driver. The major problem is the quantification of the complexity and defining what background objects form the population of items which can be confused with the target. In order to tackle this problem directly, a series of experiments were carried out. These involved:

1) the detection of a disc in various schematic backgrounds
2) the detection of a disc in a road scene
3) the detection of traffic signs in road scenes
4) field trials of discs and traffic control devices.

The results of the experiments using schematic random arrays of discs showed that the number or density of background discs has an adverse effect on the conspicuity of the target disc if it is detected by virtue of its luminance alone. If the target disc differs from the background discs by virtue of its size, then the background density has no effect at all. If the background discs varied in luminance then this was found to have no measurable effect on the conspicuity of the target disc. If the background discs varied in size then this did have an adverse effect on the conspicuity of the target disc but one which can be predicted by a single model.

The studies of traffic control devices in the road environment showed that size and edge contrast were important determinants of conspicuity. In both the laboratory experiments and field trials it was noted that while regulatory signs did poorly, symbolic signs were more more conspicuous than their alphabetic counterparts and the more visually cluttered the road environment was, the poorer was the conspicuity of the traffic control devices.

The practical implications that have emerged from the research so far are:

1. The important variables which determined daytime conspicuity are the size of the object, its contrast with the immediate surroundings and the complexity of the background.

2. If a sign is to be noticed by a driver, it will be within 10° of his line of sight. When the eccentricity of the sign becomes greater than this then the sign is most unlikely to be noticed at all.

3. The present size of road signs (400 mm to 900 mm) is sufficient to ensure that they should be conspicuous. That they are not is due to their insufficient contrast and/or a high degree of visual clutter.

4. Traffic engineers should be aware of the importance of controlling sign contrast. The means by which this can be done is by careful placement or by allowing a high contrast surround to be placed around the sign as with traffic signals. The dimensions of such a surround are at present under investigation.

5. The degree of complexity of the background is a major variable affecting conspicuity and a means by which it can be measured must become available. Experiments have shown that subjects can rate complexity with some degree of precision, but an objective measure is preferable. It is suggested that there are two aspects of complexity:

   a) Clutter where the target has to compete with other similar objects. The effects of these similar, or confusion elements can be countered by sign design if the confusion elements can be identified, if their size distribution is known and if their average reflectance is known.

   b) Distraction elements: these elements are not necessarily similar to the target, but will attract the driver's attention. The act of noticing irrelevant information will take time and thus increase the demand load on the driver as less time is then available for the driving task.

6. Not all traffic control devices need to attract the attention of the driver. Some devices are needed by only some of the drivers; e.g., direction signs, parking signs and so on need only be acquired when searched for. Appropriate sign design should make it possible to develop an orderly hierarchy of road signing.

SIGN LUMINANCE REQUIREMENTS FOR VARIOUS BACKGROUND COMPLEXITIES

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The federal standards for luminance of retroreflective materials for traffic signs are absolute; they provide no differentiation based upon driver need. Driver needs for sign luminance are of two types -- luminance levels that define sign legibility and luminance levels that define sign conspicuity. A primary reason why the standards do not reflect these fundamental driver needs is the absence of conclusive data supporting practical and reliable guidelines and the fact that available luminance is dependent on several factors other than the specific luminance of sign material.

Research groups that have recently studied sign luminance and conspicuity include Cole and Jenkins, 1980, 1981; and Mace, et. al., 1982. Both groups call attention to the importance of background complexity in the study of conspicuity. Cole and Jenkins state: "No object is conspicuous per se. It can only be conspicuous in a certain background; if the background changes then the object may or may not remain conspicous." Mace, et. al. expanded this observation, giving equal importance to the role of driver motivation and uncertainty.

> "Conspicuity, like visibility and legibility, is not an observable characteristic of a sign, but a construct which relates measures of perceptual performance with measures of background, motivation, and driver uncertainty."

This recognizes that a stop sign is more conspicuous to the driver who is alerted that one is imminent, or a guide sign is more conspicuous to drivers traveling to the location designated on the sign.

Mace, et. al. operationally define conspicuity as changes in target (e.g., sign luminance) or concomitant changes in surround or scene which will

offset the performance decrements associated with either uncertainty or background complexity. For example, a sign requiring a 2-foot lambert increase in luminance to attain some level of perceptual performance is considered twice as conspicuous as a sign requiring a 4-foot lambert increase in luminance.

Very few studies have examined the effects of the visual complexity of nighttime highway environments on driver requirements for sign size and luminance. In general, the literature suggests that sign detection can be considered as a function of the visual characteristics of the target and its surround. Size and contrast have been found to be more important determinants of conspicuity than luminance but both Mace and Jenkins have found that scene complexity has a significant effect also. In fact, when visual complexity is high, the earlier study of Mace suggested that complexity was more important than sign luminance or contrast, although increased luminance could offset performance decrements produced by scene complexity. A subsequent field study suggested that in low complexity areas, signs below federal luminance standards for Type 2 sheeting may be adequate and that in high complexity areas, even new Type 3 sheeting may not be adequate for conspicuity.

While it may not be possible to produce a continuous scale reliable throughout the range of visual complexity, it may, from a practical perspective, be adequate to trichotomize the complexity dimension. The low end of the scale would define locations where sign maintenance is less important and the high end would define locations where special attention may be necessary.

In an effort to simplify the scaling of complexity, we have recently reduced the large number of complexity measures from our earlier work into four orthogonal factors:

1) number of traffic signs
2) demand of driving task
3) ambient brightness of the background
4) number of distracting elements

Subjective ratings on these factors were obtained for the same scenes as used in an earlier study and their validity using a sign recognition criterion from that study was compared with several global scales. The results suggest that global ratings lack validity, but that the orthogonal factors show promise. More recently a field study was conducted with 21 new highway locations. Complexity ratings were obtained from both photographs and site visits. Sign recognition and legibility distances are being obtained in the field using 3 levels of sign luminance at the 21 sites, which vary from very low to high complexity. We are hopeful that we will identify a procedure which will allow us to identify sites which require signs of higher luminance than Type 3 sheeting and sites where even degraded Type 2 sheeting is adequate.

DETERMINING MAINTENANCE NEEDS FOR TRAFFIC SIGNS

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The reconstruction of the nation's highways became a federal mandate with the recent approval by Congress of the motor fuel tax increase. With the availability of these funds, the highway community now has an obligation to produce results that go beyond the simple elimination of pot holes and the replacement of the most obsolete bridges. With the improvement in roadway surfaces, bridge widening and curve straightening will come increased traffic volumes and speeds. Increases in speeds and volumes are gauges of success. At the end of the first year of operation, however, another measure will be the accidents and fatalities. Will the increased speeds and volumes extract their price? There is clearly an obligation to take some strong measures to incorporate the optimum safety features at the time of restoration and rehabilitation.

Although some satisfaction may be taken from the gradual decrease in traffic fatalities for 1981 and 1982, these figures tend to conceal the fact that nighttime reductions are simply not there. Indeed, the nighttime fatality rate (fatalities per 100 million vehicle miles) was 2.7 times the day rate in 1971 and now, a decade later, stands at 4.3 times the day rate. While we have seen a reduction in daytime fatalities from 25,600 in 1971 to 19,400 for 1981, fatalities from nighttime accidents have risen from 29,100 to 31,400 for the same periods. These figures simply state that although driving is apparently safer in daytime, it is now more hazardous at night. What are we going to do about it?

There are numerous factors that have intervened which we can blame: 1) smaller vehicles with less crush space, with greater danger for object intrusion, 2) greater disparity with heavy trucks, 3) alcohol with, perhaps, a more disastrous interaction with youthful drivers, 4) changing demographics which have resulted in more younger and older drivers on the road while the number of middle aged, those with the best safety record, has decreased. Visibility has changed. Highways become commercialized and a concentration of complex and confusing nighttime surrounds may now encroach and pollute roadways planned only a decade before. These alarming trends will likely continue and should stimulate action now rather than reaction later.

Retroreflection and roadway lighting can help in every instance: older drivers, alcohol-impaired drivers, poor roads, vehicle size disparity, driver inattention and preoccupation. Research conducted over the past decade has sufficiently quantified the improvements that can be achieved with measures such as wider pavement markings, oversize and brighter signs, and maintenance techniques and equipment to inspect and identify deficient signs and markings.

Most recently, Sivak and Olson[1] have identified nighttime sign performance in terms of required luminance for percentage of users served at design legibility thresholds, as shown in Table 1.

The values apply to white, yellow and orange backgrounds of signs with black legends and to legends of signs with reflectorized backgrounds of up to 0.4 cd/m^2. The values apply to ideal, that is dark, conditions.

The translation of luminance values to coefficient of retroreflection (R^1, $cd/lx/m^2$) employs the model derived by Olson, Sivak and Egan[2].

Interpretation indicates that for 75th percentile performance retroreflectivities equal to or in excess of values obtainable from Type III