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

Abstract:
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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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Chairman, Examining Committee

Graduate Dean

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Abstract

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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 perceiving 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 on 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 kinesthesis 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, Moscowitz, 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 criticle 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 prearranged 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 presentation 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 (l,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

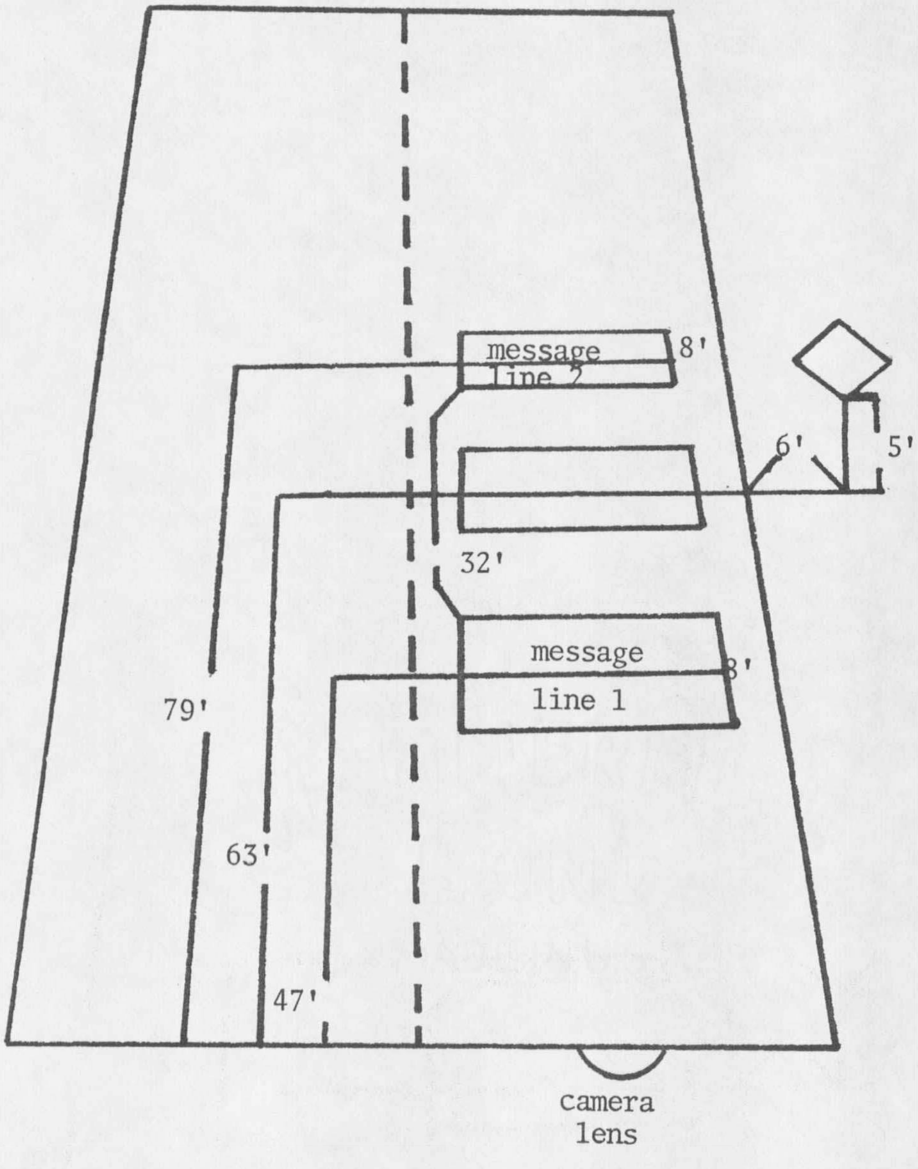

Figure 1. Physical sign location format

Table 1. Height of projected full-height letters

	SPECIFICATIONS	POSTED	PAVEMENT
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.