



Highway road signs : a comparison of sign location, letter case, and word order with respect to driver response time  
by Kathleen Kuk Bissonnette

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Psychology  
Montana State University  
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Subjects were selected from a pool of high school and university students. Selection was made on the basis of age, binocular visual acuity, and driver licensing.

A Mobile Traffic Education Simulator was used to simulate the physical driving situation. A T-2K Constant Illumination Tachisto-scope was used to present the stimulus materials.

Results indicate that sign location and letter case are mutually dependent ( $p < 0.01$ ). Closer investigation of this interaction reveals that pavement messages in upper case lettering are significantly better with respect to correct response time ( $p < 0.01$ ) than pavement messages in lower case lettering. No such difference was found to exist with respect to posted sign messages. There is some evidence to indicate that word order may have been confounded with reading strategy, both in the main effects and in interaction with the other variables.

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Date November 28, 1973

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Approved:

  
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## Abstract

The effects of sign location, letter case, and word order, on correct response time were studied using simulated highway posted sign and pavement located messages. The general experimental procedure employed in this research is a modified version of that described by Forbes (1964).

Subjects were selected from a pool of high school and university students. Selection was made on the basis of age, binocular visual acuity, and driver licensing.

A Mobile Traffic Education Simulator was used to simulate the physical driving situation. A T-2K Constant Illumination Tachistoscope was used to present the stimulus materials.

Results indicate that sign location and letter case are mutually dependent ( $p < 0.01$ ). Closer investigation of this interaction reveals that pavement messages in upper case lettering are significantly better with respect to correct response time ( $p < 0.01$ ) than pavement messages in lower case lettering. No such difference was found to exist with respect to posted sign messages. There is some evidence to indicate that word order may have been confounded with reading strategy, both in the main effects and in interaction with the other variables.

## Introduction

Although efficient motor vehicle transportation, primarily privately owned transportation, is of high priority value to the modern American lifestyle, failures in the driver-vehicle-highway system remain a major social problem. Any such man-machine system, in order to function properly, must be designed to minimize the possibility of error. In the driver-vehicle-highway system, the driver is in control. Thus, all elements of the system must be designed around his limitations and capabilities.

Interest in the human factors approach to highway safety began as early as 1927 (Forbes, 1972). The first research programs orientated toward driver behavior came as a result of recommendations by the National Research Council. Much of this early work was directed toward accident proneness - the psychology of the accident repeater. Other more universal problems were approached as well, during these early years. The effects of fatigue, vision, perception, and general attitude were among the more general topics considered. Such human factors research was and is used to guide traffic engineers and highway design.

One specific area of traffic safety which has attracted research interest is the task effectiveness of highway signs. A highway sign's task is to transmit necessary information to the highway driver. Failure to transmit information can be the result of several factors,

singly or in combination. First, the sign may be completely undetected by the driver. Sign location, sign to background color and brightness contrast, or stimulus overload may contribute to this kind of failure. Secondly, a message may be unreadable at the necessary distance in order for a correct response to be accomplished. Brightness contrast, letter size and width, spacing, color-any or all of these factors may be involved. Finally, the message information may be misinterpreted by the driver, thus yielding an incorrect response. The problem in this case is primarily message clarity - the degree to which the message is correctly understood.

This research investigation was designed to determine the effects of sign location, letter case, and word order on the correct response time of the automobile driver. In this study, the investigator attempted to examine the effects of these variables, individually and in combination, on the correct response time of the automobile driver with respect to simulated highway warning signs. Correct response time is defined as a composite of the time to detect, comprehend, and react to simulated highway warning signs.

Understanding the tasks in any given man-machine system is important to understanding the system. Task analyses of the automobile driving task are available in the literature (Forbes, 1965). The system is divided into three major components: 1) input or environmental stimuli, 2) driver information processing including sensing and per-

ceiving of information plus vehicle-directed response, and 3) vehicle response. The information processing component is primary to the specific problem of highway signing. First, one must consider the driving activity as the sign is approached. Studies on eye movements in the driving situation have shown that drivers' eyes are not simply fixating on the road surface ahead of his vehicle (Mourant, Rockwell, and Rackoff, 1970; Thomas, 1968). Instead, in situations where no car following is involved, the driver's eye fixations seem to occur primarily in the area above and above-right with respect to the road surface ahead of the vehicle. Occasional fixations on the road surface just ahead of the vehicle and in the opposing lane, as well as the area above the road surface in the opposing lane were also noted. Thus, sign location should influence the initial detection time, and consequently the total correct response time to the sign and sign message. Signs located where a driver is most likely to look should have the lowest detection time.

Signs must also be detected as relevant stimuli in the presence of other environmental stimuli. Considering the natural environment, the road, and the presence of other vehicles as a constantly changing, yet constantly present visual input, the amount of information bombarding the driver's visual sensory system is extensive. Assuming an unfamiliar highway situation, the problem seems to be one of selective attention.

Treisman (1969) made an important differentiation between focused and divided attention. A subject can either focus his attention on a single stimulus, or he can divide his attention between two or more stimuli. The sets of experimental questions regarding these two divisions of selective attention are independent. For instance, with divided attention the investigator should be testing the necessity of a selective mechanism. In this case, one might measure the extent to which the human being is capable of handling two or more sensory outputs efficiently - the extent to which attention is capable of being divided. With focused attention, however, the question changes to how efficiently can a human being select or focus on a single stimulus while ignoring all other information.

The driving task is primarily an example of divided attention. The driver is required to distribute his attention among several environmental factors in close temporal and spatial proximity. He must, for example, maintain vehicular position on the highway, be aware of oncoming vehicles in both the same and opposing directions, detect and comprehend all relevant signs, and be aware of any potential "danger points" in his environment. The complexity of the driving task is obvious.

As is implied in the example above, the driving task consists of several subtasks relying primarily on the visual sense. Although audition and kinesthesia are also important in the actual driving task (horns, bumps, speed, etc.) their roles seem to be basically supportive

to the visual tracking task.

Treisman (1969) indicated that the main limitation on efficiency is set by the double use of a single analyzer in the selective process. That is, then the same sense modality and essentially the same problem-solving process is required for the inputs among which attention must be divided, efficiency is low. Studies cited by Treisman (1969), indicated that efficiency in a visual-visual dual task problem is greater than that for an auditory-auditory dual task problem, but both are significantly inferior to a mixed (visual-auditory) dual task. Since the driving task is primarily visual, and that a considerable amount of the relevant information transmitted to the driver is done so through the visual modality, the auxiliary task using in this present study was designed primarily as a visual task.

Each subtask of the driving task is cognitively loaded. That is, each subtask requires a certain amount of cognitive processing time and effort by the driver in order to be successfully accomplished. This point was discussed by Forbes (1964) and Mourant et al (1970) and incorporated into their research. A driver has a cognitive load limit. Beyond this limit, a driver becomes systematically or nonsystematically selective of the information processed. Thus, the auxiliary task used in this present study was designed to contribute some degree of cognitive load, in order to simulate a true driving subtask.

The readability of a sign message is essential to sign task success. A sign appropriately positioned for easy detection and solitary in attention value is of no use to the driver if the message cannot be read and understood easily.

Tinker (1963) discussed the effect of letter case on the legibility of reading materials. His findings indicated that the lower case letters increase reading speed and accuracy of printed material. Larger upper case letters require more eye fixations per line than do lower case letters. Also, there is a component of familiarity favoring lower case letters over upper case letters. People in Western cultures normally read lower case lettering. Upper case letters have an advantage over lower case letters in that stimulus detection distance is greater for upper case letters than for lower case letters.

Forbes, Moscovitz, and Morgan (1950) tackled the problem of comparing upper case letters specifically for highway signing. They found that the sign familiarity increases recognition distance for both letter cases, but this increase is greater for lower case letters. Words printed in lower case have specific form or patterns due to the differing letter shapes. For this reason, the word form could easily be learned, and thus function as a symbol for the word message.

Whereas Forbes et al (1950) were concerned only with overhead destination signs, the present study tested the effects of letter case with respect to both pavement and posted sign message locations. Also,

Forbes et al (1950) used city name messages. Consequently, the lower case messages contained a mix of initial upper case letters. The present study used warning messages with uniform lettering over the entire message to eliminate any such mixing of letter case.

Tinker (1963) investigated the effects of word order on reading speed and accuracy. They verified the assumption that people of the Western cultures do best when reading in a top to bottom direction. Two word pavement messages, however, are uniformly printed in the reverse manner. One justification for such positioning is that the driver sees the word closest to him first, and consequently reads this word before the one to follow. This justification can be questioned, however. A critical minimum distance between the two words on the pavement has been set in the Manual on Uniform Traffic Control Devices (MUTCD, 1971). If both words are legible simultaneously at the critical distance, perhaps this distance is not sufficient to ensure the nearer word will be read before the further one. Considering the Western reading techniques, a strong tendency may exist to attempt a top to bottom reading strategy when possible. The present study was designed to study the effect of word order on the response time of drivers with respect to posted and, more importantly, to pavement located messages.

Thus, three variables were considered in this present research. These were sign location, letter case, and word order. In the MUTCD,

pavement messages are cited as being best under favorable conditions because these signs do not divert the driver's attention from the roadway. The research on drivers' eye movements cited previously indicate that a driver's eye fixations are not primarily located on the roadway. A substantial amount of time is spent observing the shoulder area. Thus, a difference in correct response time between posted sign messages and pavement location messages, given favorable conditions of weather, traffic, and roadway, may exist. The direction of this difference, however, may not be that indicated in the MUTCD (1971).

Letter case has been studied varying loop height, spacing, and width by Forbes et al (1950). In this present research, letter case is studied with respect to the standard alphabets (Standard Alphabets for Highway Signs, 1966). Following MUTCD specifications, upper case lettering is used in practice on all warning sign messages for both the posted and pavement message locations. The appropriateness of this procedure is tested in this present research with respect to correct response time.

Finally, Tinker (1963) indicated that in the Western cultures, normal reading order is top to bottom as opposed to bottom to top. Two word messages in the posted location are designed on a top to bottom basis, but two word pavement word messages are designed bottom to top. If both lines of a pavement message can indeed be seen simultaneously, then word order may be a factor affecting correct response time.

## Method

The general experimental procedure employed in this research is a modified version of that described by Forbes (1964). Stimulus slides taken of an actual driving scene with simulated highway signs, and identical scene slides without signs were presented tachistoscopically. An auxiliary task was used to load the subject and to assure a varied eye fixation pattern approximating that of actual driving conditions. The auxiliary task consisted of a combination visual search-consecutive counting problem. The primary task consisted of physical driving responses - braking, signaling, steering - made to specific instructions given by the sign message. The purpose of this research was to measure whether or not differences in correct response time occur under specific conditions. The use of still pictures limits the direct applicability of study results to those driving situations where a sign is suddenly exposed to the drivers' view. Some such traffic situations are rounding a curve, coming over a hill, or passing another vehicle.

## Subjects

A number of local high school and university students were available for this study. In order to control for within population differences in age, binocular visual acuity, and general driving qualifications, a set of criteria were imposed on subject selection. Each subject was required to be between the ages of 16 and 25, have 20-20 vision as measured by the Snellen eye chart test, and be a holder of

a valid (U.S.) driver's license. Due to the limits imposed by these criteria, and the relatively small university enrollment of summer quarter, recruitment of the required 80 experimental subjects had to be extended over several weeks.

The total subject sample consisted of 40 men and 40 women student volunteers. Of this sample, five men and five women were randomly assigned to each of the eight experimental conditions tested. Each subject received monetary payment (\$1.50) for his participation in the study. Each subject received 20 trials during the course of the experiment. The mean for these 20 trials constituted the dependent variable value for each subject in the analysis. The total experimental time for each subject was about 15 minutes.

#### Apparatus

A Mobile Traffic Education Simulator (Allstate) owned by the Montana Department of Public Instruction, was available for this research. Each of the 16 units in the simulator is a replica of the driver's side of a modern American-made sedan, complete with driving controls and dashboard. For purposes of this study, only one unit of the simulator was used in order to control for subjects' distance from the viewing screen. The subject to projection screen distance was 23 feet.

A T-2K Constant Illumination Tachistoscope (LaFayette Instrument Co.) was used to present the stimulus material. Each of the two

projectors was equipped with a 7 inch Kodak lens in order to provide a clear, full-screen image at the projector-screen distance of 54 feet. One of the projectors was set in a normally open position (scene-slide projector), while the second projector was set in a normally closed position (stimulus-slide projector). The settings were such that the two projectors were never both in an open position or a closed position simultaneously. The final effect was a constantly projected scene with signs suddenly appearing and disappearing.

The scene slide projector was used to maintain constant illumination throughout the course of the experiment, and to serve as a source of viewing material for the auxiliary task. This projector was open for durations of six to ten seconds. The number of seconds between stimulus slide presentations was determined according to a pre-arranged randomly selected sequence. (CRC Handbook of Tables for Probability and Statistics, 1966). This randomization was used to prevent the learning of a set time duration between stimulus presentations. The randomization schedule remained the same for all subjects in all conditions, and was manually controlled with the timing apparatus.

Correct response time (CRT), the dependent variable, was defined as the amount of time from stimulus presentation to the completion of a correct response. Correct response time was measured by an electronic Hunter 0.01 second digital timer and recorded manually by the experimenter. The timer was electrically set to start with the presenta-

tion of a stimulus slide and end with a correct response or at the end of three seconds, whichever occurred first.

The stimulus slide projector was electrically regulated to be open for three seconds. The slides, five messages with four replications of each message, were randomly arranged in the slide tray sequence. This random order remained the same over all conditions studied.

#### Stimulus Preparation

The experimental scene consisted of a one-half mile segment of rarely used state highway, a frontage road. Permission to use this highway segment was obtained from the Montana Department of Highways. For experimental reasons, brightness contrast and direction, and color were controlled factors in this study. These factors with respect to posted warning signs were changed so as to agree with the pavement messages in these specific dimensions.

Posted sign stimuli were made using 36 inch X 36 inch fiberboard painted with #658 Spar Enamel (dearborn gray - Gilt Edge). Stapled to the fiberboard were letters, seven inches in height, cut from white posterboard. Upper case letters followed the Series C design, and lower case lettering conformed to the same illustrated in Standard Alphabets for Highway Signs, 1966. See Figure C. A metal sign stub and sign blank were furnished by the Montana Department of Highways, and installed along the road in standard position, as defined in MUTCD (1971). The posted sign stimulus was mounted over the sign blank with

heavy wire in "picture-hanging" fashion.

Pavement letters were made from 24 inch wide white freezer wrap. Upper case letters were made in accordance with the standard pavement alphabet (Federal Highway Administration, Personal Communication, 1973). Lower case lettering was adapted from the lower case alphabet in Standard Alphabets for Highway Signs (1966), such that the full height letters (I, b, h, etc.) were eight feet in height. The elongation of the letters was such that for every one inch in width the letter was two inches high. Letters were individually attached to the pavement with gray sheet metal tape. See Figure D. Some problems arose in preparing the pavement messages for photographing. The exposures could only be taken when the sun was behind the camera, allowing only the morning hours to be utilized for this purpose. Also, the weather conditions had to be ideal for this purpose; dry roads and clear skies were necessary to provide favorable conditions. The wind posed special problems for pavement message preparation since the letters could not be secured well due to the crumbling pavement surface.

Relative sign message position was determined so as to control for visual angle differences between the pavement message and the posted message. The posted message was located in standard position at the right pavement edge, 63 feet from the camera lens. In Figure 1, line C marks the center line between the pavement message line 1 and the pavement message line 2. Thus, the final projected image of each

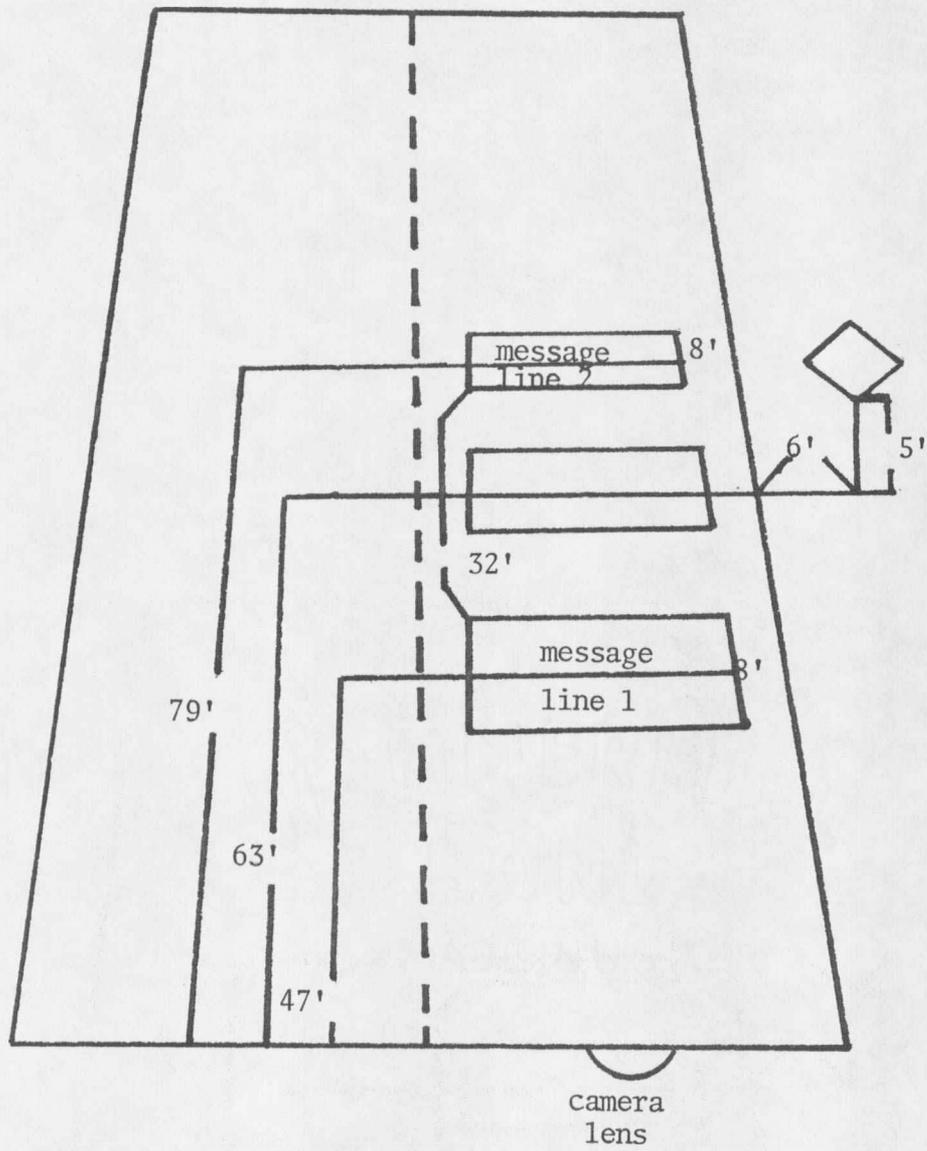


Figure 1. Physical sign location format

Table 1. Height of projected full-height letters

	<u>SPECIFICATIONS</u>	<u>POSTED</u>	<u>PAVEMENT</u>
UPPER	Total height line 1	2"	1"
CASE	Total height line 2	2"	3.5"
LOWER	Total height line 1	2"	1"
CASE	Total height line 2	2"	3"

posted message line was equal in height to the average of the projected pavement message line height, the average of pavement message line 1 and pavement message line 2. See Table 1.

Stimulus slides (35mm) were photographed from the driver's seat of a 1963 Buick Electra automobile. The camera (Nikon - 58mm lens) was secured to a tripod such that the lens be 46 inches from the pavement, the estimated eye position of a driver. All exposures were taken with the automobile located in the same position on the road (center of the driving lane) in a parked, "engine off" manner. The windshield remained in place while the photographs were taken. Slides of the experimental scene only (no signs) were taken within the same constraints of location and camera position. All photographs were taken using Ektachrome ASA64 slide film.

#### Procedure

Each subject was first tested for binocular visual acuity by means of the Snellen eye chart test procedure. He or she was then seated in the experimental unit of the simulator and given the instructions necessary for the completion of the primary and auxiliary tasks.

Primary task. The subject was instructed to engage in the auxiliary task until such time that a sign appeared in the projected scene. At this time, the subject was to stop the auxiliary task, and respond to the sign by doing what the sign message instructed. The sign message instructions all required a simple driving response; steer

left, steer right, signal left, signal right, and pedal right (brake with the right foot). These particular messages and responses were chosen with the capacities of the simulator in mind, as well as the applicability as warning messages and consequent responses. "Pedal right" was chosen to provide a foot response in opposition to the hand responses of the other messages. The phrase "pedal right" was coined in order to maintain the two word, similar length message pattern, and to include a direction similar to the other messages.

Auxiliary task. The auxiliary task consisted of searching the stimulus scene (no signs present) for objects which could be counted. The prescribed manner of counting was a modified consecutive numerical order. The subject was instructed to count in consecutive numerical order and attach to each number in the sequence an object in the projected scene which appeared at least that many times. For example, one telephone pole, two pavement stripes, three fence posts, etc. The purpose of this task was to insure that the subject was looking over the whole scene and not staring at the eventual sign message site.

General procedure. The experimental task consisted of responding to twenty sign stimulus slides, four replications of each of the five messages. The scene slide and the stimulus slides were alternated in tachistoscopic fashion. A practice period consisting of five sign stimuli and the scene slide preceded the actual test run. This practice was necessary to familiarize the subject with the signs, the messages,

the appropriate responses, and the auxiliary task. At the end of this practice session, the subjects were able to ask questions about the tasks. During this break between practice and test periods, the scene slide was projected to avoid any sudden changes in light intensity.

A small pilot run of the experiment suggested the problem of incomplete trials - trials in which no correct response was made. The problem was resolved by manually reversing the stimulus slide sequence and simply repeating the missed trial. The subject was unaware of this alteration and the times indicated no consistent effects. This technique was followed in order to insure a complete factorial arrangement and to maintain a constant number of subjects in all cells of the design. The subjects who required the use of the repeat technique appear in all cells of the design. No subject had more than two such repeated trials, and no trial was repeated more than once.

A post test interview was given a small informal sample of subjects in all cells of the design. Questions regarding the subject's interpretation of the message word order were posed at this time.

Randomization of subjects to the experimental cells was accomplished just prior to each subject arrival. Each of the 80 subjects were represented numerically according to cell on a small card. These cards were balanced according to sex, shuffled, and distributed into two large envelopes. The experimenter shuffled and drew a card from the appropriate envelope to determine cell assignment. The experimental

design was a completely randomized design in a 2 X 2 X 2 factorial arrangement. This design is illustrated in Figure 2.

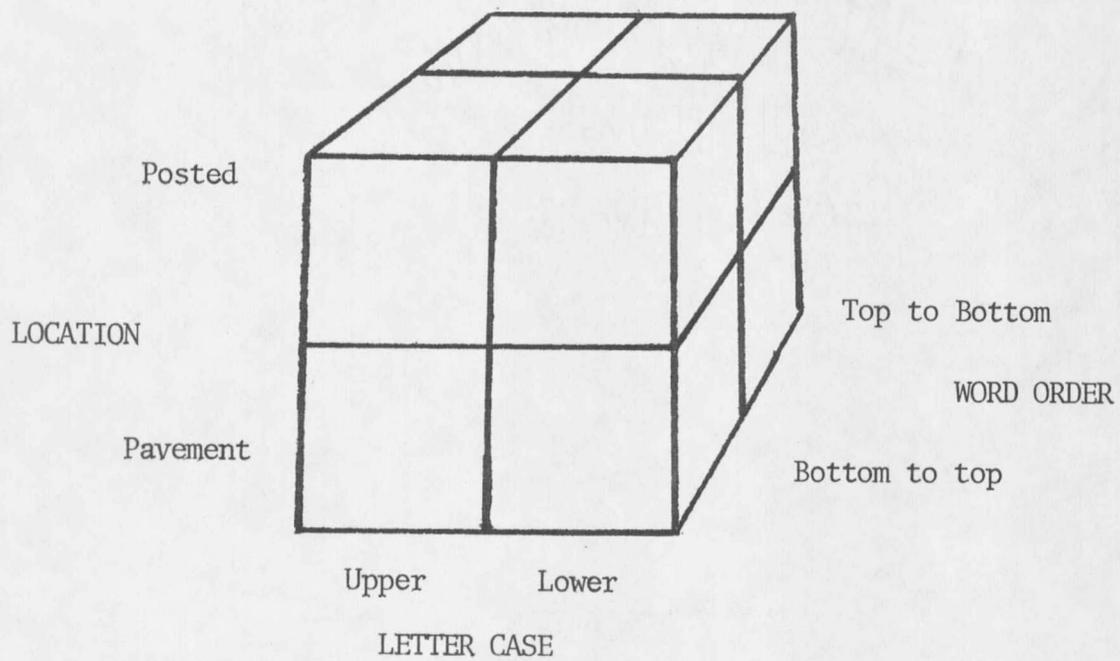


Figure 2. Experimental design

Completely randomized design in a 2 X 2 X 2 Factorial Arrangement: N = 70

Subjects: ten per cell; five male and five female.

## Results

Correct response time data were transferred to computer data cards and, subsequently, the computer was used to aid in analysis. Each subject was represented by a single dependent variable value, the mean CRT of his or her twenty trials. Data were combined for each cell over male and female subjects.

Statistical tests used in this analysis of the data were the analysis of variance, Duncan's Multiple Range Test, and correlations. The null hypotheses were tested at the 0.05 level.

Mean response times for the various combinations of experimental conditions are presented in Table 2. The combination yielding the shortest CRT was pavement-upper case-bottom to top, while that combination yielding the longest CRT was pavement-lower case-top to bottom.

Means for each level of the three independent variables studied were also calculated. See Table 3. The largest between level difference occurred with letter case; the upper case mean being 0.076 seconds shorter than the lower case mean. Sign location has the next largest between level difference; the posted mean being 0.048 seconds longer than the pavement mean, while word order had the smallest between level difference.

The analysis of variance is shown in Table 4. The interaction of location and letter case was significant at the 0.01 level. A graph of this interaction (Figure 3) is useful to illustrate just what this significance indicates. Mean CRT for the posted location appears to

Table 2. Cells means (sec.)

<u>CONDITION</u>	<u>MEAN</u>	<u>CONDITION</u>	<u>MEAN</u>
Posted Upper Top to Bottom	1.369	Pavement Upper Top to Bottom	1.221
Posted Lower Top to Bottom	1.272	Pavement Lower Top to Bottom	1.462
Posted Upper Bottom to Top	1.411	Pavement Upper Bottom to Top	1.211
Posted Lower Bottom to Top	1.408	Pavement Lower Bottom to Top	1.373

Table 3. Mean correct response times for the three independent variables

I.V.:	SIGN LOCATION	LETTER CASE	WORD ORDER
	Posted	Upper case	Top-bottom
	1.365	1.303	1.331
	Pavement	Lower case	Bottom-top
	1.319	1.379	1.351

Table 4. Analysis of variance

SOURCE	SS	df	MS	F
Location (A)	0.0465129	1	0.0465129	1.33
Letter case (B)	0.115292	1	0.115292	3.31
AB	0.315507	1	0.315507	9.05**
Word Order (C)	0.007900	1	0.007900	0.23
AC	0.094806	1	0.094806	2.72
BC	0.0002664	1	0.0002664	0.01
ABC	0.0374543	1	0.374543	1.07
Between	0.617730	7		
Within	2.50893	72	0.0348463	
Total	3.12667	79		

\*\* p = 0.01

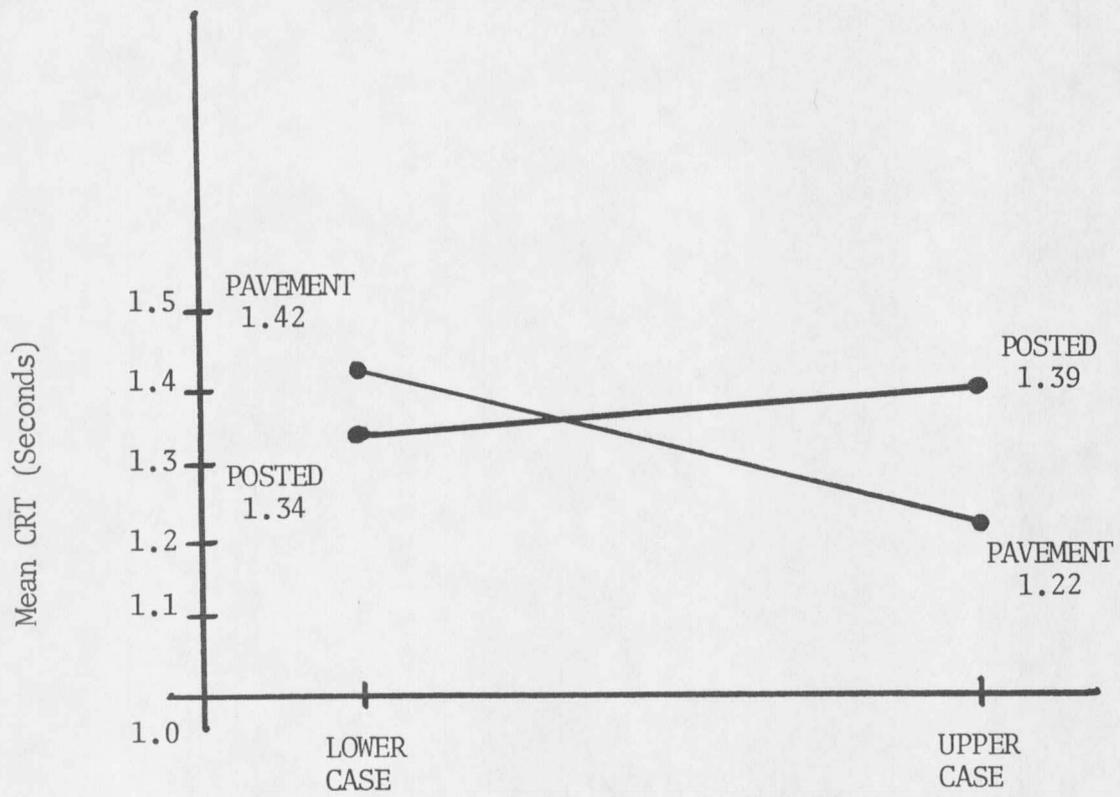


Figure 3. Interaction of location and letter case.

vary only slightly with letter case; the upper case posted mean is 1.39 and the lower case posted mean is 1.34 seconds. A test of this difference using Duncan's Multiple Range Test indicated that this difference was not significant.

The situation is different with the pavement location, however. Here the difference between upper case pavement and lower case pavement is quite large (difference = 0.20 seconds). This difference is significant at the 0.01 level using Duncan's Multiple Range Test.

Figure 3 also illustrates the effect of letter case on the differences between the two sign message locations. For the lower case conditions, the difference in CRT between sign locations is smaller than for the upper case conditions. The difference between sign locations for lower case conditions is not significant at the 0.05 level. The difference between sign location for the upper case conditions is significant at the 0.01 level.

Correlations among response times for the different sign messages were also determined and appear in Table 5. One interesting phenomenon appears in the correlational analysis. "Signal" message commands correlate most highly with the command (i.e. signal right with signal left and vice versa) while the "steer" message commands correlate most highly with the direction (i.e. steer right with signal right and steer left with signal left). Although these correlations are not significantly higher than the others, the pattern is consistent.

Table 5. Message correlations

	Pedal R.	Signal L.	Steer L.	Steer R.	Signal R.
Pedal R.	1.0000	0.5018	0.4553	0.5206	0.4753
Signal L.	0.5018	1.0000	0.6072	0.5817	0.6883
Steer L.	0.4553	0.6072	1.0000	0.5992	0.5637
Steer R.	0.5206	0.5817	0.5992	1.0000	0.6275
Signal R.	0.4753	0.6883	0.5637	0.6275	1.0000

The third independent variable studied was word order. Analysis indicated that the two levels of word order examined - vertical top to bottom and vertical bottom to top - were not significantly different. See Table 5. Apparently, the sign messages studied were comprehended with equal ease under both conditions of word order. But there are supplementary data which temper this conclusion.

Sex differences in CRT were also analyzed. There was no significant differences in CRT between males and females overall in this study.

## Discussion

In the Methods section, mention was made that the methodology used in this study was a modified version of that described by Forbes (1964). The most important procedural modification lies in the design of the auxiliary task. Forbes (1964) used a visual, cognitively loaded task essentially involving the relighting of a set of lights located at road level on the projection screen. In the present research procedure, the subject is required to search the entire projected screen for objects which could be counted in the prescribed manner. This task, too, is a visual, cognitively loaded task. In this latter task, a large majority of the countable items or objects appear in the area just above the road surface and to the right of the driving lane. Referring to the eye movement studies cited earlier, Mourant et al (1970) and Thomas (1968), this area is that in which most eye fixations occur in the driving task, assuming no car following. Thus, this modified task is designed to yield a closer approximation to actual driver eye movements. With his auxiliary task, Forbes was able to insure that each subject's eyes would travel the same "route", distance and direction, from the auxiliary task stimulus to the primary task stimulus, for any given stimulus presentation. In the present study, this control is not present, and thus the task yields a higher individual difference in this category than does Forbes'. The trade-off was made between experimental control and the realism of actual driver eye movements.

A second very important methodological modification made in this present study was in the subject's response to the primary task. In Forbes' technique, the subjects simply pressed an appropriate button to indicate his response to the primary stimulus. In the present study, on the other hand, the emphasis was placed on closeness to the real driving situation. Subject responses are designed to be actual driving responses made to the sign message information. Response times most important to the driving situation are driving type responses.

In reviewing the main effects of the independent variables considered here - sign location, letter case, and word order - it must be concluded that these variables do not influence CRT independently. Letter case and sign location effects were mutually dependent. Word order may have been confounded with reading strategy in this study; a point which will be discussed further in later paragraphs.

The possible implications of the significant interaction between letter case and sign location are important on both an applied and pure experimental planes. First, within the posted conditions, there was no significant difference in CRT between upper and lower case lettering. The sign messages were designed to be relatively unfamiliar in terms of wording. Assuming these messages to be, in fact, unfamiliar to the subjects, then perhaps any advantage the lower case lettering should have had as a result of learning (Tinker and Paterson, 1950) did not have sufficient time to be detected. Forbes (1950) found that

legibility distance increased more with lower case letters than with upper case letters as familiarity increased. If CRT and legibility distance are highly correlated, then one could conclude that, in time, performance on lower case lettering on posted sign messages would surpass the performance on upper case lettering.

With the pavement conditions, however, there was a significant difference between upper and lower case lettering - upper case being superior to lower case in CRT. Again this effect could well be modified by learning; lower case messages may not have had sufficient time to demonstrate greater effectiveness. Another explanation may be familiarity. Familiarity has been established as a factor in recognition distance (Forbes, 1950). Keeping reaction time constant, an increase in recognition distance would logically yield a decrease in CRT - CRT being measured from a constant initial distance beyond the furthest recognition distance. All pavement word messages are presently written in upper case. Thus, upper case pavement messages may simply be more familiar to the highway driver than pavement messages in lower case.

Lower case lettering, then, had no effect on CRT for the posted message location while significantly increasing CRT for the pavement message. Perhaps this phenomenon can be explained in terms of shape recognition. Hake (1957) stated that there is evidence to indicate that the shape of an object (in this case, a word) is not invariant

with orientation. In fact, an object can be partially defined in terms of orientation characteristics. Words written in lower case and positioned in the posted message location are in a familiar reading orientation. Words written in lower case and positioned in the pavement message location, however, are not in a familiar reading orientation. Some positive transfer of shape recognition could logically take place from common reading materials to posted sign messages due to the similarity in orientation. Thus, less time would be needed for the shapes to be recognized in the posted message location than if no positive transfer had taken place. If in fact lower case word shapes are partially defined in terms of orientation characteristics, then a negative transfer of shape recognition would be expected to occur from common reading materials to pavement sign messages due to the differences in orientation. Thus, more time would be needed for the shapes to be recognized in the pavement message location with negative transfer occurring.

Words in upper letter case are uniform in shape; all words are rectangular. Thus, the learning of word shape and word shape recognition should not play an important role in defining words in upper case lettering. The shape orientation problem discussed relative to lower case lettering would not apply to as great an extent to upper case letters. Little or no transfer would be expected to occur, positive or negative. Therefore, CRT should not be affected one way or the other

by shape orientation or shape recognition.

The major implication of the significant finding for signing design is a warning about warning signs. New innovations found to be effective for one sign location may not be effective for another sign location. For instance, the new international signs, once learned, are expected to reduce CRT over posted word messages (MUTCD, 1971). The effect on CRT of these symbols used in the pavement location is conjecture at this point, and should not be assumed. If the hypothesis is correct that the shape orientation is in part defining the shape, then there is a strong possibility that using these symbols in both orientations would yield confusion and increases in CRT.

One might suggest from studying Figure 3 that the combination of pavement location upper case lettering has the lower mean correct response time, and is therefore the "best" of the combinations studied. To be sure, applying Duncan's Multiple Range Test, this combination has significantly lower CRT than all the other combinations.

This argument has one severe limitation, however. The results apply only to the experimental conditions given, a characteristic of any Fixed Constant design. While the pavement located messages were designed in apparent closeness to the standards expressed in MUTCD (1971), those in the posted location were not. For experimental reasons, color, brightness contrast and direction were controlled; the posted sign being changed to agree with the pavement messages in

these specific dimensions. These factors have been shown to contribute quite highly to the task success of the sign messages. (Forbes, Pain, Joyce, and Fry, 1968; Pain, 1969). In these respects, then, the posted message suffered the disadvantage over pavement messages. Therefore, the data processed here for the posted location is negatively biased with respect to standard highway warning signs, and should not be considered equivalent to warning data. In light of the data, the inclusion of standard posted warning signs in the framework of this present study would have provided a test of these allegations.

Word order as a main effect and in interaction with the other variables had no apparent effect of CRT. There was some evidence, however, which indicated that the variable could have been influenced by another, uncontrolled factor, reading strategy.

A small informal sample ( $N = 13$ ) of post test interviews, taken from those subjects receiving the pavement location condition, indicate that there were at least two different reading strategies employed by those subjects. The first strategy - the traditional one in Western cultures - is the straightforward top to bottom order. The second strategy is the "read the larger word first" technique - thus bottom to top on the pavement. Both strategies seemed to have been employed in spite of any given message word order. Certainly, the traditional strategy would logically yield shorter CRT's in the top to bottom conditions. Of course the reverse would be true in the case of the other strategy. Referring to Table 2, one will note that the mean CRT's

within the pavement conditions as a whole were consistently shorter for the bottom to top conditions. Perhaps this fact indicates that the "read the larger word first" strategy was used more frequently than the traditional one. Considering that the two reading strategies are necessarily opposing, then one might consider the possibility that the strategies were working against each other within the word order conditions, thus cancelling out at least partially what may have been a word order effect.

Further evidence that this confounding may have taken place is available from the data for the posted location conditions. Those subjects sampled under these conditions ( $N = 10$ ) all indicated the use of the standard strategy - the traditional top to bottom order. Referring again to Table 2, the cell means for the posted conditions indicate that the top to bottom word order yields consistently shorter CRT's. Also, one might note that the differences between top to bottom and bottom to top word order conditions for the posted location conditions are much greater than those for the pavement location conditions. Perhaps the smaller difference occurring with the pavement location conditions is due to some cancellation resulting from the use of the opposing strategies.

Some important information may be gleaned from this apparent confounding of word order with reading strategy with specific reference

to pavement word messages. Two distinct and opposing reading strategies were employed in the pavement conditions. One must consider the effect of this finding on the argument for the present pavement word order system. The basic argument is that a driver sees and reads the first word he approaches before he sees and reads the ones remaining. If in fact this reading order is desirable, then the present critical distance between any two pavement message lines is not sufficient. The present critical distance apparently does allow for the use of another reading strategy. A major requirement of a successful man-machine system is the minimization of human error. Reading a message backwards logically yields temporary confusion, and even temporary confusion can lead to error.

Several procedural variations and independent variables for consideration were left for further research. The most obvious procedural variation lies in the stimulus presentation. For strict laboratory or simulation research, moving picture presentation of the stimulus material should be approached. Moving pictures would allow for more generally realistic presentation, as well as rather naturally approximating the normal driving behavior including eye movements. The problem of the dependent variable arises with moving picture presentation. A technique used in the educational films accompanying the Mobile Traffic Education Simulator and developed for its use by Allstate, may be a feasible solution. In these films, correct driving responses are

programmed into the sound track of the film. For instance, if a student should be applying his brakes at a particular moment of the film, the programmed directions will check for the correct response. Similarly, a point from which a response measurement should begin could be so programmed. This technique would give a constant point from which time could be measured. Although expensive and technical in preparation, this technique could be useful in incorporating realism into the laboratory.

Ideally, of course, an actual highway surrounded by a relatively constant environment would be desirable for complete realism. But the natural environment is by nature uncontrolled. Thus, in order for the natural situation to yield usable results, we need data on these variables uncontrollable in the natural environment. Therefore, the need for further laboratory and simulation research is essential.

The amount of information gained from human factor research with specific relevance for highway signing is extensive. This information has been used to improve the task success for signing in many different dimensions. Due to the importance and relevance of human factors research to highway safety problems in general, one final suggestion needs to be made. On page 5 of the MUTCD (1971), future publications should justifiably read:

"The decision to use a particular device at a particular location should be made on the basis of an engineering study of the location with full consideration of the human factors involved."

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Appendix

SIGN	TIME	SIGN	TIME
6	pedal right	6	signal right
9	signal left	7	pedal right
10	steer left	8	steer right
7	steer right	9	signal left
10	pedal right	8	steer left
6	pedal right	6	steer left
9	signal right	9	signal left
7	steer right	8	signal right
9	steer right	7	steer left
6	signal left	10	signal right

COMMENTS:

CELL # \_\_\_\_\_

DATE \_\_\_\_\_

TIME \_\_\_\_\_

Figure A. Experimental Recording Sheet

This study is concerned with highway signing and driver response time. You will be required to accomplish two tasks in succession, one right after the other. First, a scene will appear on the screen. Like this \_ . While maintaining normal driving position i.e., hands on wheel and your right foot on the accelerator pedal, you are to count any items you can identify in this picture in the following manner:

- 1 ..... (fence post)
- 2 ..... (trees)
- 3 ..... (clouds) etc.

Count these items OUT LOUD as accurately and as quickly as you can. If you are unable to find the next number of items, you must immediately return to 1 and begin again. You must continue to count in this manner until a sign appears in the picture. At this time, stop counting, read the message on the sign, and respond by doing what the sign says: STEER RIGHT, STEER LEFT, PEDAL RIGHT, SIGNAL RIGHT, STEER LEFT. (DEMONSTRATE) Respond to the sign as quickly as you can and as accurately as you can. This sign will remain on the screen for only a very few seconds.

Soon after you respond, the sign will disappear and you will begin counting again. This will begin your next trial. You may repeat any items used in previous trials plus any new ones you choose. You may re-use any item anytime you return to 1 and begin again. Now we will begin a practice set to get you acquainted with the task. Count and respond to this practice set just as you would the real thing. After the five practice trials, a slide will appear upside-down - that will be the cue that the practice is over and the experiment is about to begin.

REMEMBER: COUNT OUT LOUD - THE OBJECT IS TO GET YOU TO LOOK ALL OVER THE PICTURE SO DON'T JUST STICK TO ONE PLACE.  
RESPOND TO THE SIGN AS QUICKLY AS POSSIBLE AND AS ACCURATELY AS POSSIBLE. WRONG RESPONSES WASTE TIME AND ONLY CORRECT RESPONSES CAN STOP THE CLOCK.

Figure B. Primary and Auxiliary Task Instructions



Figure C. Examples of the posted located sign messages



Figure D. Examples of pavement located sign messages

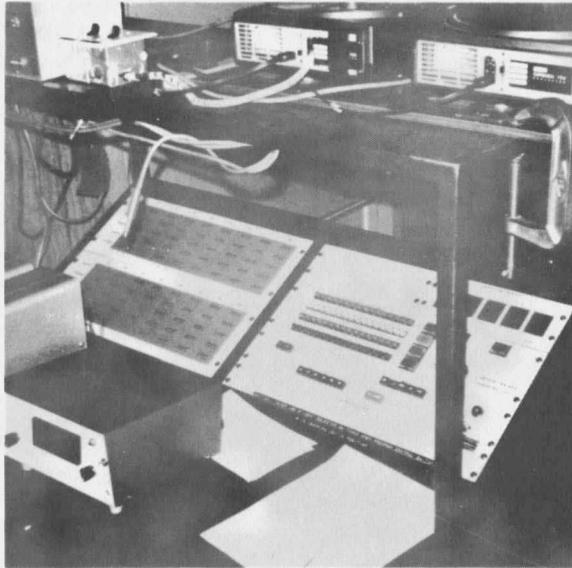


Figure E. Controls, timing equipment, and dual tachistoscope (Top), and the experimental simulator unit (Bottom)

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	Piper <sup>1972</sup>
FEB 2 1973	B. McGuffee
OK	John McNeil

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