. the situation in which there is construction but light traffic?

{Skip over question 2, to next sign.}]

C. I will be stopped for _____ minutes.

D. I will be in stop-and-go traffic for _____ minutes.

E. I will be in slow traffic for _____ minutes.

[In that case, What does "slow" mean to you? Speed = _____ mph.]

F. Traffic will be stopped for _____ miles.

G. Traffic will be stop-and-go for _____ miles.

H. Traffic will be slow for _____ miles.

[In that case, What does "slow" mean to you? Speed = _____ mph.]

I. I must go ________ mph.

J. Other:

Q2: How will the construction affect the arrival time at your destination?

Additional ____ min hours

Or, lastly, how about this sign: {show 4th/last sign}

Q1: What does this sign mean to you?

A. It will take me _____ minutes to reach the end of the construction.

B. It will take me _____ minutes longer to make my trip.

[In that case, will it take you more minutes longer compared to:

i. the situation in which there is no construction?

ii. the situation in which there is construction but light traffic?

{Skip over question 2, to next sign.}]

C. I will be stopped for _____ minutes.

D. I will be in stop-and-go traffic for _____ minutes.

E. I will be in slow traffic for _____ minutes.

[In that case, What does "slow" mean to you? Speed = _____ mph.]

F. Traffic will be stopped for _____ miles.

G. Traffic will be stop-and-go for _____ miles.

H. Traffic will be slow for _____ miles.

[In that case, What does "slow" mean to you? Speed = _____ mph.]

I. I must go ________ mph.

J. Other:

Q2: How will the construction affect the arrival time at your destination?

Additional ____ min hours

Thank you. Now one final question: {Show summary sign sheet.}

Q3a: Here are the four signs you have just seen. If there were a traffic problem, which sign provides you with the most useful information?

A. Current Delay 20 Minutes

B. Current Travel Time Through Construction 50 Minutes

C. Current Backup 1 Mile

D. Current Speed Through Construction 30 MPH

E. No Sign is better than any of the others (No preference)

Q3b: Why?

APPENDIX E.

Participant Informed Consent Form

Development of Guidelines for Message Content of Variable/Changeable Message Signs

You are invited to participate in a study to gain an understanding of how drivers interpret information presented on variable message signs when driving towards a construction zone. You were selected as a possible participant in this study because you are a licensed driver. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

If you decide to participate, we will require you to complete the following task. We will ask you to watch a computer simulation of a driving situation. Your main task will be to observe variable message signs on the monitor and interpret the meaning of the signs. A secondary task will be performed at the same time. This task will be described later, in detail. Your response will be in multiple choice format. You will be requested to respond to a total of 24 scenarios. The study will take approximately 60 minutes to complete.

Any information obtained in connection with this study that can be identified with you will remain confidential and will be disclosed only with your permission. If any written reports or publications follow, no one will be identifiable and only aggregate data will be presented.

On completion of your participation in this study you will receive $5 (five dollars).

Your decision whether to participate will not affect your future relations with the University of Minnesota in any way. If you decide to participate, you are free to discontinue participation at any time without effecting such relationships.

If you have any questions about the research and/or research participants' rights or wish to report a research-related injury, please contact Dr. Max Vercruyssen (principal investigator) or Douglas Wagner (research assistant) at:

Human Factors Research Laboratory
60 Norris Hall, 172 Pillsbury Drive, S.E.
University of Minnesota, Minneapolis, MN 55455
Telephone 625-7884

You may keep this form by detaching the section below.

You are making a decision whether or not to participate. Your signature indicates that you have read the information provided above and have decided to participate. You may withdraw at any time, without prejudice, after signing this form should you choose to discontinue participation in this study.

Statement of Consent:

I have read the above information. I have asked questions and received answers. I consent to participation in this study.

____________________ ____________
Participant Signature Date

____________________ ____________
Researcher Signature Date

APPENDIX F.

Institutional Review Board Application

University of Minnesota
IRB: Human Subjects Committee
1300 South 2nd Street, Suite 10
Minneapolis, MN 55454
(U.S. or Campus Mail)
Phone: 612/624-9829
Fax: 612/626-9755

Code #: ______
Date Received: ______
(For Office Use Only)

REQUEST FOR EXEMPTION FROM COMMITTEE REVIEW OF RESEARCH INVOLVING HUMAN SUBJECTS

1. **Project Title:** (Use same title as grant application, if applicable)
   Development of guidelines for message content of variable message signs.

2. **Exemption category claimed:** 2 .
   (Insert the category number from pages ii and iii.)

3. **Principal Investigator** Max Vercruyssen Ph.D.
   (first mi last degree)
   Telephone number 612 - 625 - 7884
   University Department name
   Investigator's address
   Kinesiology Department
   Human Factors Research Laboratory
   60 Norris Hall, 172 Pillsbury Drive S.E.
   University of Minnesota

4. **Inclusive dates of project:** March 1994 through December 1994

5. Project has been / ~~will be~~ submitted to the following funding agency: CTS and MnDOT
   Funding decision ~~is pending~~ / **has been awarded.**
   Agency-asigned grant number (if known): ______
   If this study is part of a program or center grant, provide the title and principal investigator: ______

6. **Check one:**
   X Faculty/Staff research
   ___ Fellow/Post doctoral
   ___ Student Research
   ___ Undergraduate
   ___ Graduate

7. **If principal investigator is a student:**
   Advisor's Name X
   Address ______
   Telephone ______

In order to request an exemption from Committee review, the following questions must be addressed completely. Any request involving surveys or interviews must be accompanied by copies of the instruments which will be used to gather data. Research applications must include a consent statement or consent form appropriate to the research questions. (Use the sample form as a guide in preparing forms, letters and oral statements.) Research involving the use of pathological specimens and existing data *without identifiers* does not require consent from subjects.

8. **Abstract / Lay Summary**

Describe the research including research questions and methods to be used (hypothesis and methodology). Describe the purpose of the research and the tasks subjects will be asked to complete—explain what the subjects will be asked to do. **Use lay language—language understood by a person unfamiliar with the area of research. Area-specific jargon should be avoided or explicitly explained.** If using existing data, records or pathological specimens, explain the source of the data, the type of tissue used, and the means of access to the data.

See attached sheet.

9. Subject Population:

a. Number: Male 20 Female 20 Total 40

b. Age Range: 18 to 40

c. Location of Subjects:

(Check all that apply)

- ____ elementary / secondary schools
- ____ outpatients
- ____ University Hospitals and Clinics
- ____ other hospitals
- X University students
- ____ other special institutions: specify ____
- ____ other hospitals: specify ____

d. Special Characteristics

(Check all that apply)

- ____ inpatients
- ____ prisons / halfway houses
- ____ patient controls
- X normal volunteers (adults)

e. If research is conducted off-campus, written documentation of approval/cooperation from that outside agency (school, etc.,) should accompany this application.

f. Describe how subjects will be identified or recruited. Attach recruitment information, i.e., advertisements, bulletin board notices, recruitment letters, etc.

Subjects from the university population will be recruited from posters that will be located around the university. They will respond by calling the research assistant and leaving a contact number with her. A copy of the poster is attached.

g. If subjects are chosen from records, indicate who gave approval for the use of the records. If records are *private* medical or student records, provide the protocol for securing consent of the subjects of the records and approval from the custodian of the records.

X

h. Who will make the initial contact with the subjects? Describe how contact is made.

The participants will initially make it known that they wish to participate in the study. The researcher will then telephone the volunteers to schedule suitable times for participation.

i. Will subjects receive inducements before, or rewards after the study? If yes, explain. (Include this information in your consent documents.)

Subjects will receive a token payment of $5 (five dollars). They will receive this when they have completed the study session.

j. If subjects are school children and class time is used to collect data, describe in detail the activity planned for non-participants. Who will supervise those children? (This information must be included in the consent form.)

X

10. **Confidentiality of Data.**

a. Describe provisions made to maintain confidentiality of data. Who will have access to data? Will data be made available to anyone other than the principal investigator? School officials, medical personnel? If yes, explain below and in the consent form.

Names will be replaced with identification numbers which are accessible only by the investigators. All data storage is according to coded identification numbers.

b. Where will data be stored and for how long? If tape recordings or videotapes are created, explain who will have access and how long the tapes will be retained. Written consent is required for recordings; the consent form should include the information requested above.

The data will be stored on an IBM hard disc. It will be stored for 10 years.

11. Informed Consent Process

Simply giving a consent form to a subject does not constitute informed consent. Using the sample attached, prepare and attach a consent form, statement, or letter for review (for exemption categories 1, 2, 3, 5, 6).

Researchers are cautioned that consent forms should be written in simple declarative sentences. The forms should be jargon-free. Foreign language versions should be prepared for any applicable research.

consent form:

- signature of subject and/or parent is required for research involving risk, and for research where a permanent record of results are retained (including videotapes).

consent statements/letters to subjects:

- statements read to study subjects or distributed to participants prior to interview or as a cover sheet for a written survey should be modeled after the sample consent form but do not require signature. (Provide text of consent statement with the application.)

no active consent:

- no active consent is required for observation of public behavior. Photos, films, videotaping, etc., require review by the Committee and written consent of subjects.
- no active consent is required for review of public records, private records already stripped of identifiers, or research involving pathological specimens which are not identifiable by name or number.

12. **Exempt Category #4: Pathological Specimens**

All pathological specimens should be stripped of identifiable information prior to use. Registries or tissue banks where subject's samples are identified or identifiable are *not exempt* from Committee review.

Describe the source of the specimens. How will they be obtained? If not obtained by the principal investigator, then by whom?

13. **Exempt Category #5: Public Service Programs**

In addition to the information provided under *abstract*, above, provide documentation of conformity to the requirements of category #5, including written documentation or cooperation from the public agency involved in the research.

14. **Exempt Category #6: Taste Testing**

To be eligible for this category of research, all food tested must be GRAS (Generally Recognized As Safe) and wholesome. Food ingredients must be at or below the levels found to be safe by federal regulatory agencies. Describe the food to be tested and provide assurance that these conditions are met.

Applications for approval to use human subjects in research require the following assurances and signatures:

(Note: original inked signatures are required; no stamps or "per" signatures allowed)

The signatures below certify that:

- The information provided in this application form is correct.
- The Principal Investigator will seek and obtain prior written approval from the Committee for any substantive modification in the proposal, including, but not limited to changes in cooperating investigators, agencies as well as changes in procedures.
- Unexpected or otherwise significant adverse events in the course of this study will be promptly reported.
- Any significant new findings which develop during the course of this study which may affect the risks and benefits to participation will be reported in writing to the Committee and to the subjects.
- The research may not be initiated until final written approval is granted.

This research, once approved, is subject to continuing review and approval by the Committee. The PI will maintain records of this research according to Committee guidelines.

If these conditions are not met, approval of this research could be suspended.

Signature of Principal Investigator Max Deroy[illegible] Date 2/15/94

Student Research: As academic advisor to the student investigator, I assume responsibility for ensuring that the student complies with University and federal regulations regarding the use of Human Subjects in research:

Signature of Academic Advisor ____________________ Date ____________

Faculty/Staff Research: As department head, or designee, I acknowledge that this research is in keeping with the standards set by our department and assure that the principal investigator has met all departmental requirements for review and approval of this research.

Signature of Department Head [illegible] Date 2-23-94

ABSTRACT

The objective of this study is to determine how the message content of changeable message signs is interpreted by drivers. We have chosen two types of content to assess, a sign that expresses time, and a sign that expresses speed. Subjects will be recruited from the University student population. The task requires the subjects to view a video presentation of a simulated road environment. On the left side of the screen is a primary task which approximates a mentally demanding activity to make reading the changeable messages more difficult. The primary task requires subjects to monitor five letters which are illuminated at random, the subject then has to state which of five letters was illuminated the most during a predetermined period. On the right side will be a dynamic simulation image of a road with static and variable message signs. A trial consists of performing a primary task problem while viewing signs and passing through a simulated work zone, and subsequently completing multiple-choice questions on primary task performance, sign detection, and sign content understanding. Expected results include the identification of ideal sign content and presentation formats for variable message signs located prior to work zones. Specifically, this research will distinguish detectability and comprehension of four message types for advanced warning time delay/transit information and four message types for speed advisory presented on conventional two-digit display signs with border text and sequencing double-display changeable message signs.

Participant Consent Form

Development of guidelines for message content of variable message signs

You are invited to participate in a study to gain an understanding of how drivers interpret information presented on changeable message signs when driving towards a construction work zone. You were selected as a possible participant in this study because you are a licensed driver. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

If you decide to participate, we will require you to complete the following task. We will ask you to watch a video of a simulated driving situation. You will be required to observe changeable message signs in the video scenarios and interpret the meaning of the signs. Your response will be in a multiple choice format. You will be requested to respond to a total of 24 scenarios. The study will take approximately one hour to complete.

You will receive a payment of $ 5 (five dollars) on completing the study.

Any information obtained in connection with this study that can be identified with you will remain confidential and will be disclosed only with your permission. If any written reports or publications, no one will be identified or identifiable and only aggregate data will be presented.

Your decision whether to participate will not affect your future relations with the University of Minnesota in any way. If you decide to participate, you are free to discontinue participation at any time without affecting such relationships.

If you have any questions about the research and/or research subjects' rights or wish to report a research-related injury, please contact Dr. Max Vercruyssen (principal investigator) or Douglas Wagner (research assistant) at:

Human Factors Research Laboratory
60 Norris Hall
172 Pillsbury Drive, S.E.
University of Minnesota
Telephone 625-8774

You may keep this form by detaching the section below.

You are making a decision whether or not to participate. Your signature indicates that you have read the information provided above and have decided to participate. You may withdraw at any time without prejudice after signing this form should you choose to discontinue participation in this study.

Statement of Consent:
I have read the above information. I have asked questions and received answers. I consent to participate in this study.

________________________ ____________
Participant Signature Date

________________________ ____________
Researcher Signature Date

APPENDIX G.

Institutional Review Board Approval

UNIVERSITY OF MINNESOTA

Twin Cities Campus

Institutional Review Board: Human Subjects Committee

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Minneapolis, MN 55454

612-624-9829
Fax: 612-626-9755

March 7, 1994

Max Vercruyssen
Human Factors Reserach Lab
60 Norris Hall
Minneapolis Campus

RE: "Development of Guidelines for Message Content of Variable Message Signs"

HUMAN SUBJECT CODE NUMBER: 9402E7860

Dear Max Vercruyssen:

The University of Minnesota Committee on the Use of Human Subjects in Research has determined that the referenced study is exempt from review under federal guidelines 45 CFR Part 46.101(b) category #2 SURVEYS/INTERVIEWS; STANDARDIZED EDUCATIONAL TESTS; OBSERVATION OF PUBLIC BEHAVIOR.

The above code number is assigned to your research. That number, along with the title of your study, must be used in all communication with the Committee office.

Upon receipt of this letter, you may begin your research. If you have questions, please call me at (612)624-9829.

The Committee wishes you every success with this research.

Sincerely,

Ellen Stewart

Ellen Stewart
Executive Assistant

EHS/cdl

APPENDIX H.

CTS Annual Research Conference Proceedings Paper

The Evaluation of Message Content of Changeable Message Signs

Douglas G. Wagner[1,3], Max Vercruyssen[1,2], Peter A. Hancock[1], Gayna Williams[1], & Amy Briggs[3]

1 Human Factors Research Laboratory, University of Minnesota, Minneapolis, MN 55455

2 Center on Aging & Department of Psychology, University of Hawaii, Manoa, Hawaii.

3 Department of Psychology, University of Minnesota, Minneapolis, MN 55455 (227–8408)

Merwin (1991) reported a 60% increase in highway work zone related fatalities from 489 to 782 between the years 1982 and 1989. While many issues must be considered for improving safety in work zones, successful communication of traffic signs with motorist is tantamount. Changeable message signs (CMS) can be used to provide pertinent real–time information. However, the choice of message should be empirically demonstrated as appropriate, given that drivers must detect, comprehend, and translate signage information while being preoccupied, to some degree, with the task of driving the vehicle. The goal of this research was to develop a prototype dual–task methodology which could vary the degree of primary task (driving) in order to assess the appropriateness of CMS content, especially for those signs used in work zones. This research involved a survey study and a pilot experiment.

A survey was conducted as a preliminary investigation into the information content of CMS for road construction zones. Four CMS were used in the survey. The subject pool was restricted to 75 willing participants who stopped at a rest area on Interstate 35 West (Northbound) near Minneapolis–St.Paul. Two questions were asked about each sign concerning meaningfulness and the delay of journey. It was found that while a driver may understand the content of a message, it does not necessarily mean s/he can predict the consequences of the information, and vice versa. Variations of three signs used in the survey were also used the pilot experiment.

A pilot experiment was conducted to test the prototype dual–task system and to assess the effect of message type, display type, content, and repeated exposure to the signs on comprehension and translation. A total of 20 participants (mean age = 25 yr.) viewed a computer simulation of a stretch of road leading up to a work zone site which had optically expanding CMS along the road side. Signs were of two message types (for both speed and time signs), three display types (two inexpensive, one with full text wrap–around and one with partial wrap–around, and one expensive matrix of three lines by eight characters flashed twice), two similar message versions, and a complete repeat for reliability in a 2x3x2x2 design. The primary task required attending to a grid line in the rearview mirror and remembering which signal had appeared. The concurrent, secondary task was reading the message content with readability times comparable to traveling at 70 mph. Questions regarding the grid line signal and of sign comprehension and interpretation followed. The results demonstrated the potential ability of this methodology to evaluate CMS content. Also, message type significantly affected comprehension and translation, but display type did not.

Although preliminary, these findings suggest that all traffic signs are not created equal in terms of comprehension and interpretation. In situations, such as construction zones, where miscommunication can lead to fatalities, margins for error must be greatly reduced. The computer–assisted methodology employed by this research provides a more valid method of assessing message content by having visual expansion of CMS, consistent readability times, and varied display types in a divided attention task, with an opportunity to manipulate attentional demands of test subjects in video projection environments without expensive simulators, and to provide a method of evaluating CMS content.

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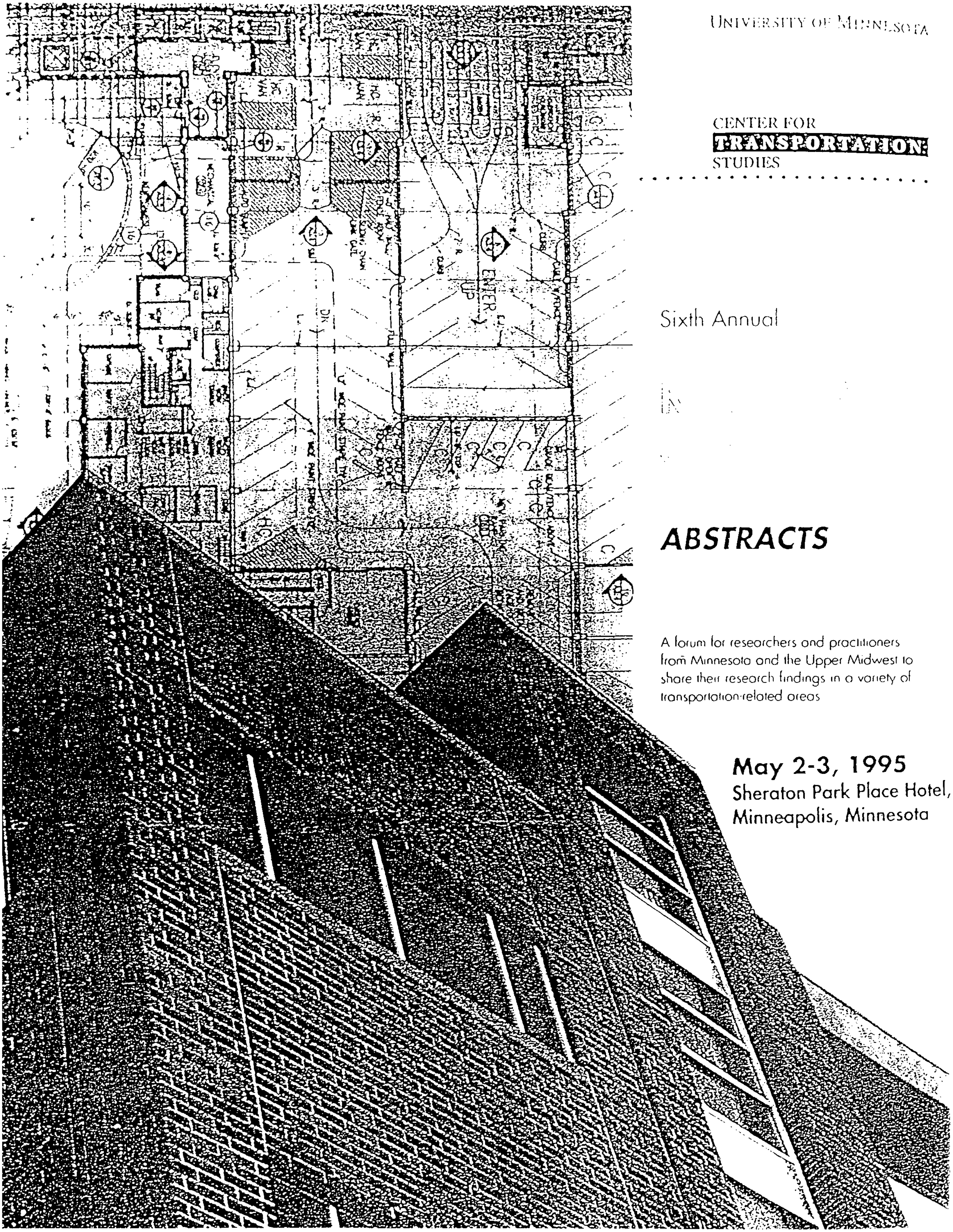


Sixth Annual

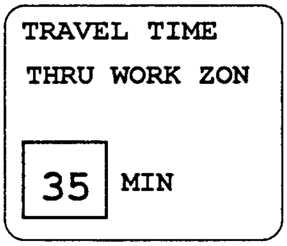
ABSTRACTS

A forum for researchers and practitioners from Minnesota and the Upper Midwest to share their research findings in a variety of transportation-related areas

May 2-3, 1995
Sheraton Park Place Hotel,
Minneapolis, Minnesota

APPENDIX I.

Simulation Experiment Sign Content: Time Signs



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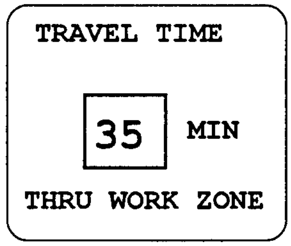

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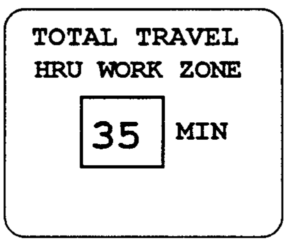

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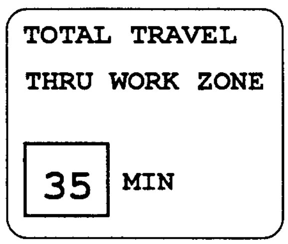

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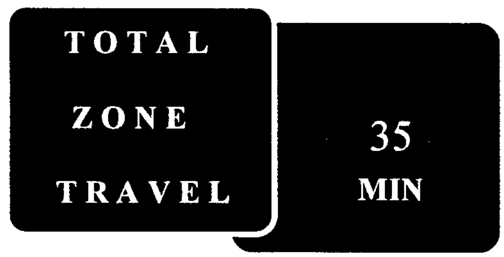

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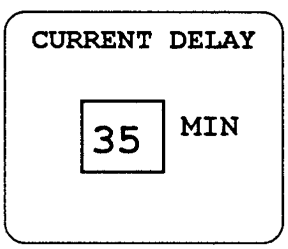

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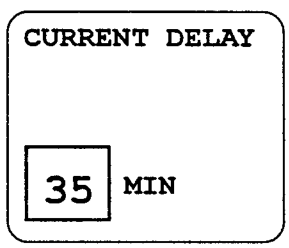

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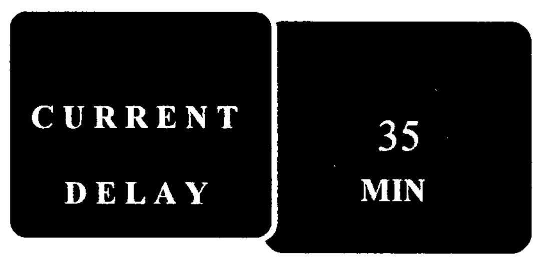

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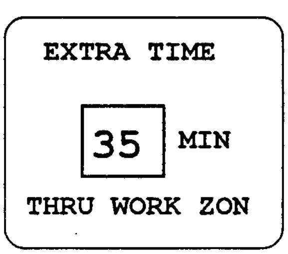

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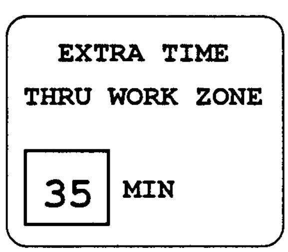

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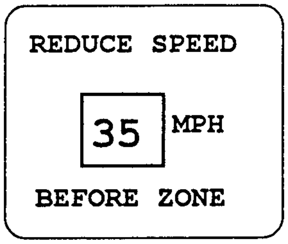
Delay D3 C2

Simulation Experiment Sign Content: Speed Signs



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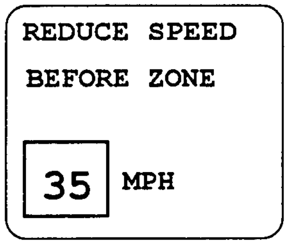

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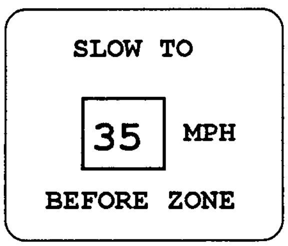

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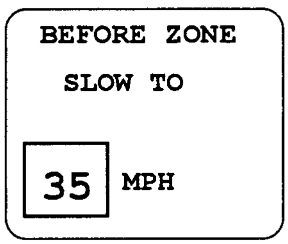

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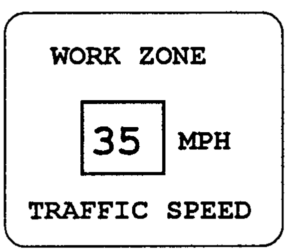

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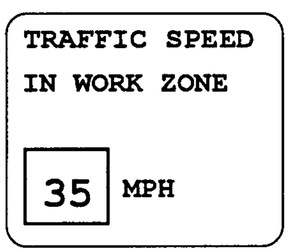

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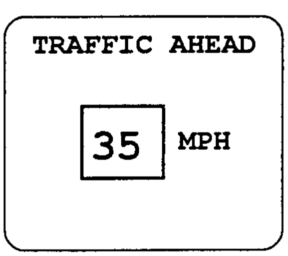

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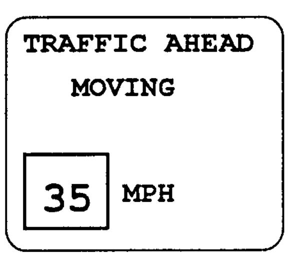

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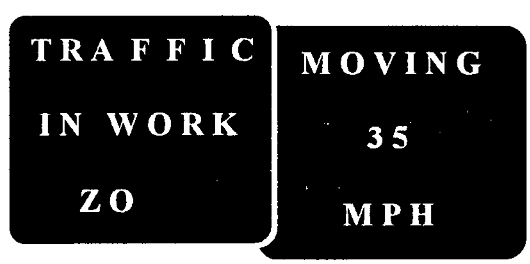

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