REVIEW OF VISIBILITY FACTORS IN ROADWAY SIGNING

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The transmission of information to drivers on the highway has been a challenge since the early days of the automobile. Visual transmission by means of signs was an obvious development. The many highway problems (among them visibility, legibility, message content, and national uniformity) that have developed since World War I have required systematic work and resolution.

It is generally acknowledged that sign performance is dependent on attention value and legibility. Forbes (8) has reported that these are functions of target value and priority value, pure legibility and glance legibility respectively. Each factor is related directly to contrast—the sign with surround, providing attention value; letters with background, providing legibility.

Literally, contrast is the difference in brightness and color between an object and its background. It is a subjective experience that is given to extreme variation, particularly at night. Excessive stimuli from glare sources (such as opposing headlights and luminaires, colored taillights, and electric advertising) contrast with the generally inadequate luminance for effective nighttime perception elsewhere in the highway scene. A study by Forbes (8) described pure legibility as the reading distance derived from an unlimited observation time for reading the sign and glance legibility as the distance under limited reading time.

Target value is generally employed to describe those characteristics that make a sign stand out against its natural background or surround, and priority value refers to other factors, such as location or mounting position, that affect the order in which signs might be read. It has been shown that contrast factors affect target value and that location, number of signs, reading habits, search procedure, and "mental set" affect priority value.

LEGIBILITY FACTORS

Many studies of sign legibility have served to identify such factors as letter-to-background contrast, letter height, height-width ratio, stroke width, spacing between letters, and vertical spacing between lines as being important to daylight legibility (10).

Mills (25) tested various color combinations in studying sign legibility. His first recommendation was black on yellow, and his second was black on white or white on black, thus indicating the importance of letter contrast. In 1932 Lauer (21) recommended a light yellow and also a letter height-to-width ratio greater than 33 percent, a stroke width of 20 percent of average letter width, and a spacing of 50 percent of average letter width.

Two later studies (20, 31) indicated an optimum stroke width for block letters in the range of 15 to 25 percent of letter height. Other studies (11, 2) have shown that legibility increases with letter width up to a square letter.

A number of studies have investigated the irradiation effect of black-on-white versus white-on-black letters. Although they differ in detail, all of these studies indicate that the light letter is more effective when letter design and spacing are optimized. Case et al. (6) found black letters better at close spacing and white letters better when spacing was wide [equal to letter height of Series E (wide) letters]. In a laboratory experiment, Allen and Straub (2), using 3 alphabets of different width [Bureau of Public Roads Series A (narrow), C, and F (wide)], found bright internally illuminated letters better at intermediate brightness.

Allen et al. (1) found bright letters on a low-luminance background more legible than the reverse against low and medium ambient illumination, but not against a high ambient background. Based on the information from the Case et al. study (6), the National Committee on Signs, Signals, and Markings and the Bureau of Public Roads developed first a standard block-letter alphabet, then a rounded-letter alphabet, and finally a lowercase alphabet design.

LEGIBILITY DISTANCES FOR HIGHWAY SIGN DESIGN— HUMAN FACTORS ENGINEERING

It has been known for many years that 1 min of arc represents so-called normal vision for young subjects, but this is not of much assistance to the highway sign designer. Traffic engineers and those designing highway signs have needed to know the maximum distance at which most drivers can read a sign of certain letter size and design. Accordingly, a method for determining legibility distances for a standard block-letter alphabet was developed by Forbes (8) and applied by Forbes and Holmes (11).

From these full-scale outdoor observations a linear relation was noted between letter height and legibility, yielding a distance of about 50 ft/in. of letter height in daylight for black-on-white Series D (medium-wide) letters. The narrower Series B letters gave about 33 ft/in.

Six- to 24-in. letters and 6-letter place names with one misspelling were used for test signs. Floodlighted signs at night gave legibility distance from 10 to 20 percent shorter. Subjects were required to record all letters accurately, including misspellings.

LOWERCASE LETTERS AND FAMILIARITY EFFECTS

A comparison of legibility distances of lowercase and capital letters using both familiar words and scrambled letters (12) showed distances similar to those found in the 1939 study (8) for the scrambled letters. Legibility distances for lowercase alphabets in terms of loop height were comparable to those with capital letters. Longer legibility distances resulted when familiar words were used. The scrambled letters averaged about 55 ft/in. of letter height, whereas familiar words gave about 65 ft/in. of letter height.

EFFECT OF LETTER BRIGHTNESS ON LEGIBILITY

The luminance desirable for dark rural conditions has been reported (30) for letters 8 in. through 18 in. in size. Under the test conditions (from 0.1 to 100 ft-L for white letters on black backgrounds), maximum legibility for the Series E letters occurred at luminances of 10 to 20 ft-L. Satisfactory results were shown to be within a range of letter luminances from 1.5 to 100 ft-L. The reduction in legibility distance at 100 ft-L was attributed to halation or "overglow." At 1 ft-L, legibility was reduced to approximately 80 percent of maximum; 0.1 ft-L was shown to yield 45 percent of maximum.

Despite the relatively large luminance span from 1.0 to 100 ft-L, the corresponding legibility was shown to range from 63 to 74 ft/in. of letter height. A similar study (7) of "illuminated suburban" conditions (0.2 ft-L ambient and typical of an illuminated highway without oncoming headlight glare or competing advertising lighting) reported legibility distances essentially consistent with the dark rural conditions reported by Allen.

A test of an even greater range of brightnesses was reported by Allen et al. (1), who used internally luminated bright-on-dark and dark-on-bright background signs and familiar 3-letter syllables.

By using sign luminance values ranging from 0.2 to 2,000 ft-L (with and without headlight glare and with 3 different levels of ambient illumination), they found that legibility distances are substantially affected by headlight glare and competing illumination. Here again, resulting average legibility distances were generally from 40 to 60 ft/in. of letter height in the range between 2 and 20 ft-L, but ranged from 12 to 65 ft/in. in glare and in high ambient illumination. For rural sign brightness, 10 ft-L was recommended; for lighted areas, 100 ft-L was considered optimum.

Allen et al. (1) reported that a large, very bright sign face will impair the driver's dark adaptation and his vision for low-luminance objects on the road beyond the sign. Additionally, they observed that a driver does not ordinarily observe a highly luminous sign continuously on his approach as did their subjects.

NEED FOR CONTRAST

The need for 40 to 50 percent contrast for day luminance and 50 to 60 percent contrast under night driving luminance levels is indicated in a study by Richards (29). He measured the visual ability of subjects to discriminate letters, not their response to sign legibility distances. He found a great need for high-contrast targets by older subjects.

GLANCE LEGIBILITY

When time is limited to a short glance of about 1 sec, as in much seeing by drivers on the highway, Forbes (8) found that the legibility distances reduced from 10 to 15 percent and only about 3 or 4 short, familiar words could be recognized. The limit for familiar words with about 1-sec exposure was confirmed in a study by Hurd (18).

CALCULATION OF NECESSARY LETTER SIZES

A method for calculating required letter size for a given highway design speed and warning distance was suggested by Mitchell and Forbes (26) in the United States and in England by Odescalchi et al. (28) and Moore and Christie (27). To accomplish this, time to read signs plus warning time needed for maneuvers must be known or assumed.

LEGIBILITY SUMMARY

It has been shown that legibility distance changes with the following parameters: letter height, width, spacing, contrast, and brightness. Each of these parameters interacts with and influences the others. Familiar words are seen at longer distances. Scrambled-letter determinations give better reliability, and the distances are probably more representative of the 20/40 vision of many drivers. Relatively high sign luminance is needed against comparatively bright surrounds, but usually not for ordinary rural roads.

TARGET VALUE

Target value is the capability of a sign to be visible against its background and to provide early recognition and discrimination of the sign type. This in turn prepares the driver for the potential message moments before actual reading of the legend. Major factors affecting target value are the sign color and brightness, producing contrast with the natural background or surround.

The visual factors of color and contrast are relatively well understood. As shown by Hanson and Dickson (15), the more contrast a sign has with its surround, the greater will be the distance for its discrimination and recognition. The importance of color is highlighted in 2 studies (5, 17). A conventional red stop sign was placed in a prominent location with the letters rearranged to read TOPS. Under the assumption that a stop sign registers primarily because of its color and shape, it could be expected that few people would note anything unusual. After passing the sign, 86 percent of the drivers admitted that the word TOPS had been overlooked. Drivers who used the road frequently took less notice (87 percent) than did strangers (79 percent). As Birren (5) observes, "To think continually in the process of seeing is quite contrary to human nature. Bright colors will mark danger spots far more effectively than words and legends. The reason is simple enough: visual reaction to color is involuntary while words require deliberation." Hulbert arrived at a similar conclusion in a 1965 test of "do not enter" signs used to control wrong-way freeway entries. Black-on-white and white-on-black "do not enter" signs were compared with white-on-red-background signs. After testing 81 subjects in a driving simulator, the experimenters concluded that white-on-red signs can be seen from a much greater distance than can black-and-white signs. Forbes et al. (10, 13) found that the range of effectiveness of a given sign color depends on its brightness contrast with the prevailing surround. To maximize sign effectiveness on a system-wide basis of utilizing a single relatively uniform color, careful consideration of all potential backgrounds should be made. The diversity of natural backgrounds with which a sign must compete is very broad.

In an inventory of more than 4,000 Interstate guide signs, Hanson and Woltman (16) found the most frequent surround to be dark trees, occurring 23.1 percent of the time. Sky and bridge surrounds were the next most frequent surround, occurring 19.1 and 15.8 percent respectively. Overhead signs had a somewhat higher incidence of sky surrounds than did shoulder-mounted signs, which were predominantly seen against a dark tree surround.

A 4-year study of attention value was reported by Forbes (9), indicating that signs with good attention value must have good contrast within the sign and good contrast with the surround. Several mathematical models were advanced to describe the factors of detection and identification of the sign against many natural surrounds. The contrast levels between the legend and sign background, and between the sign background and its surround, were found to be of equal importance. Of significance is the total luminance of the sign, other things being equal. An evaluation of the relative merits of sign position favored the overhead location.

ANGULAR POSITION

Although target value is greatly influenced by background, it is somewhat dependent on the sign's position with respect to the driver's central point of fixation. For optimum attention and identification, Matson (24) suggests that a sign should fall within a visual cone of 10 to 12 deg on the horizontal axis and 5 to 8 deg on the vertical axis throughout the intended range of sign effectiveness. Greenshields (14) states that 5 deg to the left or right is ideal but that practical considerations may force a wider visual field. He suggests a value of 10 deg to the left or right for the maximum angular displacement.

In areas where the terrain is flat, sign positions were found by Hanson and Woltman (16) to be within the suggested angular limits. In metropolitan areas and on gently rolling terrain, sign positions of 10 and 37 percent respectively had greater than optimum angular displacement. The mountainous area was most severe, with 53 percent of the shoulder-mounted signs falling outside the optimum range of 10 deg horizontal displacement.

LUMINANCE CHARACTERISTICS

Sign luminance for illuminated signs is directly measured with footcandle meters and comparatively straightforward instruments of little complexity. The determination of the luminance of reflective signs is less straightforward and must generally be calculated in the manner first described by Straub and Allen (30). Elstad, Fitzpatrick, and Woltman (7) employed planes to describe luminances for several signing positions for sign-viewing distances from 1,200 to 75 ft. King and Lunenfeld (19) used computer analysis to investigate the effects of horizontal and vertical roadway curvature on sign luminance.

These techniques employ careful determination of reflective luminance in absolute values. Reflective efficiency varies widely with divergence angle, the angle subtended by the headlights, the sign, and the reflected light beam at the observer. This angle undergoes significant change as the motorist approaches the sign and greatly influences the resulting luminance. The separate values for each headlight necessitate separate calculation of the luminance for each headlight and for each divergence angle.

Illuminance depends on the alignment of the sign with the headlight beam, and its determination requires the location of the reflective device in the appropriate area of the headlight isocandle diagram for both high and low beams and for typical conditions of highway alignment. (Calculation for each lamp is required, as is change in sign position, alignment, or distance.) Luminance values are then obtained by application of the inverse square law.

As a result of computer analysis of luminance variables, King and Lunenfeld (19) found the following:

1. There was only a negligible change in brightness for the different types of cars;
2. The farther the sign is located from the traveled way, the dimmer it appears to the driver;
3. A substantial difference in sign brightness results between high- and low-beam usage;
4. The overhead sign in the right lane is brighter than the signs located in the median or over the median lane;
5. Brightness is only slightly affected by degree of curvature;
6. As the grade change becomes larger, brightness increases for crest vertical curves and decreases for sag vertical curves;
7. A slight headlight voltage change has a minor effect on sign brightness; and
8. A vertical misaim of 1 deg upward increases the brightness of the sign; a misaim of 1 deg downward reduces sign brightness.

Only recently have field photometers of portable size, high sensitivity, and small angular resolution become available to make in situ luminance measurements of signs, thereby resolving the inherent question of the relation between real-life data and theoretical calculations. An extensive study by Youngblood and Woltman (33) of guide signs of contemporary reflective legend and background materials, for both day and night driving situations, was made to evaluate sign luminances.

Sign legend luminances of more than 1 ft-L were found on low beams for encapsulated lens and button reflective materials on unlighted overhead signs for the legibility distances available. Three legend materials were in excess of this level for the shoulder-mounted location on low beams. With high beams, luminances of 10 to 20 ft-L, equivalent to those exhibited for illuminated overheads, were found for several materials on both overhead and shoulder-mounted signs. The effect of adjacent vehicles in the traffic stream is to raise sign luminance for low beams from 2 to 5 times for adjacent vehicles on low beams and up to the level of high-beam luminance if adjacent vehicles are using high beams.

Maximum reflective sign luminance was found to occur at distances similar to the maximum legibility distances for the letter sizes prescribed by the Federal Highway Administration (22). Such luminance depends on the headlight distribution pattern, sign offset, material efficiency, and letter sizes used.

THE INFORMATION SYSTEM

King and Lunenfeld (19) have extensively described reception and information processing capabilities. The present information channel is primarily visual. It has the farthest unaided range of all sensory channels. Because information can be presented externally and at a distance, it does not require the presence of equipment in the vehicle, and the signing system is relatively permanent and inexpensive.

However, the visual channel may be adversely affected by the differences between day and night, attenuation factors (such as fog), and speed of vehicle (which limits perceptual time). Drivers can attend to only one channel at a time, and information may be missed because it was not processed by the driver.

The authors list the following requirements of a basic information system: user-centered, applicable to the existing highway system, usable by all drivers at all times, fail-safe, compatibly evolutionary, and economically feasible. The system must be compatible with the worst-case driver.

SIGNS AS A COMMUNICATIONS TECHNIQUE

Signs are the main technique for accomplishing visual communication, and there are several cogent reasons for retaining and maximizing the use of the sign as the primary visual display technique. These include the following:

1. Expectancy—drivers expect to receive information from signs and willingly respond to messages displayed on signs;
2. Investment—sign panels and supports already exist; therefore, costs of any changeover to a new information system will be minimized; and
3. Implementation—personnel, organizations, technology, and equipment necessary to implement any sign system already exist.

SYSTEM ANALYSIS AND RECOMMENDED PRACTICE

The identification of deficiencies in the present system of signing, delineation, and marking has been made by D. L. Woods et al. (32). Using a diagnostic team study technique, they evaluated existing visual communication systems on freeways, arterial streets, and 2-lane highways. The following subsections give the visibility subjects that were investigated during the study and the practices or treatments that were recommended. (Some of the language has been paraphrased.)

Signs

Freeway directional signing is expected by the driver to have a green background, and, in instances where the background color is different, drivers have a tendency to overlook the entire sign assembly. A driver approaching an exit is searching for a green background sign, and only after reading all such signs will he scan the other signs in the area in search of his desired destination. The time lost during this scanning process can consume most of the lead time provided the driver.

The use of a diagrammatic sign to convey to the driver the necessary maneuver when he approaches a cloverleaf interchange was desired by many team members. Confirmatory route markers are most desirable just downstream from every major decision point.

The priority of control devices normally assumed in the design of signing is totally reversed on modern freeways. Directional signs are of the highest priority on freeways, with regulatory and warning devices assuming a much lower level of importance to the driver. When asked why the black-on-white regulatory signs were not read, one subject driver replied as follows:

> Those little black and white signs tell you anything: "don't throw litter on the highway," "don't park on the shoulder," almost anything. The one thing that is important to me is which lane I have to be in to get where I want to go.

Black-on-white regulatory signs will probably not be effective when they are located in the vicinity of a major overhead structure.

Team drivers reported that they frequently experienced difficulty in locating entrance ramps to freeways, especially at night when the total roadway environment is not visible. Drivers are often confused by side roadways intersecting in close proximity to the interchange. Better definition of entrance ramps could be accomplished either by route markers with directional arrows at the entrance to the ramp or by signs designed specifically to designate the freeway entrance.

Signing of freeway entrance ramps on frontage roads is considered inadequate. Confusion at entrance ramps can be minimized by use of prominent and concise directional signing. More beneficial, however, are specially designed freeway entrance signs.

The use of route marker assemblies on a more extensive basis was strongly supported by the team members. Route markers were desired along the most direct route to the freeway in the desired direction. Trailblazing to hospitals offering 24-hour emergency service was considered desirable by team members.

Motorists traveling on freeway facilities have become accustomed to the freeway signing. After leaving this highway system, however, they are often confused because of a lack of continuity in signing or a complete absence of signing. A communications breakdown often occurs at this interface. An equally critical problem occurs in the reverse situation. To enable drivers to effectively maneuver along the desired route between freeway and arterial street systems, we must provide them with sufficient information.

Drivers report that arterial street name signing is not aiding them effectively, resulting in an inability to utilize turn lanes. The legibility of street name signs is inadequate for the posted speed limit, and lettering is generally too small on signs located at intersections. Such signs should be located on both the right and left sides of all arterial streets, with alternative locations in the median or overhead. When arterial streets converge at major intersections, drivers should be able to read the street names before reaching the intersection proper. This could be accomplished with larger signs at the intersection or a combination of advance and intersection signing. (Span-wire-mounted overhead signs are the most economical and would be the logical choice for use on such arterial streets.) The lettering should be a minimum of 6 to 8 in. in height for adequate legibility. With a few improvements in current techniques, street name signing could be very beneficial.

Visibility is an essential prerequisite to all other signing considerations. Drivers frequently pass intersections where they wish to turn simply because the sign is placed too far off the roadway. Signs placed too close to the point at which a driver must make a decision have also been criticized. Intersecting roadways are critical areas on 2-lane highways, and advance road name signing should be provided.

Urban Signing

The frequency of regulatory parking signs on urban arterial streets is often excessive and unattractive. The diagnostic team members felt that the problem was of sufficient magnitude to justify exploration of alternative methods of parking control. One suggestion was the concept similar to the "snow emergency route" designations to control parking, which might be combined with the use of pavement markings to designate the restricted area.

Pavement Markings

Many drivers felt that the view of the roadway surface ahead was their principal source of information to accomplish the driving task. The view of the roadway is especially important on a 2-lane highway where drivers are more dependent on road geometry for guidance.

The effectiveness of edge lines was suggested repeatedly by team members on all types of highway facilities. Despite a high contrast between the shoulder and through lanes, drivers are benefited by the presence of an edge line. Drivers recommend that edge lines be used on lighted freeways and on all entrance and exit ramps. Edge lines were recommended for use on arterial streets for guidance around obstructions, or when required to guide to the left. The majority of participating drivers expressed a desire for edge lines on all types of highways, except in urban areas where there are raised curbs. Edge lines apparently give the driver a greater sense of security in operating his vehicle, and, if this is in fact the case, edge lines should be provided in order to allow the driver to perform the driving task under more nearly optimum conditions.

The effectiveness of pavement messages on arterial streets is diminished by dense traffic, which limits the view of the message. Span-wire-mounted overhead signs were suggested as a more economical and effective means of conveying information.

Rural 2-lane highways present the driver with the task of tracking, and thus attention is focused on the pavement. Under these conditions, the pavement message can be very effective.

Delineation

The following practices were recommended for use at a hazardous structure: a combination of post-mounted delineators gently tapered to the obstruction, an edge line following the same general course, and a hazard board or equivalent treatment at the obstruction.

Guardrail delineation has been found to confuse some drivers when it is placed only at the ends. Continuous delineation is more meaningful to the driver.

The placement of post-mounted delineators in the medians of freeways was considered unnecessary. This is particularly true on a lighted freeway.

Drivers desire delineation on horizontal curves, especially on 2-lane roadways. This seems to be accomplished effectively by placement on the outside of the curve.

A wide variety of devices are now being used to delineate mailboxes and private driveways along rural highways. These devices startle drivers, provide incorrect information, and are responsible for additional visual "clutter." Specific requirements should be developed to replace the great variety of devices to establish uniform standards.

The standards for signing in the United States are prescribed by the Manual on Uniform Traffic Control Devices (22), which gives standard colors, sizes, and legends for signs, signals, and pavement markings.

The efficacy of urban signing was also questioned by Markowitz (23). He observes, "None of the sign systems of the world deal with the urban sign problem in any significant manner." The Manual (22) hardly acknowledges the problems and provides very little in the way of guidance for those responsible for the implementation of urban signs. In order to help reduce the proliferation of signs, and at the same time expedite communications, we explore the use of special subsystems of signs for particular user groups.

The urban signing problem is also dealt with by Ashley et al. (3). They provide many specific suggestions designed to improve the flow of information supplied by traffic and pedestrian signing of both an official and commercial nature. In nearly all cases, tests indicated that new sign designs were a significant improvement over the conventional. New signs furthermore were welcomed in the surveys conducted. Signs were generally larger and color coordinated and employed symbols for rapid detection and comprehension.

DIAGRAMMATIC SIGNS

A study of diagrammatic signs by Berger (4) recommends that they be installed at interchanges where unusual or inconsistent geometrics are involved and where high volumes or perceptual difficulties are encountered. The design itself should be simple and incorporate not more than 2 choice points where possible. Such signs should be of the aerial or plan view and be designed to indicate the correct lane for the appropriate exit maneuver.

The blockage of signs by trucks is described in terms of probability for the number of trucks and speed of traffic by King et al. (19). The geometry of the blockage problem was defined in terms of the line of sight from the sign determined by the extremities of the sign and by the extremities of the truck as viewed from the sign.

The driver will have his vision blocked if his line of sight falls within the truck's "shadow." The extent of this shadow is a function of truck speed, size, and position and size of the sign. The final probability is given for a random car in the shadow for a percentage of time greater than the total time it is on the roadway. The obvious implication of blockage suggests a redundancy of devices where amount of traffic or number of lanes is excessive.

FUTURE RESEARCH

No review would be complete without an observation on the direction of future research. Future work should appear to be directed to system-wide analysis with particular emphasis on user-oriented needs at the freeway-arterial street interface, arterial and major street identification, urban signing for parking control, and pedestrian needs. At these levels the solutions appear ready for implementation. Previous research of legibility and attention value has been timely and accurate. The diagnostic team findings level virtually no criticism of freeway signing where the principles of this research have been properly interpreted and deployed. Necessary information required by the motorist for such freeway facilities may still be lacking in terms of message content and sequence of information provided, however.

Specific visibility questions can still be identified in areas such as the extensive proliferation of various reflective devices along rural highways and of advertising devices along arterial streets and at points of traffic confluence. Of serious concern is the low-beam performance of reflective devices in view of more extensive low-beam usage.

Although the Manual (22) requires reflectorization or illumination of signs, delineators, and pavement markings, no values are specified and no minimal maintenance of luminance is suggested. The 3 classes of devices, for the several environments, require not only quantification but also identification of practical techniques for specification, field inspection, and maintenance.

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DISCUSSION

T. W. Forbes

The paper by Woltman gives a fine review of research reports on visibility factors in roadway signing. Well summarized are the research results of the use of dark letters on a light background versus light letters on a dark background. He notes that in some cases a light letter on a dark background was better, and in other cases the reverse was true. These results can be understood logically in terms of irradiation of light on the retina of the eye, which acts like halation on a photographic film. A bright feature, whether letter stroke or a bright space between letters, can be expected to spread as intensity increases. If the spacing between letters is greater, this spreading has more room to occur before encroaching on another letter. Therefore, one can expect different effects with different combinations of stroke, width, and letter spacing.

In reviewing legibility distances, we should remind ourselves that these distances depend on the visual acuity of people. Therefore, measurements of legibility are usually made with large groups of observers, and legibility distances are often given either as average values or as 85th percentile values. The average values are statistically most stable. These values allow valid comparison of different factors and conditions.

Because an average legibility distance is one at which 50 percent of a group of drivers can read a sign, for most applications to sign design, an 85th percentile value should be used so as to include most drivers. This results in larger sign letters and usually corresponds to 20/40 vision if legibility distances are determined on a group of observers whose corrected vision averages 20/20.

Thus an 85th percentile distance may be preferable to an average legibility distance for design purposes. This means that the legibility distances should be shorter and the letters larger than the average values would indicate.

In reporting a study of very high luminance in the range of 100 ft-L to 2,000 ft-L by Allen et al. (1), the very important comment is quoted that such high brightness levels in a dark rural surround may impair the driver's vision for low-luminance objects beyond the sign. This comment of the researchers should not be overlooked. Time for recovery from exposure to such high luminances may range from a fraction of a second to several seconds or more, depending on exposure. Needless to say, even 1 or 2 sec of blind driving may be serious at 50 to 70 mph.

A more recent study adds to Richard's report that 40 to 60 percent contrast is required for discrimination of letters and that much higher contrast is needed by older subjects. A study of low-contrast vision under simulated night driving conditions found that a few subjects in each 10-year age group had difficulty in discrimination of test letters (34). Further work (not yet published) seems to indicate that a reaction to glare may be involved.

Familiarity of place-names may give some rather interesting but misleading research results at times if not carefully controlled. For instance, familiar names of certain length or combinations of short and long words may appear to be recognized much farther than the actual legibility distance. But if other test words of the same pattern and length are presented, this excessive legibility distance will shrink dramatically. In other words, subjects think that they recognize a word, but they really recognize the wrong word. Control of the familiarity factor was achieved in one study participated in by the discussor. We used several sets of place-names having similar lengths and patterns, e.g., San Francisco and San Bernardino, and others that were short single words. Familiarity of test words still increased legibility distances slightly.

Studies of target value of signs are well summarized, and the importance of background characteristics noted.

A comment might be made on angles of effective clear vision assumed by different authors, which range from 5 to 10 or 12 deg. The basic consideration here is a 5-deg central cone of clear vision that is fairly well determined in psychological and visual studies. Earlier studies assumed a central 5 deg (plus 5 deg to each side) as the minimum field of view, and others have adopted other combinations. Ordinarily the eyes do not remain still; therefore, a minimum of a central 5 deg plus 5 deg to each side seems reasonable. Head movements, of course, will add to this angular field of vision.

The field measurements of actual sign luminance by Youngblood and Woltman furnished information that has been badly needed.

The information system is of great importance in transmitting information to the driver, and the inclusion of the study by King and Lunenfeld is helpful. Perhaps, however, their statement that the system must be compatible with the "worst-case driver" for practical purposes needs to be interpreted as the "90th percentile driver."

From the system analysis study of signs by Woods et al. (32), factors of special importance are information needs of the driver and expectancy, i.e., his idea of the type of sign for which he is searching. This systems analysis helps to interpret findings made several years ago by Schoppert, Hulbert, and others on California freeways, where many drivers did not recognize destination names and more than 15 percent were actually lost. One solution, the numbering of freeway interchanges, was initiated on the New Jersey turnpike some years ago and has been used on other toll roads; it now is being adopted on many freeways.

Another important finding is the objection by drivers that signs are often placed too close to interchanges or intersections. This is often justified and emphasizes the need for sign design allowing sufficient perception, judgment, and response time for the maneuver required. Reports of methods of determining sign letter size are quoted by the reviewer.

Reports of driver uncertainty from delineators and obstruction markers call for application of the basic principles of perception of lighted markers and beacons. A single marker or small group of markers may be ambiguous, but a line of markers with unique characteristics will be perceived as a line. However, as noted by Connally at a previous meeting, if delineators or other lighted markers are surrounded by a variety of other lights, this "visual noise" interferes with correct perception, thus causing errors.

Berger's recommendation of diagrammatic signs is in line with recommendations of others. A recent conference was held by the International Road Federation on this subject. The principle of symbol signs is most effective if the symbols are self-explanatory and can be kept simple and easily interpreted by the driver. A method of comparing effectiveness of different symbols for drivers from countries with a given cultural background was reported in a study of symbols for lane control signals.

Reference

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It is difficult to "reply" to Woltman's paper, which is an excellent review and condensation of literature spanning almost half a century and from several countries. Rather, it is more appropriate to give emphasis to some of the points brought out in the paper and to discuss some of the implications for future work. This should begin to order our priorities and increase the emphasis on applications of existing knowledge by operational personnel.

It was gratifying to see that several speakers at this workshop have made the point that roadways designed to Interstate specifications, safe and efficient as they are, will never replace the great majority of 2-lane, 2-way roadways throughout the nation. A great deal of information on visibility and driver behavior in relation to signs and markings has yet to be established firmly enough such that it can be applied to the poorer quality roads on which the great majority of the fatalities occur. It would be highly questionable to assume that future study can be confined to new roads.

Another important assumption is that it is not accidents that need study but driver behavior. It remains difficult to point to "causes" of accidents, but evidence is beginning to grow on factors that contribute to erratic maneuvers, critical incidents, near misses, and other intermediate criteria of system operation, many if not most of which are influenced by visual information needs.

It is obvious that visibility factors are more important in night driving than in day driving, and, in a few cases, there seem to be contradictory requirements for day and night. For example, irradiation with bright reflective signing using white letters on a dark background calls for a smaller stroke width in the lettering at night as compared to the optimum for daylight use. This apparent incompatibility may not be real because it should be possible to develop an opaque white material that appears white in the daytime but that does not allow retro-reflection at night. Under headlight illumination, the opaque white portion would appear black because no light gets to the beaded surface, whereas the normal translucent white portion of the lettering would continue to reflect the same legend but with a narrower effective stroke width.

It was pointed out in the discussion of sign contrast that the contrast provided by urban, urban freeway, 2-lane rural, and Interstate roadways can vary over a broad range. In some research on vision, a slightly different set of terms is used from that described by Woltman. In addition to the lettering or legend, there is the background on which the legend is placed. Immediately outside of this is the surround, and beyond this is the general environment. Because environments are very diverse, the provision of an artificial surround, such as flat black expanded metal screening, could provide a break in a cluttered environment by isolating the sign and thus providing a better target or priority value. Such surrounds have been used in the past, but they reduce standardization and may increase the cost as well as the mounting requirements because of additional wind resistance.

Another point that has been raised in previous discussions is the desirability of very high speeds. It is my opinion that speeds beyond 70 to 80 mph are not cost-effective with manual driving control. In the few places where it is feasible to drive at very high speeds, information requirements are inherently low. Even at ordinary freeway speeds, the time available to read a sign of reasonable size allows use of only a few short familiar words, depending on the "mental set" of the driver. There is much to be discovered about the "chunking" of information, messages fed in segments to the driver to establish his expectancies or mental set and to provide information gradually over a period of time. Problems arise as to how big a chunk, how much redundancy, and how many segments there should be in such messages. Where unusual situations or even unusual place-names appear, the driver must be reassured that what he perceived on the first sign is actually the case by confirmation with additional signs.

A general conclusion of Woltman's paper is that overhead signing is probably best. It, too, is speed-limited, and such things as the tinted strip in windshields may further reduce the reading time available. Where it is possible to design a roadway for cars only, overhead signs can be lowered to reduce the vertical angle and increase exposure time as well as improve the illumination from headlights.

The topic of sign brightness brings up the problem of locating a spot in space. On a meandering road, a sign that is visible from a distance can "wander" in space because of the lack of cues to its actual position. Post-mounted reflectors, especially when each is a single small bright point, provide no size cues, and even a pattern of such points can make the apparent course of the roadway ambiguous. A pattern of two such spots separated vertically by a standard distance (probably 12 to 18 in.) on the same post would provide the information needed to estimate distance realistically.

As Woltman pointed out, signs will probably remain the most practical communication technique for some time. Although the complicated calculations of reflective luminance now can be handled by computer techniques, communication by signing is hampered most by lack of clear-cut descriptions of the users: the lack of specification of the worst-case driver or design driver. Several committees of the Highway Research Board are beginning to study the design-driver concept, though a set of design drivers for specific situations will probably be necessary. Because classified driver licenses are now being advocated, a corresponding set of design-driver specifications for each category seems feasible.

Pennsylvania State University has recently completed two studies (35, 36) that were not available in the literature covered by Woltman. As part of the latter study, a film was made that outlined the problem, the analysis in which erratic driver behavior was examined and driver interviews were used, and some techniques for solution.

References

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