# DETECTABILITY OF HIGHWAY SIGNS

Robert Dewar, Psychology Department, University of Calgary
Calgary, Alberta, Canada

ABSTRACT - *Detectability is one of the primary criteria for an effective traffic sign. Several factors including sign characteristics, condition of the sign, driver information load, sign placement, environment conditions (darkness and poor weather), and individual differences among drivers, influence whether a traffic sign will be detected. Each of these factors is examined in a review of the relevant literature.*

In the driving task, the driver's attention is occupied by many things -- control of the vehicle, guidance information from the roadway, navigational information from signs, elements of the environment, such as scenery, buildings, and billboards, and distraction from passengers and other stimuli inside the vehicle. It is easy to see that driving is a divided attention task in which the driver must attend to a variety of incoming stimuli, some of which are more relevant than others to the driving task. It is therefore essential that traffic signs be highly conspicuous, or have high detectability or attention value for the driver.

Forbes makes the distinction between "target value," the characteristics which determine whether a sign will be seen or not, and "priority value," the order in which signs will be seen, depending on factors such as sign location, relative position, and drivers' reading habits.

Among the factors which can influence conspicuity of signs on the highway are sign brightness, size, and color; contrast between the sign and its background; the placement of the sign relative to the driver's line of sight; importance of the sign to the driver; reduced processing capacity of the driver due to input overload; and individual differences due to motivation, fatigue, intoxication, familiarity with the road, age, sex, and eye movement search patterns. Each of these will be examined in a review of the research relevant to detection of traffic signs.

## APPROACHES TO THE PROBLEM

Several approaches have been used to study traffic sign detectability. One roadway technique involves stopping drivers a few hundred meters beyond a sign and asking them whether they detected and could identify the sign just passed on the roadway. Another common roadway technique is to have individuals drive a car or ride as a passenger in a car driven along a specified route, during which time the subject indicates each time he detects a sign. Variations on this procedure involve pressing a button whenever a sign is detected and naming each sign as it is detected. One series of laboratory studies involves a subjective report of which one of a number of signs is seen "first and best", Forbes (1). Both of these methods have their limitations, the laboratory method being somewhat artificial. The roadway experiments also have difficulties; the one in which the driver calls out traffic signs is somewhat unrealistic, since he or she is attending very closely to traffic signs, not the typical situation in driving. Most studies done on the roadway have been carried out in daylight and good weather conditions. Relatively little has been done at night or under adverse weather conditions. In addition, much of the work seems to have been done on freeway guide signs or similar types of guide signs, with little effort to study smaller signs of different shapes and sizes (e.g., warning and regulatory signs).

Numerous laboratory methods used by experimental psychologists provide information about the general issue of stimulus detection, and therefore have implications for learning about traffic sign conspicuity. Some of these will be described later in this paper.

## BASIC PERCEPTUAL PROCESSES

Traffic signs are mounted above the roadway, so they often do not appear in the driver's direct line of sight. Therefore their initial detection occurs in peripheral vision. Visual acuity becomes progressively poorer, the farther the image falls away from the fovea of the eye. In order to be easily detected in peripheral vision then, a sign must be relatively large, stand out from its environment, or contain moving or changing components.

In a laboratory investigation of the influence of central search task luminance on peripheral visual detection time Zahn and Haines (2) found that detection time was much slower in peripheral vision under conditions where subjects' attention was directed to a visual central panel of high luminance, as compared with one of low luminance. This has important implications for the distraction likely to arise from brightly lit streets and headlight glare during nighttime driving.

A recent experiment by Nobel and Sanders (3) examined the influence of several variables on the ability to search for and find target traffic signs among several other traffic signs. The variables examined were: number of signs, sign density (whether they were packed closely together or spread out), color -- the extent to which color was a major cue in the subject's being able to detect target signs, number of target signs (from one to four), and whether the subject was engaged in a tracking task. The subject's task was to indicate the number of targets (ranging from one to four) present in the array.

The results indicated faster search times to find the targets when color could be used as a cue (the color of the target sign borders in the easiest of the four color conditions was distinctively different from the borders of the non-target stimuli). Search times were faster when the signs were closer together (the dense condition). Search time was essentially a linear increasing function of the total number of stimuli, ranging from ten to nineteen. Performance was somewhat worse (125 msec longer) when subjects were engaged in the tracking task while searching for the targets.

Attention is obviously an important factor in information processing. Lapses of attention, distraction and input overload all reduce the driver's ability to take in information. There is a need for advanced warning in low attention areas, such as rural freeways, so that the driver will be prepared to attend more closely to his driving. For the purposes of preparation and attention, there is an optimal distance between signs. This distance depends upon the various distractions, including competing signs, which use up the driver's information processing capacity. As speed increases, attention to the driving task increases, and the focal point of attention shifts further ahead of the vehicle.

A number of psychological studies have examined the influence of input overload on performance. A distinction is made between input overload (too much total input) and information overload (too much input which is relevant to the driving task). Both situations can impair driving. Various factors influence the point at which performance will deteriorate under conditions of overload. There are various methods of coping with overload. One involves chunking or grouping the information in such a way as to process it more efficiently. In some cases a certain amount of information is missed; that is, only part of the information is detected. Errors also may occur, or it may take a greater length of time to process the same information under high input conditions. A good example of overloading in driving is a very busy intersection with numerous traffic signs, advertising signs, traffic lights, and heavy traffic conditions. Under such circumstances the driver has to take in a great deal, determining which input is relevant, initially, and then processing more thoroughly that which is relevant (or that which he thinks is relevant).

A study by Lee and Triggs (4) required subjects to detect small lights inside their vehicle in their peripheral visual field while driving under various conditions. Detection was much poorer while driving in shopping centers or in suburban locations, as compared with freeway and isolated residential street driving. Surprisingly, there was no difference between performance while subjects were driving and while they were passengers. Under both conditions subjects detected only about half of the lights when driving in suburban areas and in shopping centers.

The importance of distraction by billboard advertising signs has been demonstrated by Johnston and Cole (5) in a study done in Australia. In a laboratory simulation task they found that performance on a tracking task was worse under conditions of distraction from advertising signs than under a control condition. The relevance for this with regard to detection of traffic signs is obvious. Not only are advertising signs likely to serve as visual noise, making it difficult to notice traffic signs in the visual environment, but also they tend to distract the driver from the driving task.

## SIGN CHARACTERISTICS

A number of physical characteristics of traffic signs influence their conspicuity. Forbes and his colleagues have done much of the laboratory research on this issue. Forbes (6) describes a procedure developed for measuring the probability that a traffic sign of given brightness, color, and contrast characteristics can be seen against various day and night backgrounds. Requirements for valid measurement of the perception of highway signs and a discussion of the advantages and disadvantages of movies and slides were presented. It was concluded that the discrete presentation method (slides) was to be preferred. Details of the procedure can be found in Forbes' paper in this symposium.

Forbes (1) summarizes a systematic series of studies of sign visibility. A total of 14 laboratory experiments were conducted using more than 500 subjects. For most signs, a green material matching the U.S. interstate green signs was the basic color. Simulated signs of different brightness were made by applying different density neutral overlays. The subject was required to respond by indicating which of the four simulated signs he saw "first and best."

Forbes also had subjects view the signs against a "day-snow" background or against a night background. Four different sign sizes in each of the four brightnesses were varied systematically, as were the four sign positions over the roadway. Results indicated that the signs "seen first and best" were those with greatest brightness contrast against the background, and those which were larger when brightness was held constant. In addition, relative size and contrast might enhance or oppose each other when both were varied. Against a night background, the brightest of four signs was seen best, while against a day background, the darkest sign had the advantage.

Two experiments presented simulated signs against different colored backgrounds. Results indicated that no one color was best against all backgrounds. The brightest green was most visible against dark green trees and the darkest green was most visible against a blue-gray or yellow-brown background. When seven different colors were presented in pairs against dark green trees, yellow-brown hill, gray-blue cliff, and day-snow backgrounds, the light green and yellow were "seen best" most frequently. Mathematical models were developed for relative size and brightness contrast.

In order to check the laboratory simulation studies against actual observations on the highway, subjects rode in the right-hand seat of a station wagon driven by the experimenter, and called out all signs as soon as he saw them, giving the color of the sign and its location, and indicating whether it was an advertising sign or a highway sign. Although there were considerable individual differences, the observed results coincided fairly closely with those predicted from the laboratory studies.

Attention-getting characteristics of highway signs were measured by Pain (7) using Munsell gray chips. The subjective response of "the stimulus which they saw best and quickest", and subjects' eye movements were measured.

The subjective measure was found to be more consistent than the eyemovement measure. Some subjects had no eye-movements to the stimulus which they saw best and quickest, further illustrating the importance of peripheral vision in driving. In general, the stimuli seen best were those with the greatest brightness level and those with the highest brightness ratio.

## ROADWAY STUDIES OF TRAFFIC SIGN DETECTABILITY

Laboratory investigations play an important role in evaluating sign detectability and the factors which contribute to it. However, many researchers believe that it is difficult to beat the "real thing" -- measures of detectability on the roadway.

Odescalchi (8) tested white signs of various sizes under open conditions (field and hedge background and shaded trees). Signs were placed at the side of the road according to existing British standards. Subjects were instructed to look down the road, not directly at the sign, and rate the sign as "too large, just too large, adequate, just too small, or too small." It was found that a white sign had to be 1.5 $m^2$ (16 $ft^2$) in area to be conspicuous at 225 m (250 yds) and for each additional 90 m (100 yds) the sign should be 1.22 $m^2$ (13 $ft^2$) larger, up to the tested maximum of 4.7 $m^2$ (50 $ft^2$) at 450 m (500 yds). Larger signs were required in shaded areas.

A second experiment attempted to determine the amount by which signs of various colors would have to be larger (or smaller) than white signs to be equally conspicuous. A paired comparison technique was utilized. The results, in terms of the amount the colored sign area had to exceed the white sign area to be equally conspicuous, were: yellow - 8%; red 7%; blue 24%; green 42%; and black 125%. Conspicuity increased as the luminance factor increased, with the exception of green.

Johansson and Rumar (9) investigated the capacity of car drivers to get information from road signs. Five subjects were driven through the 170 km (105 mile) test area and instructed to press a button each time they detected a road sign. Ninety percent of the total estimated road signs were "registered" by the subject.

In another experiment drivers were stopped and interviewed about 200 m (1/8 mile) beyond the sign. The drivers were asked "What was the last road sign you passed?" All testing was conducted in the daytime and approximately 200 drivers were interviewed for each sign. An attempt was made to explain the data on the basis of the "urgency" of the sign's message. The five signs, arranged in descending order of registration, were: Pre-warning for speed-limit zone (78%); Police control (63%); Road surface damaged by frost (55%); Warning (non-specific) (18%); and Pedestrian crossing pre-warning (17%). The authors conclude that there "was a signficant difference between the percentage of drivers registering the different signs."

An extension of this work was done by Johansson and Backlund (10). The following objections to the validity of the method were pointed out by the authors. The time and space span between passing the sign and reporting it is fairly large, and there may be a substantial memory decay after 15 to 30 seconds. If so, the percentage of people remembering the signs would be low. The appearance of a police barrier could result in a sudden emotional disturbance, causing the momentary forgetting of the sign. This hypothesis was examined by having half of the police in uniform and half of them in plain clothes when they were stopping motorists. No differences were found.

In the study by Johansson and Backlund (10) signs were tested in different locations. Instead of testing each sign on separate experimental occasions, all five signs were tested on every occasion. When the measurements were repeated with the conditions held as constant as possible, a significant variation in probability of recognition was obtained, casting doubt on the reliability of the results.

A more recent study of traffic sign detection on the highway was carried out by Summala and Naatanen (11). They required subjects to name all the traffic signs they saw as they drive along a 257 km (160 mile) route in Finland. Their subjects were able to report approximately 97% of all signs on the route, a figure much higher than some earlier researchers had found. It was concluded that earlier results suggesting the relative inefficiency of traffic signs were due to deficient motivation of the subjects. The results indicated more unreported signs in urban driving (8.95%) as compared with highway driving (1.06%). This is to be expected, in view of the high visual load and attention demand encountered on urban streets.

## SIGN PLACEMENT

Sign placement is very important, since the sign must be properly located to be seen and acted upon in time. Specifications for placement are laid down in sign manuals, however, these regulations are often either violated or turn out to be inappropriate for specific locations and conditions. Buildings, structures such as bridges, and road geometry frequently necessitate modifications in the rules which govern sign placement. Many signs are currently placed so that they cannot be seen by the driver when is using low beam headlights.

A primary concern in sign placement is the angle of view -- how far away from the forward line of vision a driver must look in order to read the sign. The farther off the road a sign is, the larger it must be. Certain messages need to be placed not only on the right side of the road, but also on the left side. In some locations NO PASSING and NO LEFT TURN signs have been placed on both sides of the road. This is desirable, since the driver will be on the left side of a two-lane highway when he is passing, and his view of the sign may be obstructed by the vehicle he is passing.

In a study by Brown (12) a NO PASSING sign, in the form of an isosceles triangle mounted on its side, was placed on the left side of the road. After three months, arrests for illegal passing dropped 63 percent. On three control highways, arrests rose 20, 10 and 7 percent. It has been demonstrated in both field (13) and laboratory (14) studies that overhead signs are easier to detect.

## ENVIRONMENTAL FACTORS - DARKNESS, WEATHER, CONSTRUCTION ZONES

Night driving presents a set of visual problems not encountered under daytime conditions. Glare from headlights, reduced visual acuity and color sensitivity, and sudden changes in dark adaptation level can influence perception of traffic signs at night. In addition, the visual properties of the sign may be different at night than in the daytime. Problems can arise from very bright signs which may alter the driver's dark adaptation and impair perception of other signs in the vicinity of the bright sign.

The following factors influence the brightness of a sign: photometric properties of the sign face material, lateral and vertical position of the sign, distance from sign to vehicle, vertical and horizontal alignment of the roadway, driver's eye position, and vehicle headlights (number, type, arrangement, location, and high or low beam). Signs which have adequate conspicuity under daylight conditions may be difficult to detect at night. Therefore, daytime inspection of the adequacy of signs may not be appropriate.

A systematic examination of the surrounds (background) against which signs appear at night was carried out by Woltman and Youngblood (15). Several instruments for measuring luminance of nighttime sign surrounds were evaluated and their accuracy compared with that of a laboratory quality telephotometer. The authors describe a technique for surround evaluation and point out that conventional descriptions are often inappropriate.

The detectability of two types of retroreflective material--engineering grade (EG) and high intensity grade (HIG) were examined at night in a study by Godthelp (16). Subjects drove along an 11 km (7 mile) route on a rural roadway in Holland, and indicated when they could detect each of the 9 signs and when they could recognize the sign shape and read its message. Differences in detectability were negligible when sign detection was at less than 50 m (165 ft) for cars (100 m (330 ft) for trucks). At distances of more than 100 m (330 ft) (200 m for trucks) the luminance of HIG signs was about three times that of the EG signs. Under conditions of dense fog (visibility = 0.2 km or .12 miles) the detection distance for HIG signs was approximately 20% greater than for EG signs.

The NCHRP Report #123 (17) describes a computer program which permits the insertion of the actual highway alignment, taken off construction plans, and the determination of the brightness of any sign at any point along this alignment for any special type of vehicle approaching in a specific lane. This can provide valuable information on sign placement for optimum viewing, whatever the road geometry may be.

Relatively little research has been done examining the conspicuity of signs under adverse weather conditions. One of the most frequently occurring adverse conditions involves rain. A study by Hutchinson and Pullen (18) examined the scattering of light from droplets of dew and crystals of frost on retroreflective sign materials. The relative performances of a number of combinations of signing materials were subjectively evaluated under natural conditions of signing material were subjectively evaluated under natural conditions of dew and frost at night. Various combinations of encapsulated lens enclosed lens and button copy materials were tested. The signs were examined under headlight illumination, using on-site observations and photographs. On the basis of the subjective evaluations, messages mounted on encapsulated lens reflective material performed better than those mounted on enclosed lens material. It was found that all of the combinations of materials were less affected by frost than by dew.

A common cause of poor sign conspicuity, especially at night, is dirt on the sign. A study in Sweden by Rumar and Ost (19) examined the extent to which dirt on traffic signs reduces their effectiveness by reducing reflected light contrast. The signs were measured for dirt accumulation once a week and cleaned each week. Weather conditions were important, with wetness of the road being the most detrimental factor. The reduction in reflected light varied from 0 percent (very rare) to 69 percent.

Another environmental condition which interferes with detection of signs can be found at roadway construction sites. Poor traffic sign conspicuity is a particular problem in construction zones for several reasons: signs are often poorly placed (lower than the recommended height); signs tend to get dirty quickly because of this low placement and because of the increased amount of dust and mud in the vicinity; atmospheric dust reduces visibility; vehicle windshields may also be dirty for these reasons; detours may result in poor roadway alignment, which makes it difficult to place signs in the driver's line of sight; signs may be hidden by machinery, mounds of earth, etc; driver's attention may be distracted due to complex roadway geometry, presence of construction vehicles and personnel, etc. Such problems tend to be magnified at night, especially if good advance warning is not provided.

## DRIVER FACTORS

So far a number of factors relating to the sign and the environment have been examined. In all phases of the driving task it is essential to consider the capacity and state of the driver as well.

An important individual difference variable involves cognitive style. As indicated earlier, visual distraction can make it more difficult for drivers to detect signs and other relevant information. A sign embedded in a context of other signs or other distracting visual input is less likely to be detected, as indicated by Loo (20). In a reaction time study (using slides as stimuli) which measured time taken to detect and identify traffic signs he found that it took a good deal longer when the sign was embedded in a natural scene, as compared with when the same sign was presented by itself. Embedding signs in a context led to much poorer performance on this task among subjects who were field-dependent than among field-independent subjects. This difference is to be expected on the basis of the literature on cognitive style. The fact that there was an interaction between field dependence-independence and whether or not the signs were embedded indicates that the impairment was due to increased time required to detect the stimulus, rather than to identify it. Such individual differences are seldom taken into account in studying traffic sign perception or other driving tasks.

Alcohol has been found to narrow the field of view of objects, a phenomenon sometimes referred to as "tunnel vision." This narrowing of the visual field, or inability to detect peripheral targets, seems to occur when attention to the central visual field is required (21). A related phenomenon is the manner in which the driver scans the visual environment when intoxicated. Visual scanning is less active and more limited to the center of the roadway under the influence of alcohol, according to Moskowitz, Zeidman and Sharma (22).

## CONCLUSION

Detectability is a primary criterion for any traffic sign, for if it is not detected, obviously its message will never get to the driver. Several factors which influence traffic sign detectability have been examined. A sign may be missed because it is too small, embedded in a complex visual environment, poorly placed, poorly maintained, or because the driver has inadequate visual capabilities, is distracted, or is overloaded by other elements of the driving task.

How can all of these problems be remedied? Greater care must be taken in placing and maintaining signs. Drivers should be made more aware of the problems associated with traffic signs detection. Driver education requires students to learn the meanings of signs and the shape and color codes. They should also be taught efficient means of scanning the environment and processing relevant information such as that on traffic signs. The simple need to detect traffic signs presents many problems to the driver. Those responsible for signs must pay greater attention to the basic information needs of the driver.

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