Traffic Sign Requirements

I. Review of Factors Involved, Previous Studies and Needed Research

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Published research reports for 10 years were systematically searched for studies of factors affecting highway sign effectiveness. Attention gaining characteristics proved to have been relatively little studied compared to legibility, but were indicated to be of equal importance.

Analysis of the driving task indicates the importance of multiple response tasks in measuring attention gaining characteristics. Further research on the latter is planned.

•MANY studies have been done on characteristics of street and highway signs to improve their effectiveness. Many of the results of these studies over the last 30 years have been put into practice by traffic engineers and sign designers to achieve a great improvement in traffic sign effectiveness. In some early studies both attention value and legibility factors were given some study. Since that time, however, the greatest amount of research has been on sign legibility and much less on attention value and what the message should be.

The present study, therefore, was undertaken to review previous research and to carry out further research with a special emphasis on attention factor problems.

This preliminary report analyzes the driving task in a simplified way using the "human engineering," "engineering psychology," or "man-machine-systems analysis" approach. It then summarizes briefly previous research reviewed. It also indicates briefly types of studies known to be under way. Finally, it suggests general areas which should be studied and those it is proposed to attack first as next steps in this study.

MAN-MACHINE ANALYSIS OF THE DRIVING TASK

To analyze the variables and interrelationships playing a part in traffic sign effectiveness, it is first desirable to analyze briefly (in very much over-simplified form) the factors in the automobile driving task. Most people are so familiar with driving that is is assumed to be a simple human performance. On the contrary, when analyzed into the number of tasks which are carried on simultaneously and the functions which the human is performing, automobile driving proves to be a most complex human performance.

The driver's task was descriptively analyzed very briefly by Forbes (1) and in great detail by Miller (2). Both of these analyses as well as others which have been made showed the essential complexity of the automobile driving task.

However, a highly simplified man-machine-environment analysis of the block diagram type has become fashionable and has the great advantage of stimulating greater consideration of factors involved by diagrammatic visual presentation. Rather extreme simplification of most human performances is required to apply this approach. Figure 1 presents such an oversimplified schematic analysis.

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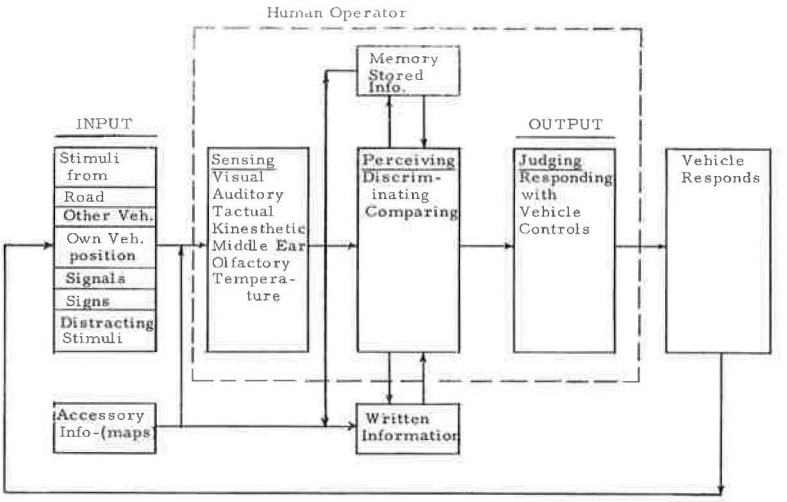

Figure 1. Man-machine-environment analysis.

A careful analysis of human operator performance in a man-machine-environment system shows that the operator represents several functions in the control loop (3). This type of analysis has been very helpful in analyzing man-machine problems in other areas and is equally applicable to automobile driving.

The driver can be viewed as a sensing, discriminating, evaluating, and responding series of units (Fig. 1). The resulting responses act through the controls of the vehicle, changing the vehicle's behavior which then feeds back and modifies the input to the sensing mechanism again. The input to the sensing mechanism includes the various road characteristics and stimuli from other vehicles on the road. It includes stimuli from his own vehicle, visual impressions for signs, signals and markings of all types. Finally it includes distracting stimuli from other objects and people who are not a part of his driving task, but which may attract his attention away from this task.

The sensing mechanism of the human involves visual, auditory, and other sensory types of stimulation.

The perceiving and discriminating function includes interpreting the various pattern of stimuli. It may involve comparing them with stored information from memory and possibly with accessory information from road maps and other previous instructions, visual or auditory.

As a result of the discriminating and comparing function, evaluations and judgments are made by the driver in determining his own responses with the controls of the automobile. These control responses affect the vehicle's behavior, and this in turn feeds back and affects the sensory input from his own vehicle's speed and position on the street or highway.

Complexity of the Driving Response

Even this simplified analysis points out the basically complex nature of the task of the driver. Although the skilled driver carries on many of these tasks almost automatically, it can be shown that the number of sensing, discriminating and judging procedures continually carried on is large because of the number of different characteristics of the road, of the behavior of other vehicles, of the behavior of one's own vehicle, and of the various instructions from signs and signals and markings. In addition, distracting stimuli may range all the way from listening to a football or baseball game on the radio or noticing activities at the roadside picnic to trying to quell a minor riot in the backseat by two or three small members of the family.

Multiple Task Required for Measuring Sign Effectiveness

It has been shown conclusively that increasing the number of stimuli and responses of any task increases its difficulty and the time required for an adequate perception, judgment and response (4). Therefore, although a driver may not always realize that his driving responses are affected by these multiple input stimuli, it is certain that they will be. For this reason, valid measurement of the effectiveness of street and highway signs requires a procedure which includes multiple input and output tasks of some sort. This is especially important for visibility and attention value studies, since they include much more than the simple question of whether the sign lettering can be read at given distances. Pure legibility measurements can be made without requiring multiple tasks. But the question of whether a given sign is actually read on the highway under the actual conditions of driving will depend on the effect of multiple inputs and outputs to the human responding mechanism.

A review of previous work by many investigators indicated that some of the previous studies have (and some have not) attempted to take account of the effect of the complexity of the driving task.

PREVIOUS RESEARCH LEGIBILITY STUDIES

A brief summary of some 40 of the most pertinent out of 210 reports follows.[1]

Measurement of Legibility

Among the earliest highway sign legibility studies, Forbes (5) distinguished between "pure legibility" and "glance legibility." The former was the distance at which highway signs could be read with the subject taking his own time and the latter was the distance for reading test signs under short glance conditions using a shutter to limit to approximately 1.0 second the time during which the sign was visible. To measure either type of legibility, control of previous knowledge and other psychological variables is vital. The observers must not know ahead of time what letter recommendations are going to be seen. A large number of observers representative of the driving public should be used, their visual acuity should be known, and a number of observations per person should be made. Many studies of sign legibility have been made, some with observers walking and recording signs read (6, 7) and some with either signs or observers moving and indicating signs read in other ways (8, 9, 15).

For wide design capital letters of the Series E or Series D type, legibility distances have been shown to be approximately $Y = 50X$, where Y is legibility distance in feet and X is letter height in inches. These values were such that 85 percent of the drivers would be included, (6, 7).

Words Read at a Glance

One of these studies (5) showed that only three or four short, familiar words could be read at a single glance. Signs were exposed with a shutter arrangement for approximately 1 second. The findings were essentially confirmed for the rounded capital letter standard alphabet (10).

Letter Size and Sign Location

At least two studies (11, 12) have calculated a basis for determining letter size and sign placement in relation to the point of required maneuver. Legibility distances, and a minimum time for maneuver and for rate of deceleration were used. Mitchell and Forbes used 1.0 second as minimum glance time for a 3 word sign and doubled it to allow for a second chance. Odescalchi et al. used a longer time as a result of Road Research Laboratory studies which measured time for a subject to find a destination name among 3, 6, or 9 destination names on the test signs. The subjects also were

[1] Total titles considered as possibly pertinent—397; total titles considered pertinent and checked—211; selected as most pertinent, read and abstracted—110.

required to give the proper direction after returning to a continuing alternate task (responding to a signal device inside the car).

Both United States (13) and British (14) standards recommend letter heights of 4 to 12 inches (height of wide capital letter or lower case letter "loop" height) for different road and speed conditions.

Letter Width and Spacing

Many other studies of various factors affecting legibility have been reported. Reported as optimum are a height, stroke-width ratio from 4 to 1 through 6 to 1 (15, 16, 17). With wide design letters a spacing of one-half the average letter width (18), a spacing adjusted for area between letters (7), and even wider spacing (19) have been found desirable. With a higher letter brightness, a narrower stroke width increases legibility by reducing merging of strokes from retinal irradiation (20).

Color and Contrast

Early studies (21) showed black on white and black on yellow to be of greatest contrast and legibility. More recently legibility has been shown to be as good or better under some conditions with white letters on a black background (22). Also, a careful study of sign brightness and legibility by Allen and Straub (23) indicated that the effect of illumination, letter design and contrast direction for best legibility is dependent on the brightness level of letters and background. For a given letter design, very high brightness may reduce legibility in a dark surround but may be required in illuminated surroundings (23). This confirms an observation in an earlier study (7).

Summary

It is not within the scope of this paper to go further into legibility studies. However, it can be seen that considerable information on the various characteristics affecting highway sign legibility has been obtained by experimental research. Further systematic studies of such factors as brightness, stroke width, and spacing are desirable in order to measure more carefully their interaction. However, for practical purposes the legibility distances of the standard alphabet letters recommended by the National Joint Committee on Uniform Traffic Control Devices are well known.

PREVIOUS RESEARCH--VISIBILITY AND ATTENTION FACTORS

Assuming that the lettering or the symbols on a sign have been designed to achieve a sufficiently long legibility distance for the conditions, there remains the important question whether the sign is actually "seen" by the driver. That is, does he actually respond to the visual stimulus represented by the sign. There are at least two questions involved here: that is, (a) visual detectability of the sign often spoken of as visibility and (b) attention gaining characteristics of the sign when it is well within visibility range.

Visual Detectability Studies

One group of studies dealt with visibility through tinted windshields or glasses. These usually involved night conditions and visibility of low contrast objects on the highway. These studies therefore are not of direct applicability and interest in connection with sign visibility.

Another research series studied threshold visibility. These measured the various brightness, contrast, illumination, atmospheric absorption, stimulus size and shape and other characteristics affecting the longest distance and the smallest target which can be visually detected. Among these Middleton (24) summarized much of the earlier work and Blackwell (25) reported one of the more recent studies. Other studies compared fluorescent and nonfluorescent painted targets for visibility at maximum visual range and reported some advantage for certain fluorescent colors (26, 27).

These studies are of most importance for visual search from aircraft and similar

problems. They are probably less applicable to the problem of what causes traffic signs to be seen or not seen when well within visual range. Some of the same factors may be of importance but probably not others.

The studies in the preceding paragraph were most concerned with day legibility. Stalder and Lauer (28) measured visibility at night from reflectorizing low-contrast objects. They showed that a few larger areas were better than many small reflectorized spots for this purpose.

Need for Attention Gaining Characteristics

Attention gaining characteristics are of importance when signs must be seen in competition with other signs or background objects. This is usually a situation where signs are well within the visibility distance threshold and, therefore, can be seen and read without any question of limitations from legibility or threshold of visibility. Forbes (5) reported a study in which drivers followed a test course on the highway and reported all signs as they saw them. From this, two classifications of factors were defined: (a) those contributing to "target value," which applies to physical characteristics such as brightness and color contrast or sign, which make one sign stand out relative to other signs and the background; and (b) "priority value" was defined as those factors of driving habits or reading habits, etc. which lead to one sign being seen earlier than others. As examples, target value would result from large size and high contrast of a sign with background and with other signs, whereas priority value would occur from such habits as reading from left to right and, therefore, would result in the greater likelihood of top, left hand name of a destination sign being seen first.

The need for such characteristics for sign effectiveness was shown in this study by certain yellow warning signs, such as a crossroad symbol sign, which were reported only one-half as far away, approximately, as they could be seen and read if the observer were intentionally looking for them (observed under daylight conditions against a straw-colored terrain).

Roper (29), in a study of seeing at night, reported unexpected objects to be seen only about 50 percent as far as the same objects under the same conditions when the driver was actively looking for them. Thus when multiple tasks are involved, as in ordinary driving, both objects and signs can be expected to be seen at less than their legibility or visibility threshold distance. Under these circumstances factors increasing the relative attention value of signs are of great importance.

Studies Involving Physical Attention Gaining Characteristics

Relatively few studies of attention gaining characteristics of signs have been carried out in the highway field. Elliott (30) traced the history of pictorial symbols for use on traffic signs and pointed out their advantage, especially where multiple languages are involved. A study of highway signs in Virginia by Decker (31) included both signs (green on white and white on blue) and striping (red on white, yellow on black, and black on white) of different widths for obstacle marking. Both day and night observations were made with observers in a vehicle moving toward the test targets. Average legibility distances were given for the signs and preference ratings for the striping.

The 6-in. diagonal striping was preferred to the 5-in. and 3-in. stripes, although there were some reversals in the results. This was true for both day and night observations. The white letters on blue background were reported to give somewhat longer legibility distances at night compared to the green letters on white background. There was little difference during the day. Some interaction between color and illumination was indicated for the three levels of illumination used (high-beam, low-beam and daylight). Since the targets were always presented in pairs on opposite sides of the road, there may also have been an attention gaining factor included in the legibility measurements.

Odescalchi (32) made experimental determinations of conspicuity of signs in rural surroundings. Observations were made against a background of trees, hedges, and fields. Observers viewed colors representative of the British standard and the U.S. Interstate standard colors in open and shaded locations. Observers looked down the

road and not directly at the panels. Ratings of adequacy were made of different sized panels, as judged by observers. Results indicated yellow, white, and red to be more effective than the darker colors. This is an interesting approach. The results may have been conditioned by the background used and by observer opinions but such work should be carried farther.

Shoaf (33) reported a policy for advertising signs near freeways in San Francisco to limit the distraction effect of such signs on highway signs as a matter of safety. Expert opinion was consulted on factors affecting distraction and retention. Limits were set on brightness, units of change, rate of change, continuous motion, and flashing lights. The limits were related to distance of the distracting sign from the freeway in San Francisco.

Powers (41) found an advantage from a prewarning route turn marker in urban traffic. In addition to the position factor, the prewarning sign design appeared to give better target value.

In the field of advertising research, it is well-known that relative size and intensity, brightness and color contrast, motion or brightness change, are physical factors especially effective in attracting visual attention. Brightness contrast, change and motion are especially effective when a sign is seen in peripheral vision (34).

Practical application of such principles has been the use of oversize stop signs in many places in the United States. To our knowledge, however, effectiveness of these factors has not been systematically studied in relation to attention factors as such.

Advantage of Familiar Legend and Symbols

Also from earlier work in advertising psychology, it is well-known that familiar symbols, colors, and legends have an advantage. The advantage is increased when public education is used to associate them with special meanings. Certain of these meanings are more easily attached to certain symbols because of their use in other parts of our culture. A study of U. S. and European sign shapes and symbols (14) showed certain symbols to be more effective in Great Britain. Another study of European road sign and U. S. road sign symbols (35) showed more of the U. S. symbols to be effective in the United States, bearing out this principle.

A study of lane control symbols (36) showed a red X to be more naturally associated by the uninstructed observer in the U. S. with the meaning "do not use this lane" than were several other symbols. This probably reflects the use of crossing-out of a page and other such use of an X indicating "do not use." This symbol has proved useful in actual practice. The same principle may be of importance in signing.

Birren (37) used four reflectorized signs with 8-in. letters. On the basis of "the average of several observers" he found black-on-white and white-on-green "best" during daylight and black on yellow and white on red best at night. These were apparently based on legibility distances but no data on reliability were given. He noted the value of color for visibility and for "impulsive attraction" and "psychological interest" and recommended white on green in spite of longer legibility distances of black on white. The 0.4- to 0.6-sec difference in legibility distance at 50 mph he thought less important than the interest and attention value of the colored sign background.

Hulbert and Burg (38) showed the value of dividing a sign by "underlining" to group the material relating to a given destination. Such organization of the legend reduced errors in relating arrows to destinations.

Summary

The reports in this area are all too few and mostly unsystematic in their approach. They do indicate, however, the importance of attention gaining factors since signs may not be seen anywhere near the threshold legibility distance of the sign. This means they may not be seen at threshold visibility distance either. There is also great importance to attention gaining characteristics where signs must be seen in competition with other objects such as advertising signs or similar features of the environment.

VISUAL ACUITY FACTORS

Both static and "dynamic" visual acuity may be of importance.

Ordinary Visual Acuity

Visual acuity as ordinarily measured is known, of course, to affect the distance at which signs may be read. Most of the legibility studies mentioned have taken this into account by measuring the acuity of the subjects and providing for 85 or 90 percent of the drivers. This is usually a visual acuity of 20/40 or 20/50.

Dynamic Visual Acuity

More recently much interest in "dynamic visual acuity" or acuity measured with a moving target has been aroused in connection with highway and automobile driving problems. Odescalchi, et al. (12) quote Westheimer as giving 30 deg per sec as the target speed at which acuity begins to be seriously affected. Hulbert (39) indicated that the critical speed is probably over 60 deg per sec. Therefore, this factor should not be serious in the case of highway signs unless the lettering is very small so that the sign must be seen at high speed from close by at a large angle from the centerline of the highway (much more than the recommended 10 deg). With the lettering sizes presently recommended, this should not be a problem of any appreciable extent.

Central vs Peripheral Vision

It is well-known that color sensitivity and greatest acuity occur in vision using the central par to the retina and that within 4 or 5 deg each side of the center vision becomes considerably less acute. Also well-known is the greater sensitivity of peripheral vision to brightness, brightness changes and stimulus motion (40).

NEEDED RESEARCH ON TRAFFIC SIGN REQUIREMENTS

From the foregoing review of previous research reports it appears that the greatest need for further research is on the subject of attention gaining factors. The present recommendations of letter size and color combinations provide a legibility distance which should be adequate when these recommendations are properly calculated for the design speed and other characteristics of the driver and highway (11, 12).

Previous studies in the field of advertising psychology suggest various combinations of factors which would be expected to affect relative attention gaining characteristics of signs in competition with other objects, signs, or characteristics of the environment. Although several studies have pioneered on measurements of certain attention characteristics, there is a need for further systematic studies of the interrelated effects of the considerable number of variables previously mentioned.

In conducting such systematic studies of attention factors it is important to take into account the effect of other driving tasks and the need for the driver to alternate his attention. Therefore a multiple response task for observers is of basic importance.

Conferences and correspondence have indicated certain studies under way in some aspects of highway sign requirements. Two of these studies involve the relative night effectiveness of destination signs and stop signs with different degrees of brightness. Two other studies involve the experimental investigation of time sharing between driving signs and of the driver's visual search at intersections. Destination sign effectiveness using a driving simulator is being studied in at least one other . Still another project involves the various effectiveness of certain physical characteristics of available sign materials and characteristics. And finally, one study is investigating the effect of colored signs and lining on motorist use of freeway ramps.

TENTATIVE PLANS FOR THIS PROJECT

In this research, systematic experimental work on various combinations of the relative attention gaining factors is planned in the laboratory with later full-scale field

checks. The studies will avoid duplicating those known to be under way. Various types of visual presentation from movies to slides and actual light source projections may be used. Measurements will be made of effects on a multiple task for observers to simulate the interacting effects of seeing of signs and of the driving task. A pilot project is estimated to require some six months and additional projects at least one additional year before results may be available.

Finally, certain of the laboratory results will be spot checked with experimental observations in the field, using vehicles and full-scale installations.

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