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# ROADSIGNS

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## III

## FOREWORD

During its meeting in Brussels (April 9-10, 1981), CIE Technical Committee 1.6, Visual Signalling, appointed a subcommittee "Signs" to draft a Technical Report which would review the visual aspects of signs. During the Amsterdam-meeting of CIE (September, 1983) this subcommittee became a Technical Committee in Division 4 (Lighting and Signalling for Transport): Technical Committee 4.05 "Signs". Division 4 changed the terms of reference during its meeting in Lausanne, Switzerland (September, 1985), limiting the scope of the report to "Roadsigns". The Technical Committee 4.05 submitted its draft to Division 4, which reviewed the document. The Board approved the document at its meeting of June 17-26, 1987 in Venice, Italy. This report includes an updated version of Publication CIE No.35 (TC-4.6) 1978: "Lighting of Traffic Signs", so that the latter document is replaced by the present Technical Report. It should be noted that any recommendations in this report are advisory and not mandatory.

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## SUMMARY

The purpose of this report from the CIE Technical Committee 4.05 is to provide information that will be relevant to an understanding of roads signs for road traffic guidance.

The report is restricted to matters that are of direct concern to the road user, and it is not concerned with any engineering aspects of signs.

The first part of the report gives a review in general terms of subjects related to the visual effectiveness of signs. The chapter on information processing demonstrates the complexity of the traffic situation and the driving task.

The discussion of four aspects: conspicuity, legibility, comprehensibility and credibility lead the user of the report to a general understanding of all aspects required for a user's perception of signs.

Many investigations have been made into the factors likely to influence the perception of road signs. An extensive chapter discusses these particular roads sign aspects as seen from a practical point of view. In this chapter again, the four aspects of conspicuity, legibility, comprehensibility and credibility are shown to be basic.

Variable message signs (VMS) are the subject of a separate chapter. While the development of these signs is still progressing a state-of-the-art is provided. It is suggested that those interested investigate this topic further.

In the last section of the report a number of different subjects are discussed, including retroreflection, influence of environmental conditions, and the maintenance of signs. Finally, a large bibliography gives the user an entrance to further information.

## IX

## RESUME

Panneaux de signalisation

L'objet de ce rapport du comité technique CIE 4.05 est de fournir les informations nécessaires à la compréhension des panneaux de signalisation pour le guidage et la régulation du trafic.

Le rapport se limite aux problèmes intéressants directement l'utilisateur de la route et ne concerne pas la conception ou la fabrication des panneaux.

La première partie du rapport passe en revue les aspects généraux des facteurs relatifs à l'efficacité visuelle des panneaux. Dans le chapitre sur le traitement de l'information, on met en évidence la complexité de la circulation routière et de la tâche de conduite.

La perception des panneaux est traitée sous quatre aspects: "conspicuité", lisibilité, compréhensibilité et crédibilité. Ceci permet de mieux comprendre les divers éléments nécessaires à une bonne perception des panneaux pour les usagers.

De nombreuses recherches ont été consacrées aux facteurs susceptibles d'influencer la perception des panneaux. Un long chapitre considérable traite des aspects particuliers de ces panneaux. Les notes de conspécuité, lisibilité, compréhensibilité et crédibilité y sont à nouveau fondamentales.

Les panneaux à messages variables sont discutés dans un paragraphe séparé qui ne traite que de l'état actuel de l'art. En effet le développement de ces panneaux progresse très vite. Il est suggéré d'intensifier les études sur ce sujet.

Dans la dernière partie du rapport, divers sujets sont abordés: la rétro-réflexion, l'influence des conditions extérieures et la maintenance des panneaux.

Enfin, une importante bibliographie permet au lecteur de compléter son information.

## ZUSAMMENFASSUNG

### Verkehrszeichen für den Straßenverkehr

Dieser Bericht des Technischen Komitees CIE 4.05 soll notwendige Informationen über das Verständnis von Verkehrszeichen liefern.

Der Bericht ist beschränkt auf die für den Straßenbenutzer relevanten Probleme. Er befaßt sich nicht mit der technischen Ausführung von Verkehrszeichen.

Es wird zunächst ein allgemeiner Überblick über die Themen gegeben, die mit den visuellen Aspekten von Verkehrszeichen zu tun haben. Am Anfang des Berichts wird die Komplexität von Verkehrssituation und Fahraufgabe deutlich gemacht.

Die Behandlung von vier Themen: Aufmerksamkeit, Wahrnehmbarkeit, Verständlichkeit und Glaubwürdigkeit ist das Leitmotiv dieser Veröffentlichung und macht damit dem Benutzer deutlich welche Faktoren alle an einem optimalen Verständnis von Verkehrszeichen beteiligt sind.

Viele Untersuchungen wurden durchgeführt, um fest zu stellen welche Maßnahmen das Erkennen von Verkehrszeichen beeinflussen können. Viel Aufmerksamkeit wurde dabei den praktischen Faktoren gewidmet. Auch für dieses Kapitel bilden die vier Themen: Aufmerksamkeit, Wahrnehmbarkeit, Verständlichkeit und Glaubwürdigkeit die Grundlage.

Der Bericht behandelt auch die Wechselverkehrszeichen. Da die neue Untersuchungen und aktuelle Entwicklungen auf diesem Gebiet einander so schnell folgen, war es nur möglich den momentanen technischen Stand zu vermitteln. Es wird vorgeschlagen weitere Untersuchungen verstärkt vorzunehmen.

Im letzten Abschnitt werden verschiedene Themen angeschnitten, wie zum Beispiel Retroreflektion, Einfluß des Klimas und der Unterhalt von Verkehrszeichen.

Eine große Bibliographie eröffnet dem Benutzer weitere Informationsmöglichkeiten.

## 1 SCOPE

This report is concerned only with matters that directly influence the road user's perception of road signs. It does not cover other important matters concerning signing practice, as for example, the location of signs and the electrical and mechanical engineering aspects of signs.

A sign requires:

1. CONSPICUITY: Signs need to attract attention so that they are noticed.
2. LEGIBILITY: The message displayed on the sign by means of alpha-numeric or symbolic characters must be legible at the distance from which the sign is to be read.
3. COMPREHENSIBILITY: The message displayed must be easily understood and the response required by the message must be clearly conveyed.
4. CREDIBILITY: The message should be such that the reader believes what is conveyed and acts upon it.

In French, the term "panneau de signalisation" only refers to a device in the form of a panel. That is indeed the type of sign which is covered within the scope of this report. It does not cover traffic lights and road markings.

The terminology in the report is generally in accordance with the "International Lighting Vocabulary" (CIE, Draft 1982).

## 2 INTRODUCTION

## Definition of "sign"

A sign is a device that provides a visual message by virtue of its situation, shape, colour or pattern, and sometimes by the use of symbols or alpha-numeric characters. It may be internally illuminated<sup>1</sup>.

The function of road signs for road traffic is to improve the quality of service of the road network. This quality can be expressed in road safety, travel speed and road capacity, and driver comfort and convenience. The functional approach to traffic facilities is treated in detail by Schreuder (1971). When the need for road traffic signs and their characteristics are deliberated, the conclusions reached may differ according to which one of the above objectives is under consideration. Thus, there may be three distinct sets of reasons for the introduction of road traffic signs. For all three sets, the visibility of the sign is essential.

The visual sense is the main channel providing most of the information needed by a road user (Forbes, 1972). Hence, the characteristics of visual perception should be seriously considered in approaching traffic problems.

Traffic problems are not only indicated by the occurrence of accidents, but also when there is a disruption of smooth traffic behaviour like erratic manoeuvres, irregularities in traffic flow, congestion and so on. Optimization of the traffic environment should lean heavily upon considerations of visual perception.

<sup>1</sup>-----  
This definition deviates from the CIE Vocabulary, Draft 1982 by introducing "visual message" rather than "visual signal".

A sign is a short message used to transfer information. The objective of such a communication is to have the receiver understand what the sender means. The sender is the sign designer and he must consider the discriminative, interpretative and recall skills of the driver, and the environmental conditions under which the driver must receive the message.

On the basis of an analysis of the accident causation process, Perchonok (1972) concluded that 30-60 percent of the accidents were mainly due to information processing failures. In most cases the information was perceived but not interpreted in the right way.

In designing messages for signs there are two factors that enhance communication: legibility and comprehensibility.

### 3 GENERAL ITEMS

#### 3.1 Information processing

The general goal whatever the mode of transport is to reach the destination safely, quickly and comfortably. These general goals are transformed into real motives.

Probably these motives are hierarchic - that is to say in driving the road layout information is primary, obstacles and other road users secondary, while the additional information (e.g. signs) that is so common along roads comes last. Consequently, information of the last type is only picked up, provided there is the time and opportunity. There is also a kind of hierarchic order within this third type of information. Some signs reduce uncertainty more than other signs.

Experience is highly individual. It has, however, several general characteristics. Every road user goes through a learning process in which he receives sets of very important, less important and unimportant "signals". These "signals" may be natural (e.g. a specific road geometry) or artificial (e.g. a road line or sign). A "signal" that has been passed many times without anything happening (e.g. a warning sign for game or road works) loses its "signal value" and gradually gets the importance corresponding to for instance that of a tree. It still contains information, but it will not be "seen". On the other hand a "signal" that is always followed by an event (e.g. a sign indicating an accident or a sharp curve) gets a very high "signal value". It contains much information. It will be seen. Credibility is a key concept for learning processes. In other words it is very important that the information we want to transmit to the road user is followed by some feedback to reinforce correct behaviour. This leads to a satisfactory learning process.

Motivation and experience influence the direction and level of attention and expectation which in turn influence sensory processes (e.g. eye movements), perceptual structuring (e.g. we see what we expect to see) and decision processes (we often get very prejudiced).

Three different levels may be distinguished in driving with regard to tasks and information processing (King and Lunenfeld, 1971). At the most elementary level the performance of the driver with regard to course keeping and speed control is central. At this level there is continuous processing of information with a preview in the order of a maximum of a few seconds. The second level covers all tasks requiring manoeuvring. This includes overtaking, changing direction, etc. The time span of these manoeuvres is in the order of a few seconds to a few minutes. At the third level, the task includes strategic decisions concerning route choice and route following with the aid of route guidance systems. At this level only occasional decisions are made, but the time span concerned may include the total duration of the trip.

At all three levels, visually presented information is of great importance; therefore in this multi-task environment the control of frequency and timing of this information is important.

A large body of literature is available on the sensory basis of perception of visual information in traffic situations. Much is known about aspects such as contrast, conspicuity, discernibility and legibility. This is discussed in par. 4.1 and 4.3. Knowledge of the variation in sensory capabilities, and of sensory defects is also often integrated in recommendations.

Much less is known about the way people process the information after it has been sensed, and the role which is then played by memory, type of processing, motivation, etc.

Although information is provided by technical means in the environment, it is in the user that perception and experience lead to a form of behaviour. Information might therefore lead to different behaviour between observers. It is the perceived situation, not the physical reality, that determines behaviour!

This is of vital importance. Engineers construct the physical traffic environment (road or harbour geometry, surface, delineation, signs, traffic signals, etc.). Many presume intuitively that the same

environment is perceived identically by different individuals. This is not the case. Every individual observer selects and interprets his own information.

### 3.1.1 Visual abilities and road safety

The question arises why so little correlation is found between visual test scores and accident rate, while visual information seems so important in driving a car. Hills (1980) gives the following reasons:

1. Burg (1967) (and others who did similar studies) concentrated on the measurement of fundamental visual abilities. The dynamic visual acuity had the best predicting value, but even then the correlation was low. A good test probably requires the determination of the abilities of the motorist on a higher level of information processing. In other words, the tests were too simple.
2. When driving a car it is probably more important to look at the right place at the right time than to observe a detail after a long period of observation.
3. Although young drivers have the best visual acuity scores (see 3.3.1, Visual Acuity), they have the highest accident rates. Learning to drive well could mean the improvement of the ability to select the available visual information, to process it and to react adequately. A decline in the primary visual abilities could be compensated for by adapting the driving behaviour. This adaptation can go to the point of deciding not to drive at all in certain conditions, for instance in the dark (see also Ysander and Herner, 1976; Hills, 1975).
4. Accidents are usually caused by a multitude of events. One cannot isolate one aspect (e.g. the visual) from the others.

It is also stated by Davison (1978) that in fact there is mounting evidence to suggest that for the majority of drivers there is only a very weak association between visual acuity and accident record.

Thus there seems to be no strong relationship between individual differences in visual performance and traffic safety. There are even drivers with large visual deficiencies, who nevertheless are successful.

ful drivers (see 3.1.1.1 and ANNEX I). We thus need a more elaborate (theoretical) framework which also encompasses characteristics of visual information processing.

#### 3.1.1.1 Visual acuity in relation to accidents

An essential in this chapter is that one has not been able to invent a visual test for predicting accident involvement. The study done by Burg (1967) in which he determined the correlation between the scores of several visual tests and accident rates for 17,000 Americans is almost classical. The large scale on which the study was performed makes it unique. The principal conclusion was that there is little or no relation between low visual acuity and accident rate. With further analysis of the data of age groups (Hills and Burg, 1977), for instance regarding the static visual acuity (i.e. the classical visual acuity), a significant correlation between accident rate and low visual acuity was only found in the group of 2975 persons above the age of 54. This suggests that more central stages of information processing are important. The practical significance of such a weak correlation, however, is limited. Of the total group of 17000, 529 were involved in an accident, 519 of them had a visual acuity of more than 0.5, 10 had less. If the driving license were withdrawn from all who did not have an acuity of 0.5, then, apart from the 10 who were involved in an accident, another 38 persons who had a visual acuity of less than 0.5 would have suffered who had never been involved in an accident. Moreover, one has to take into account the cost of testing a group of 2975 persons.

#### 3.1.1.2 Driving requirements

In some countries ophthalmological requirements have been established for obtaining a driving licence. There are no uniform requirements from country to country with regard to the method of measuring visual acuity and the visual field. Since such measurements depend greatly on precise measuring conditions the requirements are often less severe in actual practice than they seem on paper.

Throughout the world the total visual requirements show large variations, but the minimum requirement of a visual acuity of 0.5 to 0.6 can be found almost everywhere.

For one-eyed persons the requirement for the good eye can be somewhat higher, for example visual acuity 0.8 (in The Netherlands). The importance of such a requirement is still open to question. One-eyedness implies a limitation of the available peripheral visual field which cannot be compensated by a better visual acuity in the fixation point of the functioning eye.

The rules for contact lenses originated at a time when contact lenses were still a very special phenomenon. There seems to be little reason to draw up other rules for contact lenses than for spectacles (Van Norren, 1979). The use of contact lenses allows the recovery of most of the visual field which is restricted by the use of spectacles.

#### 3.1.1.3 Other visual abilities

Subjects such as three-dimensional vision, unbalance in the eye muscles and dominance of one eye have received attention in studies on driving behaviour.

According to the literature review by Davison (1978) some studies show a weak positive correlation between test results and accidents, but they usually concern relatively small populations. It has not been proven that any of these abilities are very important for the driving behaviour.

Summarising, it seems unlikely that a visual test will ever be invented that selects the accident prone driver in advance. However, from this one cannot draw the conclusion that the existing minimum requirement for visual acuity (at least 0.5) should be withdrawn. It is quite possible that this requirement, which excludes those with a very low visual acuity, is the reason why such a low correlation is found between visual acuity and accident rate.

#### 3.1.1.4 Motivation, expectation, education

Expectation patterns greatly affect observations and information processing. Hills (1980) illustrates the problem very well. In his first example a motorist looks at a cyclist at an intersection but nevertheless hits him. It may be assumed that the motorist had looked for other cars or trucks because it was with them that he expected a possible conflict situation. The cyclist did not fit in that pattern and therefore was not "seen". Although this example particularly

applies to an American traffic situation where there are hardly any cyclists, it indicates the type of problem. In a second example Hills suggests the need to exaggerate the signalling used for indicating construction work on a motorway because the motorist develops a perceptual inertia on this type of road, especially when the road is quiet. From a perceptual point of view so little is required from the motorist that more effort has to be made to induce him to react.

Roper and Howard, in a study on headlamp seeing distance, showed that unalerted drivers see only half as far ahead as alerted drivers, when looking for an object (Roper and Howard, 1938).

Advertising signs of course have to be deliberately eye catching and often have to be accepted. Their distracting influence is lessened by having an easily recognised "uniform" for traffic signs. It is important that advertising signs do not resemble traffic signs in such a way as to risk causing confusion.

The important perceptual selection and analysis is made at higher levels. Motivation and experience influence expectation and attention, which in turn control to a large extent what is seen and heard.

Education is a part of "experience" and may be expected to modify behaviour. Education is a matter of great importance, although it should not be exaggerated, as is often done. It is particularly important when any conflicting reactions of drivers are observed, or when new signs or new types of signs are being used. As mentioned above, drivers act on the basis of previous experience and react to what they think they know or expect. If something new suddenly happens while driving, the reaction cannot be precisely predicted, and can be dangerous in some cases. This is likely to happen when driving for the first time in another country, for example when going from any continental country in Europe to Great Britain, which requires a change from driving on the right to driving on the left.

Education is a fundamental tool for preventing undesirable reactions, and for explaining the significance of each sign, and this is particularly important for new drivers.

Where education appears to fail e.g. in the understanding of certain symbols, or in faulty driving habits, it may be the design of the symbols, or the assumptions regarding human behaviour which are at fault, and not the need for more education.

### 3.2 Conspicuity

The traditional view of the visual acquisition of information is that of a progressive series of stages from an early awareness of a difference in energy at a specific point in the visual field, to a realisation of form and colour and then of a detailed structure. These stages are termed detection, recognition and identification where detection is an awareness of the presence of an object, recognition is the ability to place the object into a particular class for example vehicle or vegetation, and identification is the ability to name the object as a particular member of the class, for example, a tank rather than an armoured personnel carrier.

The task of detection depends on the sensory capabilities of the observer whereas recognition and identification depend also on memory and association which have been previously learned. The progression detection-recognition-identification does not describe different types of visual performance but relates to the characteristics of the target which can be detected and the level of discrimination required of the observer. Thus visual acquisition is concerned primarily with the process of detection whether it be of the presence, form, colour or intrinsic detail of the object.

This traditional view has grown largely from the visual search area where the observer has the task of detecting known targets. In many situations, however, the primary task is not the detection of targets. It is often that information to be given to the observer is subsidiary to his/her main task and the visual signal must invade the observer's perception i.e. he/she is not searching for the signal but is monitoring the visual environment and the signal must gain the observer's attention before its information can be acquired.

In the environment there is an enormous influx of visual information with which an observer has to contend. It is essential that priorities be allocated to this information so that attention can be directed to only those facets which are necessary to complete the task.

The perceptual system must therefore perform a filtering action by which the majority of the visual information is shed and the important and necessary information is attended to and used. What information is considered important and so attended to, depends on the message of the sign and its relevance at the time.

Thus some degree of pre-attentive processing of all information must occur so that the important information is not discarded but progresses to the stage of consciously being used.

If the information to be conveyed is not adequately prominent, legible and comprehensible at this pre-attentive level of processing then its importance may not be evaluated and it may not warrant attention.

Conspicuity then is the attribute of an object within a visual context which ensures that its presence is noticed at the pre-attentive level of processing, and is defined therefore as: "Quality of an object or a light source to appear prominent in the surroundings" (CIE Voc. Draft 1982, see also DEFINITIONS, Ch. 5).

A sign then must meet four criteria; it must be **conspicuous**, its message must be **legible** and **understood**, also it must then be **credible** to observers - they must believe what it says and that it applies to their immediate situation.

If any of these criteria fails then the message will not be registered or it will be discarded. The information will not progress past the pre-attentive level of processing, the observer will have no recollection of it and any hoped for action will not happen.

### 3.2.1 Methods of Measurement

Inevitably the methods by which conspicuity is measured largely determine the kind of results that are obtained so it is important that the limits and assumptions of each method are given.

One measure derives from an operational definition of sensory conspicuity proposed by Cole and Jenkins (1980). This states that a conspicuous object is one that will, for any given background, be seen with certainty ( $P > 90\%$ ) within a short observation time ( $t = 250$  ms) regardless of the location of the object in relation to the line of sight.

Thus a conspicuous object requires no searching in order to be seen with certainty, and the definition implies that the primary measure of sensory conspicuity is the eccentricity at which the object is seen. This measure is very similar to the "conspicuity area" of Engel.

These methods have been established in the laboratory, their validity in the real traffic situation is not certain. Indeed it is difficult to know how such a paradigm could be transferred to the field situation. By this method a conspicuous object is one which is detected immediately, and it is this requirement which really prevents the method from being transferred to practical situations, where signs continually increase their angular subtense and eccentricity with time and their backgrounds will continually change.

An on-road method was devised by Hughes and Cole (1984) and Hughes (1983) who carried out a field trial investigating the conspicuity of traffic control devices and disc targets in a suburban environment. They used a verbal report method which included both sensory and cognitive aspects of conspicuity and, most importantly, observer variables such as their state of arousal, their expectations and their level of attention.

Cole and Hughes reasoned that these observer variables must play a major role in determining whether a sign is acted upon in the traffic situation. As a result they decided to manipulate the level of

attention of drivers by issuing two different instruction sets. In this way they could investigate two aspects of conspicuity; attention conspicuity and search conspicuity.

**Attention** conspicuity is the capacity of the sign to attract attention when the observer is unaware of its likely occurrence (instruction set: report all things which attract your attention).

**Search** conspicuity is the ability of the sign to be quickly and readily located by search e.g. when an observer needs a direction sign or street name (instruction set: report all signs which attract your attention).

The verbal report is the end result of all levels of processing. If a sign is reported it may be because:

- a. it is conspicuous, and
- b. it is important to the observer at that moment, and/or
- c. its message requires some action on the part of the observer.

If a sign is not reported it may be because:

- a. it is inconspicuous, or
- b. it is not credible, or
- c. it is so normal and accepted that it is literally unremarkable.

### 3.2.2 Determinants of Conspicuity

Conspicuity can only be discussed in the context of complex backgrounds. If the target is in a uniform background then conspicuity is identical to visibility. 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<sup>1</sup>.

An area in which conspicuity has received a good deal of attention is that of collision avoidance in aircraft where the detection of signal beacons and warning lights of other aircraft is imperative and failure to do so may involve a very high cost.

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<sup>1</sup> A number of studies on this subject are described in Annex III.

In order to tackle the problem of the quantification of background complexity directly a series of experiments were carried out using schematic backgrounds which could be quantified and yet sufficiently complex and versatile that they could be varied systematically along several dimensions (Jenkins and Cole, 1982; Cole and Jenkins, 1984). The backgrounds consisted of a random array of discs, each disc simply specified by diameter and luminance, the complexity of the background was manipulated in three ways:

- a. the number of identical background discs was varied from one upwards;
- b. the number remained constant but their size distribution was varied;
- c. the number remained constant but their luminance distribution was varied.

For each background set the target disc differed in either size or luminance. The subject's task was to locate the largest/brightest disc in the stimulus slide which was presented for 250 ms, the target being positioned at various eccentricities.

The results are, perhaps, best summarised in two parts - whether the target was discriminated on the basis of size or luminance.

#### Luminance Discrimination

Luminance discrimination was best when just two discs were compared. As the number of discs increased to occupy 5 per cent and 10 per cent of the background area performance decreased, so that the target disc must have a greater luminance difference from the background discs for it to be detected. Increasing the number to 15 per cent density did not change performance by any significant amount.

If the background discs themselves differed in luminance (but were the same size) then it was found that the degree of variability had no effect on the conspicuity of a target differing in luminance alone.

The reflectances of the background discs used to generate the stimulus slides attempted to match those which could be found in daytime environments. This would indicate that variation of luminances in daytime environments will not have a large effect on target con-

spicuity. The regression lines for luminance discrimination at the 92 per cent probability level of detection are shown in Fig. 1 and are given by:

$$C_L = 0.06 \epsilon + 0.37 \quad \text{Two Discs} \quad (1)$$

$$C_L = 0.10 \epsilon + 0.47 \quad \text{5\% background density} \quad (2)$$

$$C_L = 0.19 \epsilon + 0.35 \quad \text{10\%, 15\% background density and variable luminance.} \quad (3)$$

where  $C_L = (L_T - L_B)/L_B$  and  $L_T$  is the luminance of the target disc and  $L_B$  is the average luminance of the background discs, and  $\epsilon$  is the eccentricity in degrees.

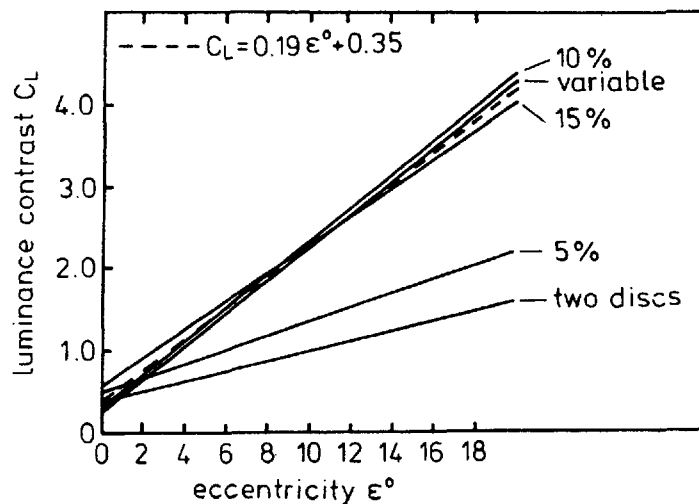


Fig. 1 Graph of the contrast in luminance between the target disc ( $L_T$ ) and background disc ( $L_B$ ) necessary for it to be discriminated 92% of the time as a function of eccentricity for all types of background complexity.  $C_L = (L_T - L_B)/L_B$ .

### Size Discrimination

The results for the size discrimination tasks showed that increasing the density of the background elements had no effect on the conspicuity of the target which differed in size only. The ability to discriminate the target was the same as that for just two discs no matter whether the background density was 5 per cent, 10 per cent or 15 per cent. The results are shown in Fig. 2 and can then be adequately summarised by the equation:

$$C_S = 0.033 \epsilon + 0.10 \quad (4)$$

where  $C_S = (D_T - D_B)/D_B$ .

However, if the background elements themselves differ in size, the degree of variability did have an adverse effect on the conspicuity of the target which differed in size only. The results of the experiment can be explained using a simple model based on the above equation.

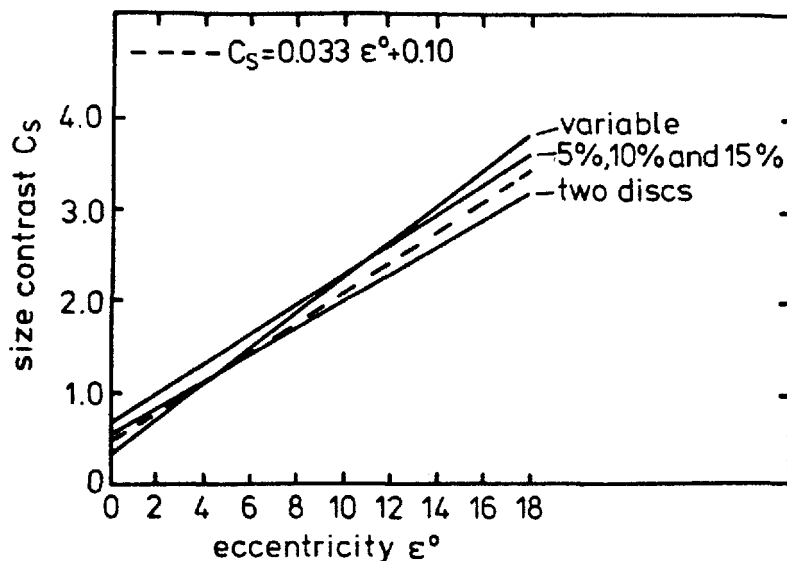


Fig. 2 Graph of the contrast in size between target disc ( $D_T$ ) and background discs ( $D_B$ ) necessary for it to be discriminated 92% of the time as a function of eccentricity for all types of background complexity.  $C_S = (D_T - D_B)/D_B$ .

This says that at a given eccentricity the largest background disc cannot be discriminated from other background discs if the contrasts in size are less than the threshold contrast given by the equation above. Thus a weighted average large background disc can be described for the population at any eccentricity. Then, to be discriminated, the target disc must be of sufficient diameter that when contrasted against this average background disc it will exceed the threshold given by the above equation. Therefore:

$$C_S = 0.333 \epsilon + 0.10 \quad (5)$$

is applicable to a wide range of backgrounds provided  $D_B$  is defined as the diameter of the weighted average of all the largest background discs which cannot be discriminated on the basis of size at a given eccentricity.

The equations 1 through 5 give the means by which it is possible to specify some physical attributes of a target which will ensure its conspicuity. But in order to do this we need to be able to determine the population of background elements which could be confused with the target, their size distribution and their average luminance.

### 3.2.3 Nighttime conspicuity

Conspicuity is the detection and identification of the sign in an environment which may vary from a dark surrounding free of extraneous lights and distractions, to a highly textured and complex surrounding in which many stimuli compete for attention. Detection of small signs of low luminance may be accomplished in dark surroundings with unlimited search time. In many nighttime circumstances, oncoming headlamps, complex surroundings, glare sources, and limited time to search require that signs have greater size and luminance to be seen. Detection provides a frame of reference to localize an object in space, while identification provides additional understanding of the colour and shape and permits the sign to be considered further or ignored.

## 3.3 Legibility

A very important factor that determines the legibility of a sign is the size of the characters or symbols that display the message.

Considering the definition, it becomes obvious that several aspects of visual abilities are of importance in the relation to the observation of traffic signs.

### 3.3.1 Visual acuity

This is a very important parameter to consider when studying signs (for definition Ch. 5). It is of particular interest to know how this human ability varies among the population, and how it is related to luminance level and contrast.

These aspects are related to the problem of evaluating visual acuity from the point of view of detection and legibility of a sign. Data on visual acuity play a role in the discussion about information carriers. Ultimately it remains a tool for estimating what proportion of the observers is able to read a sign at a certain distance, and for determining that distance.

The ability to resolve small detail is assessed by measuring the static visual acuity. Visual acuity is usually recorded in a form known as Snellen notation where the notation 6/6 indicates the ability to resolve detail of one minute of arc. Table I sets out the various notations used to specify visual acuity.

Table I. Visual acuity equivalents.

| Snellen notation |          | Visual angle                                     | Decimal notation<br>(min <sup>-1</sup> ) |
|------------------|----------|--------------------------------------------------|------------------------------------------|
| Metric           | Imperial | subtended by<br>detail resolved*<br>(min of arc) |                                          |
| 6/3              | 20/10    | 0.50                                             | 2.0                                      |
| 6/4.5            | 20/15    | 0.75                                             | 1.33                                     |
| 6/6              | 20/20    | 1.0                                              | 1.0                                      |
| 6/7.5            | 20/25    | 1.25                                             | 0.8                                      |
| 6/9              | 20/30    | 1.50                                             | 0.66                                     |
| 6/12             | 20/40    | 2.0                                              | 0.50                                     |
| 6/15             | 20/50    | 2.5                                              | 0.40                                     |
| 6/18             | 20/60    | 3.0                                              | 0.33                                     |
| 6/21             | 20/70    | 3.5                                              | 0.29                                     |
| 6/24             | 20/80    | 4.0                                              | 0.25                                     |
| 6/30             | 20/100   | 5.0                                              | 0.20                                     |
| 6/36             | 20/120   | 6.0                                              | 0.17                                     |
| 6/60             | 20/200   | 10.0                                             | 0.10                                     |

\* When the target is an alphanumeric character the details are the stroke width and gaps in the character. The character will normally have an overall height five times that of the stroke width. Thus a 6/6 Snellen letter will have an overall height subtending 5 min of arc at the observer's eye and a limb width of 1 min of arc.



### 3.3.2 Distribution of visual acuity among the population

Several studies deal with this problem; US data are given in McDowell (1964) and Roberts and Ludford (1977).

Fig. 3 gives the distribution of visual acuity in a general population.

About 73% of the population have a visual acuity of 6/6 or better when tested wearing their usual glasses (US Dept. Health Educ. and Welfare, 1964 = McDowell, 1964). However, this means that nearly one quarter of a general population have visual acuity that is less than normal even when wearing their usual glasses.

A problem which arises when applying the American calculations to situations in other countries is that the method used for determining

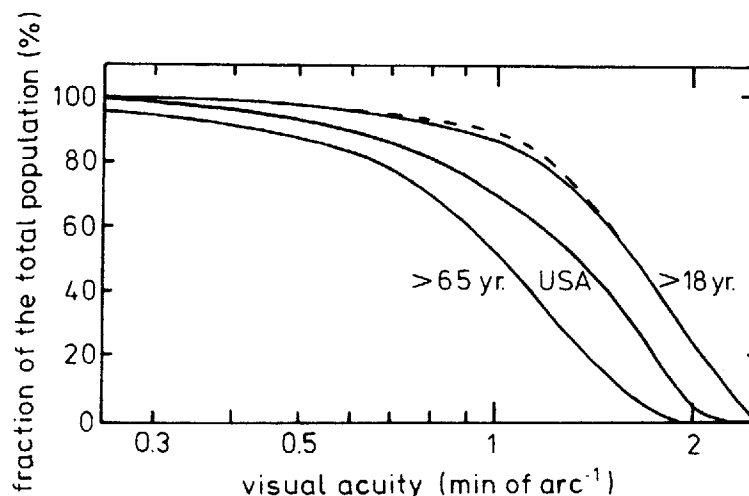


Fig. 3 Cumulative frequency distribution of visual acuity in different populations:

The >18 yr. and >65 yr. indicated lines give the percentage of a total population over 18 and over 65 years of age respectively who just reach or exceed a certain acuity limit (from Walraven and Blokland, 1980).

The dotted line gives the results of a UK survey of 1368 car drivers (Davison and Irving, 1980).

The line with the indication USA gives the cumulative frequency distribution of visual acuity in a general population including non-drivers (US Dept. Health Educ. and Welfare, 1964).

In all studies the observers are wearing their usual glasses.

visual acuity affects the visual acuity numbers. For instance, Fig. 3 shows a cumulative distribution of visual acuity based on the data of McDowell (1964) but corrected for (a) the Dutch way to measure visual acuity with the TNO Landolt-C chart (Vos, 1969), and (b) the Dutch age distribution (Walraven and Blokland, 1980). Even then uncertainties remain mainly as to whether in the US and The Netherlands the same average eye care exists, especially with regard to the correction with spectacles.

It is necessary to establish the distribution of visual acuity among the (future) users of the sign, not the general public. In the case of road traffic these are the drivers; in the case of other fields of application of signs one is usually concerned with specially selected users, who are thoroughly tested as regards their visual performance. In Britain a survey using a standardised clinical test of visual acuity<sup>2</sup> was conducted during the period March to September 1976 (Davison and Irving, 1980). Drivers were tested at a total of 25 sites in England, Scotland and Wales. The number of drivers tested at each site was predetermined, being proportional to traffic volumes measured previously at a nearby census point.

Drivers were tested while wearing spectacles only if these were observed to have been worn as they drove into the test site. They were deliberately encouraged to read the smallest possible targets of the acuity chart.

Scores were available for 1368 drivers of all ages combined; their distribution shown in Fig. 3 is very close to the Walraven and Blokland data.

### 3.3.3 The effect of reduced vision

It is conventionally assumed that the normal visual system can distinguish detail that subtends an angle of one minute of arc at the observer's eye. Since letters are often constructed on a 4x5 matrix with a stroke or limb width about one fifth the overall height of a

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<sup>2</sup>Measurements were made using a Snellen test chart the acuity values of which ranged from 6/60 to 6/4. Conditions for measuring visual acuity conformed in all respects to British Standard 4274 (illiterate E, abridged chart).

letter (see Fig. 4) a general rule is that observers with normal vision (visual acuity 1) can read letters that have a height that subtends 5 minutes of arc at the observer's eye. This means that the distance  $D$  at which letters can be read by a person with normal vision is given by the formula

$$H = 1.5 D \quad (6)$$

where  $H$  is the height of a letter in mm and  $D$  is the maximum observation distance in distance in metres at which the letter is legible. The distance  $D$  is known as the legibility distance.

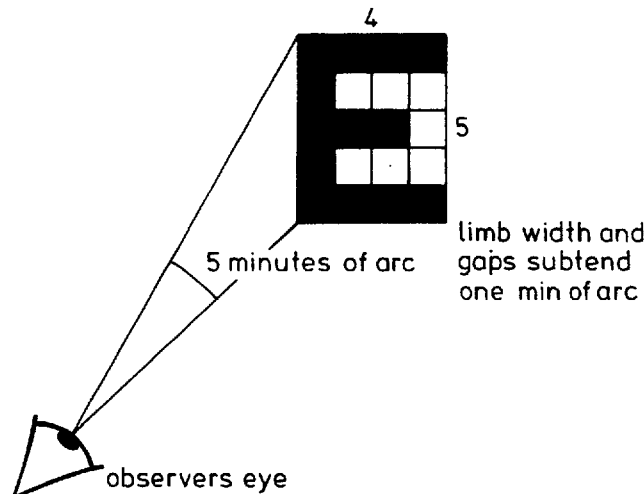


Fig. 4 The normal human visual system can resolve detail subtending one minute of arc at the observer's eye. Assuming the letter is constructed on a 4x5 matrix the height of the smallest letter that can be read subtends 5 minutes of arc at the observer's eye.

A simple statement of this rule is that letters will have a legibility distance of 20 m for every 30 mm of letter height<sup>3</sup>, but there are many other factors that need to be taken into account in determining a practical legibility distance for a given letter height. For

<sup>3</sup>Kneebone (1964) did a study on legibility distance, see for more detail Annex IV.

symbols the legibility distance has to be defined for each one separately.

This rule is appropriate only when the whole user population has normal vision, as might be the case in marine or aviation operations for which stringent vision standards are applied. In other circumstances, it cannot be assumed that all observers have normal visual acuity. For example, motor vehicle drivers are usually permitted to have a degree of reduced vision and in some applications the user population is not required to meet any visual standard. In the general population a significant number of people have a reduced ability to see small details because of an uncorrected refractive error or because of a disease or defect of their eyes.

From Fig. 5 it can be seen that 95% of an unselected general population have visual acuity of 6/12 or better when wearing their usual glasses. If the lettering in a sign is to be legible for 95% of the population at the design distance the following formula based on the height of the letters subtending 10 minutes of arc (6/12 acuity) is appropriate:

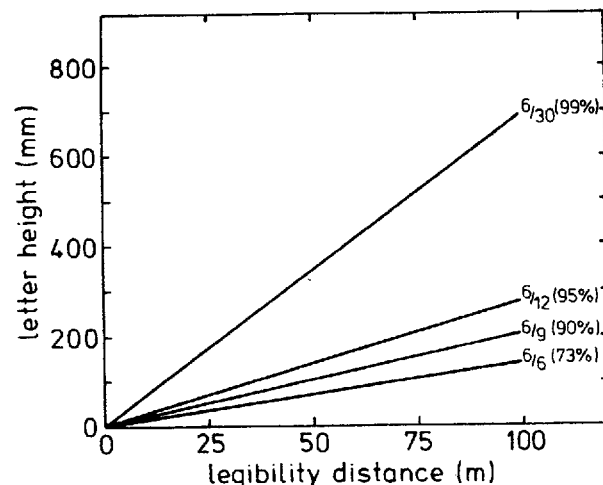


Fig. 5 Legibility distance in metres as a function of letter height in mm assuming various levels of worst visual acuity in the user population. The visual acuities assumed for each line are shown on the lines in Snellen notation. The percentages in brackets are the percentages of an unselected general population that would be able to read the letters of given height at the legibility distance, wearing their glasses.

$$H = 2.9 D$$

(7)

Fig. 5 relates legibility distance to letter height for various levels of visual acuity and shows the proportion of the population that would be able to resolve letters at the design distance D.

### 3.3.4 Visual acuity as a function of contrast (luminance)

Numerous studies exist concerning the relation between visual acuity and luminance<sup>4</sup>. For traffic signs however, only a limited number of research studies have been carried out.

For transilluminated guide signs the study of Van Meeteren et al. (1968) shows clearly that an optimal visual acuity can be reached at a luminance ratio<sup>5</sup> of approximately 10. This value is an optimum for light text on a dark background. When a light text with a text luminance of over 20 cd/m<sup>2</sup> is used on a dark background such higher luminance ratios can be the cause of irradiation (Van Norren, 1981a).

In the Van Norren study a Landolt C ring was used as symbol, on a circular background. Jainski (1976, 1977) also used a Landolt C ring in a study on non self illuminated signs in which six differently coloured signs were studied. He showed that visual acuity not only depends on the luminance ratio between text and background, but it also depends on the colour contrast. Furthermore the Jainski study (1977) shows that at smaller distances (50 m) the shape is first recognised and later the colour.

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<sup>4</sup>A separate paragraph on the effect of sign luminance is given in 3.3.11.

<sup>5</sup>Although the word contrast is usually used in the case of traffic signs and direction signs, it is better to use luminance ratio. This word is used in those cases where the adaptation condition of the eye is not clearly determined either by the text or by the background.

### 3.3.5 Visual field

Visual field defects can be congenital or pathological, the latter mainly in older age groups. A distinction can also be made between a loss originating in the brain, which generally causes a loss of the overlapping visual fields of both eyes and a loss originating in the eye or the optic nerve which can appear in one eye only or can be different for each eye.

Different studies have shown (Thalman, 1971; Council and Allen, 1974; Vos, 1974) that a fairly restricted visual field can be compensated quite well for example by making more head and eye movements than a normal observer (see ANNEX I for road drivers).

### 3.3.6 Colour vision, colour vision deficiency

No studies are known which prove a correlation between decreased colour discrimination and accident rate based upon accident statistics (Davison, 1978). It seems amazing that so few problems arise in practice<sup>6</sup>, in view of the difficulties colour-defective people experience (about 8 percent of the men and 0,6 per cent of the women) when they have to discriminate certain colours under laboratory conditions. The standardisation of the relative position of the colours red, yellow and green in traffic lights, and also an optimum choice of these colours (par. 4.3) helps people with such difficulties.

### 3.3.7 Multiple word messages

So far we have considered only the legibility of single letters. Messages on signs are usually made up of a word or a series of words and predicting legibility becomes a little more complex when strings of letters are considered.

### Contour interaction

Firstly adjoining letters interact with each other and can reduce legibility. This is known as contour interaction (Flom et al., 1963; Jacobs, 1979). If letters are very close together legibility distance

<sup>6</sup> Even Austria, one of the last countries in Europe which refused a driving licence to protanopes ("red blinds") has recently changed legislation, partly on the basis of a study of Verriest et al. (1979).

can be reduced especially for white letters on a black background (Anderton et al., 1974). However, if the space between letters is greater than 20% of their height, contour interaction has little effect (Anderton et al., 1974; Lotens and Van Leeuwen, 1976c). Nevertheless, it should also be noted that borders placed close to letters can reduce the legibility of the letters (Anderton and Cole, 1982). An example of this is shown in Fig. 6.



Fig. 6 The heavy contour surrounding the digits in design 2 reduces the legibility distance of the digits by 10 to 20%. The contour in design 3 has no contour interaction affecting legibility and the contour in design 1 causes a slight reduction of legibility of no practical significance. Data of Anderton, Johnston and Cole (1974).

Contour interaction is a readily demonstrable phenomenon and can reduce legibility but the effects are marginal. The spacing of letters and graphics need not be a primary consideration in the design of signs provided letters are not unduly crowded and surrounding graphics are not too bold and close to the letters. Uncorrected astigmatism can affect contour interaction.

### 3.3.8 Effect of the length of the message

A long word or a string of words will not be legible at a single glance if the individual letters are of a size that is close to the limits of visual acuity. The reason for this is that an extended message will be imaged, in part, on the peripheral retina where visual acuity is less than it is at the centre of the fovea. If fixation is, say, on the first letter of a long word or a string of words the letter string will extend from the centre of the fovea

where acuity is best into the peripheral retina where visual acuity diminishes progressively. This is illustrated in Fig. 7. The loss of legibility due to the lower resolving power of the peripheral retina is made greater by the fact that contour interaction is greater in the periphery than it is at the centre of the fovea (Jacobs, 1979).

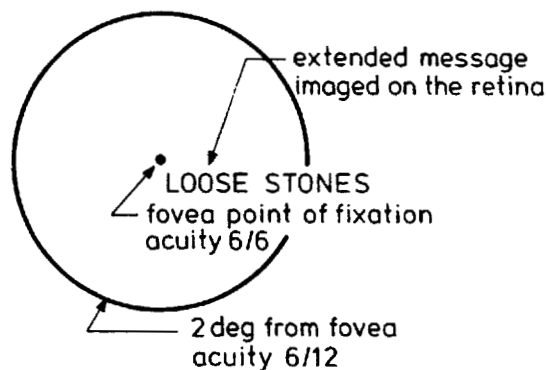


Fig. 7 The extended message "LOOSE STONES" imaged on the retina of the eye. Fixation is on the letter L which is imaged at the centre of the fovea where visual acuity is 6/6 or better. The message string extends into the peripheral retina some 2 degrees from the centre of the fovea where the acuity is 6/12. Thus if the letters were 5 minutes of arc high only the first few letters in the word LOOSE would be resolved and it would require two fixations, even three, in order to read the whole message.

### 3.3.9 Visual acuity in peripheral vision

Cole and Jacobs (1978) developed a model that takes into account the reduced visual acuity of the peripheral retina and the increased contour interaction that occurs in the periphery to predict the maximum length of a word that can be resolved for a given letter stroke width. The relationship they define is

$$L = 54 S - 0.024 D \quad (8)$$

where  $L$  is the maximum length if the word or legend is to be legible at a single glance,  $S$  is the stroke width of the letters and  $D$  is the observation distance. All terms are in the same units.

The relationship is based on the assumption that the words in the extended message will be read at a single glance with a 95% chance of the words being read correctly. The relationship assumes that fixation is on the initial letter of the word or string of words. Letter height can be assumed to be 5 times the stroke width.

The model was subject to empirical test (Cole and Jacobs, 1978; Jacobs and Cole, 1978) and shown to valid for single line strings of two or three words read at a single glance. It does not hold for longer messages especially when there is more than one line of words. Longer multiple line messages are not read correctly at a single glance even though the letters may be large enough to be resolved.

If a sign message must be read easily and at a single glance, it should contain no more than three words and the relationship between stroke width, message length and observation distance given in equation (8) should be followed.

### 3.3.10 Contrast between letters and their background

The legibility of letters or other graphics on a sign will be best when there is good contrast between the letters or graphics and their background. The highest contrast will be achieved with black letters on a white background or with white letters on a black background. Reduction of contrast tends to reduce legibility. This is shown in Fig. 8.

However, it can be seen from Fig. 8 that contrast does not have a great effect on legibility until contrast is reduced below 40%. At 50% contrast, legibility distance is about 17 m per 30 mm of letter height (for a luminance of  $10 \text{ cd/m}^2$ ) which is not much less than the 20 to 22 m per 30 mm at 100% contrast.

Contrast becomes a more complex consideration when the backgrounds of signs are coloured. Coloured backgrounds will reduce luminance contrast: for example, white letters on a green background will have a lesser brightness contrast than white letters on a black background simply because green reflects more light than does black. However, the loss of brightness contrast due to the use of colours may be offset by the introduction of colour contrast. Nevertheless certain colour combinations such as black on dark blue, black on reds or

white on yellow should be avoided if good legibility is to be achieved.

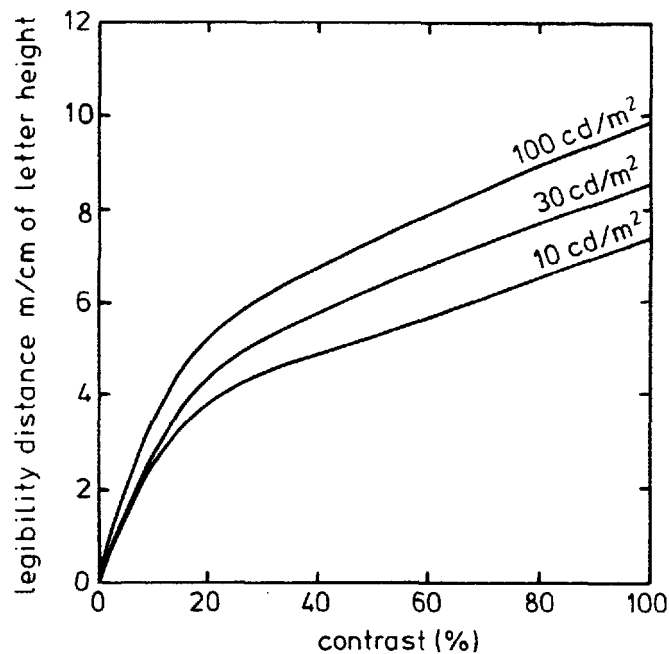


Fig. 8 Effect of luminous contrast on legibility distance. Reproduced with permission from Cole (1972). The figure is based on the data of Connor and Ganoung (1935).

A further complication arises through the use of reflectorised background material. Reflectorised background material can give rise to high luminances and reduce contrast for white letters.

Hills and Freeman (1970) have considered the problems of the use of colour and retroreflective material in signs and provide data and a method of design. They accept that as soon as the background of a sign is reflectorised it will cause a reduction of contrast for white letters and will therefore reduce legibility. They propose that the maximum acceptable loss of legibility should be 10% and on that assumption and making use of their empirical data set out a table of minimum ratios of legend to background specific luminances. Their recommendations are reproduced in Table II.

Table II. Minimum ratios of legend luminance to background luminance for white legends on red, green and blue retroreflective backgrounds viewed at night for two legend luminances.

| Background colour | Minimum specific luminance ratios           |                      | Background specific luminance                             |
|-------------------|---------------------------------------------|----------------------|-----------------------------------------------------------|
|                   | legend to background                        |                      | cd/lux/m <sup>2</sup>                                     |
|                   | for legend luminances 3.2 cd/m <sup>2</sup> | 10 cd/m <sup>2</sup> | for legend specific luminance of 40 cd/lux/m <sup>2</sup> |
| red               | 8                                           | 10                   | 4                                                         |
| green             | 7                                           | 7                    | 6                                                         |
| blue              | 6                                           | 7                    | 6                                                         |

Data of Hills and Freeman (1970). The limits proposed in the Table are based on the assumption that the loss of legibility due to the use of coloured retroreflective backgrounds should not be greater than 10%.

### 3.3.11 Effect of sign luminance

Visual acuity is best at luminances greater than 100 cd/m<sup>2</sup> and for luminances less than 10 cd/m<sup>2</sup> visual acuity reduces rapidly. Signs need to be externally or internally illuminated or constructed of retroreflective material if they are to be legible at night.

Visual acuity can be adversely affected if the sign has a very high luminance in otherwise dark surroundings (Godthelp, 1981; Van Norren, 1981a). However, Anderton and Cole (1982) found that there was no reduction in legibility in the digits of speed restriction sign when it was suddenly shown in dark surroundings at a brightness of 130 cd/m<sup>2</sup> compared to legibility at 30 cd/m<sup>2</sup>. The luminance of 100 cd/m<sup>2</sup> corresponds to the typical luminance of a sign illuminated by headlights reflected by high efficiency white retroreflective material and the result suggests that signs can have quite high luminances at night without any decrement of legibility.

### 3.3.12 Relative movement

Visual acuity is reduced when the target moves relative to the observer (Ludvigh and Miller, 1962; Brown, 1972a,b) and since users of signs are often moving relative to the sign this might be considered to be a factor determining sign legibility. Visual acuity reduces as a linear function of target velocity; at an angular velocity of 1 degree/second there is a just noticeable loss of acuity

(to about 6/9), while at a velocity of 4 degrees/second the loss of visual acuity is quite appreciable (about 6/18). However, even for the driver of a vehicle moving at high speeds the angular velocity of a sign is relatively low provided that the sign is at a reasonable distance ahead of the vehicle and the offset of the sign from the path of travel of the vehicle is not too great.

The observation geometry should be such that the angular velocity with respect to the observer should not exceed 1 degree per second. For a vehicle travelling at 100 km/h a sign must have letters large enough for the sign to be readable at distances of more than 75 m if legibility is not to be significantly reduced by the angular velocity of sign relative to the observer. Signs that have short legibility distances are likely to be very difficult to read from a moving vehicle because of the angular movement of the sign relative to the observer.

### 3.3.13 Letter style

Provided elaborately decorative styles of letters are excluded, letter style does not have a great effect on legibility (Padmos and Blokland, 1979; Cole and Madigan, 1982). Stroke width and width to height ratio are not critical factors (Lotens and Van Leeuwen, 1976b; McCormick, 1970), however, in general, stroke width to height ratio should be about 1:6 and preferably not greater than 1:10 and the width to height ratio of letters should be greater than 0.55 with an optimum of 1 (Woltman, 1972). White letters on a black background should have a thinner stroke width than black letters on white, and should be more widely spaced since white letters appear to spread so that the stroke width appears greater, and letter spacing appears narrower than it actually is. This can reduce legibility marginally through contour interaction.

### 3.3.14 Effect of familiarity

Alphabetic signs may have legibility distances greater than would be expected by prediction from the visual acuity of the observer since the envelope of the word and, in the case of multiple word signs, the layout of the words provide cues to the message even when the individual letters cannot be resolved. Jacobs et al. (1975) found that legibility distances for alphabetic road signs were some 30 to 70%



greater than those predicted from visual acuity and for some signs legibility distances were over twice what is expected from the visual acuity of the observer.

### 3.3.15 Upper case versus lower case

Lower case lettering is often used in signs, in part because the appearance of the sign is usually more attractive when lower case lettering is used. However, there is some uncertainty as to whether upper case or lower case is the more legible. It can be argued that upper case will be the more legible since the letters have a larger height than lower case; alternatively it can be argued that the ascenders and descenders of lower case letters give words a characteristic shape that enables the word to be recognized even though the individual letters cannot be resolved.

There is general agreement that in reading extended text, text which is entirely in capitals is less easily read than when lower case letters are used. Fluent reading is not based on the recognition of individual letters but on the recognition of whole words and groups of words. In this process the shape or envelope of words is no doubt important (Huey, 1916; Vernon, 1931; Patterson and Tinker, 1940).

However, most signs display only one or a few words and therefore offer fewer contextual cues to recognition. The question may therefore be asked whether words in signs that are entirely in capitals are more legible than words displayed using lower case or whether lower case letters offer greater legibility. The answer depends on the criterion for evaluation. Forbes et al. (1950) report data to conclude that lower case is more legible than upper case when the words are compared on the basis of equal length but that upper case is more legible when the comparison is made on the basis of over-all letter height (including the ascenders of lower case letters). Christie and Rutley (1961) and Hutchinson (1961) found little difference between the legibility of upper and lower case when compared on the basis of equal word length.

Johnston (1974) in a very careful laboratory experiment found that upper case words were more legible at both threshold (50% probability of correct recognition) and when the words were more readily seen (95% probability of correct recognition) when the comparison was made

on the basis of equal initial capital letter height. This is not a surprising result since the capital letters have a much greater over-all height than the loop height of lower case. It suggests however, that the characteristic shape of lower case words given by their ascenders and descenders is not a strong and reliable cue for recognition. Words in upper case have a legibility distance about 20% greater than words in lower case when the comparison is made on the basis of equal initial capital letter height.

When the comparison is made such that the loop height of the lower case letters is the same as the height of the capital letters, words in lower case letters are more legible than those in upper case.

However, Johnston (1974) points out that the practical basis of comparison is the area of the sign that is occupied by the word, since the over-all size of the sign face necessary to achieve a desired legibility distance is a very practical consideration. When compared on the basis of equal area enclosing the words there is little difference in the legibility of lower case and upper case words at 50% probability of correct recognition and a slight advantage to upper case when the comparison is made at 95% probability of recognition.

Thus it can be concluded that while words entirely in capitals may have some advantage in legibility compared to lower case, the advantage is marginal and little loss of legibility will result if, for aesthetic reasons, lower case is preferred.

### 3.3.16 Legibility of symbols

Symbolic signs usually have greater legibility than alphabetic signs since symbols are graphically less complex than letters and can use much bolder stroke widths. Jacobs et al. (1975) compared the legibility of symbolic and alphabetic signs and showed that symbolic signs have legibility distances that, on average, are twice those for corresponding alphabetic signs. This is illustrated in Fig. 9.

However, it must not be assumed that symbolic signs are intrinsically highly legible; they must be carefully designed to ensure good legibility. The critical detail that enables the symbol to be recog-

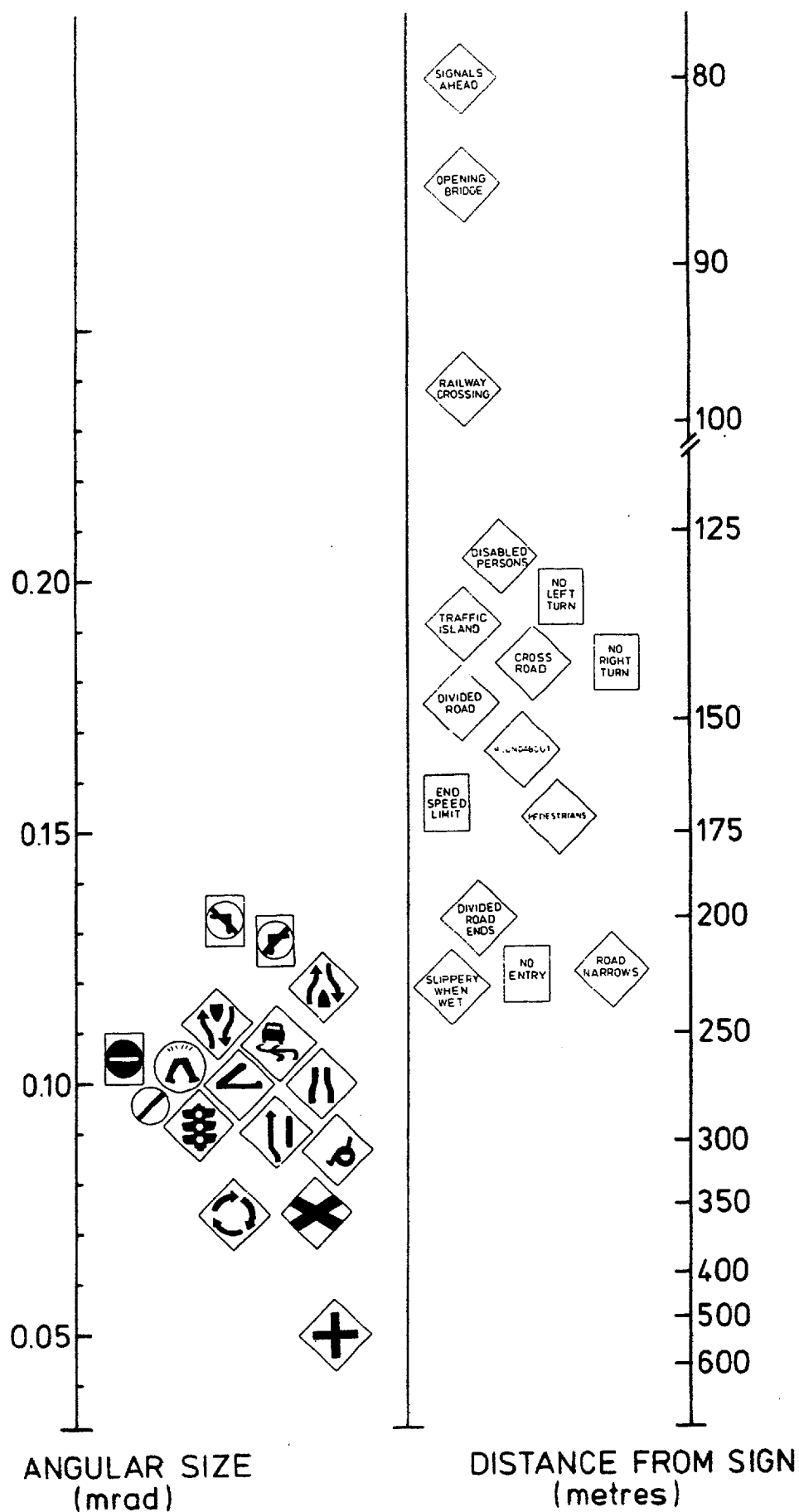


Fig. 9 The legibility distances at 50% probability of recognition for symbolic and alphabetic signs displaying the same messages. Reproduced with permission from Jacobs et al. (1975).