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AN INVESTIGATION OF THE DESIGN AND PERFORMANCE OF TRAFFIC CONTROL DEVICES

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AN INVESTIGATION OF THE DESIGN AND PERFORMANCE OF TRAFFIC CONTROL DEVICES

ABSTRACT

A design and experimental study of traffic control devices, carried out by a multidisciplinary team of psychologists, engineers and graphic designers is described. The work encompasses an appreciation of the background and operation of uniform traffic control devices, an extensive series of laboratory investigations, road tests, and a substantive group of graphic design exercises. The investigation of the basic design elements of a transportation graphics system included the study of legend, pictograph, symbol, color, shape, arrows, and destination signing. Both the laboratory and the road experiment design and data analyses draw heavily on recent advances in the theory of signal detectability, an application of statistical decision theory.

Applications of the study techniques to further problems are noted throughout this report. Also included is a graphic design discussion of the urban sign situation.

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1. SUMMARY

A balanced program of design and experimental study was pursued under the sponsorship of the Office of Traffic Operations, Bureau of Public Roads. This work embodied an investigation into the design and performance of uniform traffic control devices.

A multidisciplinary approach was formulated and effected that utilized the services of engineering and experimental psychologists, engineers, and graphic designers. This marriage of disciplines is reflected both in our research and in the content and styles of this report. Depending on his own background, the reader may resonate more strongly with some sections of this document than with others. This is not unintentional.

The work encompasses an appreciation of the background and operation of uniform traffic control devices, an extensive series of laboratory investigations, and road tests, along with a substantive group of graphic design exercises. This program is an investigation of the basic design elements of a transportation graphics system.

The design work includes studies of legend, pictograph, and symbol, with particular work on guide signs, and gives special attention to the urban problem.

The laboratory work comprises experiments on color, shape, arrow types, stack-type destination signing, and the meaning and recognizability of pictographs. Experimental design and data analyses lean heavily on recent advances in the theory of signal detectability, an application of statistical decision theory. The power of the method bears the price of complexity, but we have devoted

substantial effort to explaining its rationale and use. We have also tried to make the reader cognizant of the limitations of our approach.

The basic laboratory paradigm was one of brief visual presentations of the stimulus material. Observers were provided with a list of response alternatives and were instructed to choose the most likely and, in addition, to rate numerically their confidence in the response alternative selected.

Road tests with a more limited stimulus set were conducted using a visual interruption apparatus of our own devising. Used successfully by us in the past to measure the information input rates from roadway environment to driver, the device served in this case to delimit the information input rate. Coupled with a demanding driving task, this technique allows us to degrade sign recognition to measurable levels while maintaining speeds and driving performance consonant with safety. It simulates the distractions and switching of visual attention common to everyday driving and is, we feel, a more adequate technique than accompanying auxiliary task techniques, such as mental arithmetic or code-lock tasks, which have been used on other occasions.

Probably of greatest interest to the general reader are our findings about: arrow types, showing the superiority of one design; stack type guide signs, defining the advantageous arrow placements, the differences between dark and light lettering on contrasting surrounds, the effect of place name position; and pictographs, ranking their recognizability and meaning. We outline two different models of motorist interaction with destination signing that we feel should be given further attention. Ultimately, we hope that the study techniques that we have introduced will, through further application, prove as worthwhile as any specific findings. Avenues for further exploration are noted where applicable.

Of general interest, too, is the detailed graphic design discussion of the urban situation - particularly topical in the light of current urban beautification efforts.

An inclusive set of references is included for areas directly related to our program. This list, too, will prove of value to other investigators.

2. BACKGROUND

2.1 History of Sign Development and Regulation

When man first began to move around his earth, he was guided by nature. Paths and trails often followed the contours of the land, and were oriented by hills and rivers, chasms, lakes and oceans. Warning signs were provided by animal tracks or rushing water, by smells and sounds. There was no need for regulation by man.

It was, of course, many centuries before men grouped together in villages, and sought avenues of commerce between villages. At the same time they formed governments to rule their villages and, later, their nations. Thus it was many centuries before there was a need for, or a notion of, any formal traffic sign system.

Imperial Rome provided road signs for travelers. Under Caesar Augustus, the twenty-nine major military highways which led from the city to the outposts of the empire were provided with milestones for their first hundred miles. A law establishing compulsory measurement of these routes was enacted in 183 B.C. It took almost two hundred years for a standard milestone to come into general use.

Neither travel nor road signs changed significantly during the next eighteen centuries.

In the early days of turnpikes between settlements and cities, road signs were the responsibility of private individuals, as were many of the major roads. Some roads had signs, others did not. If the signs on one road resembled those on any other, it was likely to be a coincidence.

2.1.1 Early developments in the United States

In this country, for example, the principal highway between New York and Philadelphia was spotted with milestones as early as 1745. These markers were set at two-mile intervals and at intersections with other public roads.

The introduction of regular stagecoach travel over established routes helped to encourage the development of maps showing mileage between two points on these roads. The best of these were produced by the U.S. Post Office Department.

In the second quarter of the nineteenth century, the steam railway became an important means of overland transportation, and highway use diminished considerably.

The railroad ran a fixed course, interrupted by hazards such as highway intersections. Traffic control problems peculiar to railroads therefore caused the evolution of a special set of railroad signs and signals. For example, a sign was developed to prevent rear-end collisions. However, these signs had little to do with highway traffic problems and were of little concern to the highway traveler.

Near the end of the nineteenth century, the bicycle became very popular and bicyclists, with their boundless energy, began to agitate for better roads and better bicycle paths. New communities, and expanding populations in the cities, increased the commercial and social interaction between communities and encouraged the development of statewide road systems.

With the advent of the automobile, problems which for centuries had been benign and almost academic became complex and urgent.

Local networks of roads were integrated into statewide systems and then into interstate connections. Route numbers and names evolved slowly, but signs were sparse and inconsistent.

Private sources provided help. Automobile clubs and highway associations (formed to promote the use and improvement of specific roads) often provided signs for those roads which were of interest to them. The Automobile Club of California put signs on the principal highways within 250 miles of San Francisco in 1907. Earlier, in 1905, the Buffalo Automobile Club had provided signs for its section of New York state.

Other private organizations with interests in highway travel also stepped into the void. The B.F. Goodrich Company marked railroad crossings with warning signs and formed a touring service which marked routes and issued route books and maps. Goodrich sign crews, working out of New York, Chicago and San Francisco, erected thousands of signs each year between 1910 and 1920.

Rand McNally Company, the Chicago map maker, was another private organization with a significant commitment to highway identification. Rand McNally not only promoted the marking of highways but also paid people to do the work. These markings consisted of a system of colored bands on telephone poles; where there were no telephone poles, other posts or structures along the roadside were used. The color code was then picked up on the maps.

These commercial interests and the numerous road associations did much to provide orientation for many travelers. However the multiplicity of these organizations also fostered confusion and chaos. There was a wide range of sizes, colors and shapes of signs along main roads. Often, long stretches of major highways had many different route designations.

Even more confusing was the fact that the same road or route sometimes had several different locations. A road promoter, for example, might enlist local support from parallel communities near a proposed north-south route. If these communities were a number of miles apart, two roads would be built, one through each town, both with exactly the same name and designation. Eventually the two roads might join, only to be split again into two or more separate roadways with the same name.

Without a comprehensive system of route identification, confusion prevailed, and even the experienced driver often found himself miles away from where he thought he was.

The state of Wisconsin was a leader in the organization of principal roads within the state. In 1918, Wisconsin's roads were marked according to a systematic plan, and maps were prepared with roads identified by number.

Wisconsin not only led in the systematic organization of signs, but also in determining the physical form of the sign itself. Most early signs and route markers were painted on telephone poles or affixed or painted to structures along the roadside. (Companies owning the poles objected to anything but paint on the poles since signs would interfere with pole climbers.) Paint wore out quickly, however, and poles, culverts or bridge railings were often poorly located for driver visibility. Wisconsin became the first state to use baked enamel markers on sheet metal, supported on relatively light standards.

Many other states followed Wisconsin's lead and within a few years developed and implemented numbering systems and a few standard warning signs for their own highways.

The obvious next phase was interstate control to overcome the confusions caused by the separate state systems. In 1924, the American Association of State Highway Officials urged the creation of a comprehensive interstate route system, the development of a "uniform scheme for designating such routes," and recommended adoption of uniform signing practices.

At the time, the Bureau of Public Roads was a part of the Department of Agriculture, and the Secretary of Agriculture appointed a board to do the job.

The Board's recommendations were accepted and a manual for rural highways was published in 1927. A manual for urban streets was published in 1929 by the National Conference on Street and Highway Safety. In 1935, the two manuals were combined to form the first *Manual on Uniform Traffic Control Devices*. This Manual has been revised through the years, most recently in 1960. This edition was published by the Bureau of Public Roads in June 1961.

2.1.2 Early developments in Europe

Modern European signs also have roots in the activities of private entrepreneurs and motor clubs.

In 1909 the Convention on the International Circulation of Motor Vehicles was held in Paris. It resulted in four road signs depicting typical road dangers of the times — bump, curve, road crossing and flat or level-grade railroad crossing. Many European countries ratified the Convention; however, signs were not governmental responsibility and were installed by private organizations with the help of commercial sponsors such as automobile and tire manufacturers. These commercial sponsors felt obliged to advertise their wares on these signs so that many were badly cluttered with advertising messages. Many of the signs were verbal and therefore could be read only by those who understood the national language.

In 1926, the Convention Relative to Motor Traffic described a uniform system of signs. A very modest system containing only six signs, it specified pictorial conventions for uneven pavements and curves and also adopted the triangular shape as the international standard for danger signs. As in America, these signs were intended for rural situations and did not include urban regulatory signs.

2.1.3 The League of Nations

The Traffic Committee of the League of Nations developed a set of urban regulatory signs in 1928. In 1931 the Convention for the Unification of Road Signs was adopted in Geneva.

Under this Convention, the number of road signs rose from six to twenty-six and signs were divided into three categories: danger signs, signs giving definite instructions and signs giving indications only.

In 1939 a committee of the League of Nations recommended further refinements of the international road sign system, but the Second World War prevented implementation.

2.1.4 The United Nations

After the Second World War the United Nations developed a new "protocol on road signs," which was adopted in 1949. It specified more than fifty traffic signs and was signed by about thirty nations.

In the early 1950's a United Nations group of experts was formed to study the problem further and to recommend an international system which would take into account the other systems that were being used in the world. Their report was published in 1953. It did not, however, generate the reception which had been hoped for and ten years later only two European nations had subscribed to it. The 1949 protocol therefore remains the basis for most European sign systems today.

2.1.5 Early developments in Great Britain

The British Motor Car Act of 1903 included the authority for the erection of warning signs by local authorities. These were specified in 1904. They consisted of shape specifications only with one exception: prohibitory signs were to be indicated by a red disc. Speed limit signs were to be incorporated in circles, warning signs were to be indicated by triangles, and all others by diamond shapes. The signs were to be 18 inches in diameter, their lowest point was to be not less than 8 feet from the ground and they were to be located approximately 50 yards from that to which they referred. Beyond these specifications, local authorities were free to act on their own.

British standards evolved through national acts and circulars in 1909, 1920, 1921 and 1923. Three years after the 1926 convention in Paris, Britain ratified the agreement on road signs and, for the first and only time in its history, formally adhered to an international agreement on roadside traffic signs.

Certain of the signs included in the 1931 Geneva convention were adopted by Great Britain but it did not support the convention generally and continued its own way with a national committee in 1933.

Many British road signs were uprooted in 1940 because of the fear of invasion. A new committee was formed and issued its report in 1944. It did not recommend any radical departures, however, and the signs which were installed after the war were very much like those which had preceded them.

In December, 1961, a committee headed by Sir Walter Worboys was appointed by the Ministry of Transport to review traffic signs on all-purpose roads, including those in urban areas, and to recommend what changes should be made. The committee issued its report in 1963. The implementation of its recommendations began in 1964 and is expected to end in about 1972. And so the present British system is among the most modern in the world today, although it is based primarily on the signs contained in the 1949 U.N. Protocol.

2.1.6 Other systems

All other sign systems in use through the world today were essentially developed from the systems we have already cited. In Africa, for example, conferences were held in Johannesburg in 1937 and again in 1950 and the sign systems are essentially based on those included in the Geneva Protocols of 1926 and 1931. In the Western hemisphere, most signs are based on the U.S. system. The Canadian and Mexican systems, which will be described in the next Section, were initially developed following the U.S. or U.N. pattern.

2.2 Today's Systems – Comparison and Contrast

Each sign system has its own peculiarities and no two are exactly alike. They have, however, essentially polarized around two basic philosophies.

One of these is best represented by the U.S. system.

The U.S. system relies heavily on the use of verbal messages to transmit information. Over the years a small, but significant, body of pictographic images have become part of the system. Certainly this trend is continuing. Nevertheless, there seems to have been a general aversion to using visual shorthand, except in what would appear to be the "safest" of situations.

Canada has followed the U.S. system to a great extent. Innovations have been added or borrowed from other systems in certain situations.

The Canadians use pictographic images for regulatory signing. During their introductory period, however, supplementary plates were used containing verbal messages. (Of interest is the fact that sometimes the verbal message and the visual image differ. Verbally, for example, a sign will say "No Left Turn," while visually illustrating the fact that traffic can proceed straight ahead or turn right. In other words, the verbal message is prohibitory while the visual message is permissive.)

The Mexican system is closely allied to the recommendations of the U.N.-1953 group of experts. Mexican warning signs are usually purely pictographic, without any verbal message on the sign or on any auxiliary plate. Regulatory pictographs are partially supported verbally.

Most European countries use systems based on the U.N. protocols of 1949. The recommendation of the U.N. group of experts which met in 1952 and 1953 are principally used in Mexico and the Middle East.

Most African nations use a related system based on the League of Nations' Geneva protocols of 1931, and modified at international conventions in Johannesburg. This highly visual system reflects the diversity of African languages and also, perhaps, in the limited number of signs, the relative simplicity of Africa's traffic control problems.

The current British system is much more extensive and precise than those of the other nations of the world, particularly in its delineation of guide signs. The British system accommodates a differentiation among signs for motorways, primary and secondary roads. Color coding is used for visual differentiation of these types of roads, and specific map-type signs are included for a wide variety of highway configurations and junction situations. Still in the process of installation, the British system is the first to be devised with the continuing assistance and consultation of a graphic designer.

2.2.1 Regulatory signs

In the U.S. system, regulatory signs are considered a single category. In other systems, they are divided into two categories: mandatory and prohibitory.

Most U.S. regulatory signs are rectangular, whereas other systems use circular forms. In the Canadian system, there is often a compromise: the circular form is retained within a rectangular shape and the pictograph and verbal legend are included on the same plate.

The octagonal red STOP sign is the only octagonal sign in the U.S. system and, in fact, the only octagonal sign in any sign system. It is, at present, also the only *red* sign in the U.S. sign system (although the proposed introduction of the abstract NO ENTRY and the red YIELD signs may change this).

In our tests, and in other tests of shape, the observers were more apt to confuse the octagon and the circle, than the circle and the diamond. This raises the possibility of making the American stop sign circular. This step would have no effect on its visibility, practically no effect on its uniqueness in the American system, and would make the sign somewhat more compatible with the other stop signs of the world. Whether such a change would be worth the effort required is doubtful. (It should be noted that the diamond-shape railroad sign, an accompanying change, has been independently proposed.)

The European and British STOP signs incorporate the triangle within the circle. This arrangement presents several weaknesses. When the legend "Stop" is included within the triangle, it must of necessity be small and therefore difficult to read. When the legend breaks through the legs of the triangle, as it does in the British stop sign, the triangle loses its shape and serves almost no function.

The yellow United Nations 1953 STOP sign is based on the octagonal U.S. sign. The legend is superimposed on a pictographic image for an intersection with a major roadway. The meaning of the pictograph is lost, however, in the confusion with the verbal legend and the overall sign shape, diminishing the effectiveness of the sign.

Closely related in function to the STOP sign is the YIELD sign, which requires that a driver be prepared to stop before entering a stream of traffic. Here the systems of the world are consistent in their selection of the triangle, vertex down. Note that in European and British systems the triangular form is also used in STOP signs.

Another sign which is closely related in function to both the STOP and YIELD signs is the NO ENTRY sign. Again, the driver must stop. In the European and British systems, the abstract NO ENTRY sign picks up the circular shape of the STOP sign. The U.N. 1953 system reverts to a more pictographic form with the red diagonal bar slashed across the red STRAIGHT AHEAD arrow. In the U.S. system, the verbal DO NOT ENTER sign is completely inconsistent with both the STOP and the YIELD signs.

The obvious inconsistencies among these three signs in the U.S. system pose several problems. Although each of the signs should elicit approximately similar responses from the driver, the signs differ in shape and color. The proposed introduction of the abstract NO ENTRY sign into this country would be a significant improvement. In fact, the abstract NO ENTRY sign is quite close in its visual characteristics to the STOP sign and is therefore quite compatible with it. The proposed use of red for the YIELD sign is another useful step toward visual consistency.

Whereas the European systems and Great Britain rely on circular shape for all regulatory signs, the United States and the rest of North America use the rectangular shape.

A rectangle is a more efficient field for a verbal message than a circle and so the basic shape difference may be considered as a reflection of the verbal-legend versus pictograph dichotomy. It is also an efficient shape for pictographs and so, any change to a pictographic system would not necessarily mean a change in shape.

Although the U.S. relies on verbal messages in regulatory signing, the Canadians increasingly use pictographic images for regulatory signing. In their newer signs, they have combined the European pictograph and circle with the North American rectangle and verbal legend. From a visual point of view, the use of the circular color border is questionable. It restricts the size of the pictograph and confuses the use of shape. Perhaps a strong border following the shape of the sign, which would permit a larger image without diminishing color coding, would be preferable.

Color is not utilized in U.S. regulatory signs as it is in all other systems. Although the significance of color has yet to be determined precisely, we should question its absence in the U.S. system of regulatory signs. (Color is, of course, used in urban parking signs, but its use is obscured by the clutter on these signs and by their lack of consistency with any other regulatory signs.)

Red is internationally used as a prohibitory color. The bold red border has been familiar to European drivers since the inception of formalized sign systems and is well-understood. To provide added emphasis, the United Nations group of experts incorporated the diagonal red bar across the pictographic image to indicate prohibition in their system. Thus even the most naive driver (who may look at the red border as a decorative element) should be brought to attention by this red bar. The bar also aids those individuals who experience difficulty in red-green discrimination. Although prohibitory signs are not treated as a distinct classification in the U.S. system, nevertheless a number of control signs for moving traffic are prohibitory in nature, and might be made more efficient with the careful use of color. These black-on-white rectangular signs do not transmit any sense of strength or urgency from a visual point of view. They must rely totally on verbal legend for communication, since their shape or color tells the driver nothing.

The United States system is, through recently proposed changes, moving toward wider and more efficient use of color. There persists, however, the indecision as to whether color should be allied with sign category or sign message. Thus, yellow is used for warning signs, red for stop signs, and orange (proposed) for construction warning signs.

2.2.2 Warning signs

The U.S. diamond shape provides a convenient field for pictographic images and for very brief verbal legends. Research has shown that the black on yellow is a highly effective color combination (for visibility) and the United Nations' group of experts recommendation of the U.S. shape and color for warning signs recognized this effectiveness.

U.S. warning signs have long used pictographic images for curves and intersections. They have relied primarily on verbal legends for most road hazards, however.

Other systems of the world have historically used the triangle as a warning sign. The triangle provides a distinctive shape and was probably much more effective when it was used as an abstract form to indicate danger in the very early highway systems. For, the triangle does not efficiently accommodate pictographic images or legends. The diamond is much more efficient as a visual field and at least equally distinctive as a unique shape. There would seem to be little justification for the U.S. system to consider conversion to a triangular format. The argument for increased reliance on pictographs, however, is valid and should be heeded. But, as we have indicated elsewhere, careful attention must be given to the selection of pictographs and development of a pictographic system which will provide the visual consistency essential for effective communication.

2.2.3 Guide signs

In the very early days of sign systems, only broad specifications were enumerated by conventions or government bodies. Local jurisdictions were left to their own devices insofar as basic sign design was concerned. With the passage of time and increased sophistication, all systems have become much more specific about regulatory and warning signs. The British, however, have carried this detail into guide signs.

The U.S. system treats route markings rather carefully. In contrast, direction signs are very broadly brushed and as a result, the U.S. system may not help to guide the driver as much as do other systems. Without a comprehensive point of view, U.S. guide signs have proliferated without adding to the effectiveness of the system.

Problems involving guide signs are problems of content and of design. This was well-recognized in the most-specific British system. We do not necessarily agree with all that the British have done, or with the extent to which they have specified signs, but we do feel that much of what they have done has at least conceptual application in this country.

The British have carried the specification of map-type signs to an extreme. The manual provides a specification for almost every given situation. The specifications also provide for primary and secondary roads as well as motorways, all of which are indicated by various color codings. Accommodations are also included for route numbers, which are again color-coded. The imposition of such a detailed system might be an arduous task. There is no doubt, however, that a less complex system that (a) made use of map-type signs and (b) provided directional continuity through the color-coding of route numbers and their inclusion on signs, would comprise a significant step forward.

The American manual seems to be the only one which does not specify directional and destination signs which include route numbers and other information on a single plate. Such signs are specified by both the Mexican and the Canadian manuals and, although they do not have map-type signs, they are both somewhat more specific in their description of guide signs, and somewhat more sophisticated in their sensitivity to driver information needs.

2.3 The Driving Task

2.3.1 Driver processing of information

In the early days of automobiling, the "task" for the driver was often more physical than mental, and human performance requirements were based on the strength necessary to operate the starting handle, the tiller, and the wheel brake.

Sixty years of motor vehicle and highway development has gradually but completely changed this situation. The physical demands of the driving process now fall within the capabilities of almost all of the non-bedridden population. Investigators of the driving process commonly regard the driver as primarily an information processor with secondary physical capabilities used to interact with the vehicle controls and the environment. The driver's need for information is based on the tasks he must perform; these include lane holding, car following, vigilance for hazards, and the monitoring of gages and controls of his vehicle.

Although the *output* of such a sensor-processor-actor system can be measured and understood, it is difficult to specify what the *input* is that results in the observed output. Attempts have been made by several investigators to determine those elements in the complex visual world of road, traffic, and traffic controls that elicit the driver's responses. Recent efforts by Senders *et al.* (1967) have concentrated on the total visual information the driver takes in through the windshield as he observed the roadway ahead, and has led to a model of how information flows into the driver and is processed.

In this model, a certain information density is postulated for the roadway, so many bits per unit distance. A section of road with many curves or traffic control devices has a high information density. The faster one traveled a portion of the road, the more bits per unit time must be processed. The model then describes the requirements for visual sampling of a road, where the minimum sampling rate is related to the information density of the road and to the velocity at which it is traversed.

Were the driver to get a glimpse of the road only at fixed intervals, he would develop uncertainty about details not discernible at his last observation, and about where his car is on the road. If the intervals between observations (snapshots) were very long, then the accumulated uncertainty and the amount of information to be absorbed on the next observation would be greater. If the short observation time itself were to remain fixed, the driver would be unable to absorb the amount of information required, and would be forced to reduce the rate at which he must process the information. This would mean reducing his speed, so that the information rate, the product of information density and speed, is reduced in proportion. In this way the driver finds a limiting speed related to his information processing capabilities. It should be noted in passing that an experimental technique, based on this visual sampling, was employed in some experiments described in Chap. 3.

The sampling process just described is quite appropriate to the "normal" task of driving. Instead of the external imposition of visual sampling, this sampling process is controlled internally. Man is a sampler of the constant stream of signals reaching his central processor from his senses. Although some selective attention is apparent at the sensor level (e.g., focusing the eyes on a sign), the control resides with the central information processor which runs all the time, and switches (attends) to sensor inputs one at a time. This sampling is conditional; that is, it is based on previous inputs. If the information coming in through a few sensors does not occupy the central processor full time, man finds other things to do with the excess input capacity. If there are few signs and curves on a particular road, then the driver turns on the radio or looks at the distant scenery. He may, in fact, daydream or tend to sleepiness in order to lower the effective full load capacity of the processor. If he does reduce his excess capacity, he also increases his probability of missing a sign or signal that is important.

When the task is challenging, the effective capacity is expanded, but too much attentional demand at once will also lead to overload and missing important sensor inputs. As the driver comes to the advance exit sign, his effective processing capacity starts to reach the limit; he stops attending to (looking at) the scenery or (listening to) the radio, and switches this attentional capacity to the traffic control signs. Road geometry and unusual traffic flow patterns near the exit can also impose enormous increases in attentional demand. If this occurs, the central processor will be overloaded, and important information will not get processed. A sign which meets all ordinary requirements of legibility at distance (or for exposure time calculated from vehicle speed) may not be "readable" at all. Alternatively, drivers who do "read" the sign may have vehicle control problems. Thus they may spoil the smooth flow of traffic, or even cause collisons.

This view of information processing and its critical role in the driving task leads to several observations about the design and use of traffic control devices.

Where attentional demand of the driving task is low (as on rural expressways), the driver needs advance warning to trigger the build-up to greater information-processing capacity. The driver cannot remain vigilant for guide signing (for example) if the frequency of occurrence of such signs has been very low. If the attentional demand of guide signing had been made more uniform along the road, the difficulties with the build-up time could be avoided. Since the attentional switching (at any effective information processing capacity) is conditioned by the previous inputs, a maximum interval between guide signs could be established. This interval might be one minute or ten minutes driving time, and would depend on the size of the related information processing task at the next critical decision point.

Where attentional demand of the driving task is quite high (as on urban expressways) the driver needs signing that presents the necessary information in a way that mixes in as few irrelevant cues as possible. Such irrelevant cues can come from inconsistencies in layout, design, or presentation. If the messages *Metropolis, Utopia* and *Exit 29* appear on one sign, then they all should appear on every sign that can convey that information. Scrambling the order in which these three messages appear, using different background or alphabet styles, or changing the layout from centered to justified-left on succeeding signs introduces a great deal of irrelevant information. This information, which is just "noise" must be sensed and processed before it can be separated out and discarded. This processing often imposes attentional loading on the driver under conditions where he can least afford it. The steps necessary to reduce this irrelevant information should be as much a part of uniformity of traffic control devices as the regulation of shape and color.

2.3.2 Relating signs to the driving task

The relationship of the design of traffic-control devices to their intended use has two aspects. The manipulation of design elements, such as shape, color and content, to improve the recognizability is treated in detail in Chap. 3. Some possibilities for relating the message presented for recognition and the driving task that occupies the observer will be explored briefly in this section.

Traffic control devices are used to tell the driver something that the road does not tell him, solely to increase the probability of correct vehicle response.

Optimizing the process of communication alone is likely to be suboptimization for the system; the vehicle and the driving task itself should be considered. As discussed in the previous section, the driving task involves maneuvering the vehicle on the road as a result of decisions which are usually based on the processing of visual cues. Putting signs on a road often puts some lead, or prediction in the system. If this is the case, we should take advantage of the fact that the goal is strictly one of vehicle response. Signs do not talk directly to the vehicle yet, so at present, it seems appropriate that signs tell the driver what vehicle control actions he needs, and with what probability.

What do traffic control devices tell him now? Sometimes they tell him what the vehicle must do, or can do, and sometimes they tell him what he must expect, or can expect. Often signs combine these unconsciously, forcing on the driver an additional information processing task to select the appropriate response. This need not be the case; design elements of signs could explicitly carry such information as (a) the probability, (b) the action required, or (c) the intended reader.

Probability cues would be useful in warning signs, for example. Warning signs direct the attention of the driver to two kinds of things. One kind, indicated by a BUMP or a curve warning sign is an event that is *certain* to happen. The driver *must* make the appropriate response to keep the car on the road. The second kind, indicated by a TRUCK CROSSING or FALLING ROCK sign is an event with a probability that is usually small, but not zero. There *may* be a truck or a rock in the road, and the driver may have to take appropriate evasive action, but usually he does not, and no specific action is *always* appropriate.

A highly recognizable design element of the sign, rather than the entire message, could be used to make the distinction between *certain* events, and those of various low probabilities. Research may indicate the desirability of making additional distinctions among events of differing probability.

The second distinction, according to intended action, is a logical forerunner to the automated highway. Such a highway communicates vehicle control commands directly to the vehicle. At present, the signs speak for the highway, and address the driver. Transmitting information in order to elicit the appropriate vehicle response might be done more efficiently by encoding the message in a way related more directly to the vehicle control actions desired. The message set is not large; the driver controls the vehicle through few inputs. The feet control the longitudinal behavior (and signaling) and the hands control the lateral behavior (and signaling).

STOP signs, YIELD signs, maximum, minimum or advisory SPEED LIMIT signs all ask the driver to use his foot on the brake or accelerator pedal: these signs could share a common design element. Following the previous argument, the STOP sign and the YIELD sign would contain different probability messages, however. Such signs as route markers and trail blazers, LEFT TURN ONLY, or curve warning require turning the steering wheel, and would be distinguished by a second action message.

The third distinction, according to intended user, arises from the observation that not all signs are for all people. To require the driver of a passenger car to process the information on a sign, only to find that the message is relevant only to trucks, bicycles or motorcycles dilutes the expected value of all signs. As shown in the design exercise in Chap. 6, the development of a series of signs intended for a single class of users has two benefits: it reaches the intended audience more effectively, and it allows the remainder of the road users to concentrate on signs of utility to themselves.

3. THE PRESENT STUDY

3.1 Objectives and Limitations

This project was conceived and executed in response to a number of factors relating to uses and abuses of traffic signs, signals and markings. To help the reader appreciate better the directions that this effort took, we begin by detailing those factors that inspired the study. First and foremost, there is a wealth of dissatisfaction on the part of the driving public with the operation of our current system. While this study has made no effort to document this dissatisfaction, evidence appears daily in the free press and, we suspect, on the desks of cognizant municipal, state and federal agencies.

The majority of complaints in one way or another deal with the information conveyed by the sign. For our purposes we can divide such comments into three categories. The first category is MISINFORMATION: the message is simply incorrect — perhaps a misdirection to one's destination, an illusion to construction work completed months or years ago, or an inappropriate invitation to pass a leading vehicle. Difficulties of this sort are quite easily corrected once brought to the attention of the proper (although sometimes difficult to identify) authority.

The overt costs, in terms of time lost, fuel and rubber consumed, and damage risked, are difficult to calculate with precision, and are perhaps not excessive. Of more immediate concern to us here is the covert cost — the sacrifice in credibility of all signs. More technically, we are concerned with a driver's estimate of the *a priori* probability of the veracity of the message. If a driver holds an inordinately low estimate of this *a priori* probability (i.e., tends to mistrust signs), the effectiveness of the system may be drastically reduced. Precisely in those cases where a sign is most necessary — where it describes a situation not otherwise apparent — will that sign be ignored.

A second category of disaffection with the current system relates to MISSING INFORMATION. Signs, signals or markings may simply fail to answer a question asked by a given motorist or user group. The difficulty in rectifying this problem is, of course, the difficulty of accurately assessing the users' needs. Progress along this line is being made. Ironically, however, the more the system is upgraded, the more costly such missing information becomes to the driver. As people more and more depend upon the system, to the exclusion of, or with inattentiveness to other cues, then the more catastrophic is the absence of a piece of information.

Moreover, there is constant change in the particulars of the driving task. This change is a reflection of improvements in car and roadway design, variation in trip purpose, increases in numbers of vehicles and road mileage, and shifts in the makeup of the driver population. Concomitant with changes in the driving task are demands for new information. Thus, missing information results not only from oversights in the past, but also because of limited foresight.

The third category is that of INEXTRACTABLE INFORMATION. Confusion may stem from too much information, unintelligible or unidentifiable symbology and word legends, poor placement, generally poor design, or a lack of uniformity both in the implementation of the system and in the legal interpretations underlying the system. The primary focus of this project has been upon basic design elements, to facilitate extraction of information. And, while the outcomes of the project will provide certain contributions, this is tempered by the realization that much greater strides can be made in the short run by increased emphasis on conformity to current standards.

The genesis of this study lies also with suggestions for increased use of pictographic or symbolic information. These suggestions have had a powerful influence on the study. In order to appreciate this effort properly and to make use of its findings, it is essential to recognize the sources and import of suggestions for increased symbology. It is essential to realize that proposals for increased symbology are not directed solely at improving the extraction of information by our own driving public. In fact, desire for improved information extraction *per se* provides but a small part of the impetus.

In one way or another, a great deal of the impetus toward increased use of symbols and pictographs is provided by the traffic control practices of Great Britain and the continent. Travelers return from abroad wondering why we do not adopt one or another of the signs or symbols which allowed them to motor relatively successfully in spite of unfamiliar language, regulations, terrain and driving habits. There are also those who claim farsightedness and envisage a two-way exchange of drivers — increased tourism in this country. There are those who argue compellingly for internationally uniform traffic control devices for uniformity's sake. Then too, our own country is not completely monolingual, nor totally literate. In some cases, pictographic representations may provide a better common denominator.

Last, but in no ways least, is the complaint that many of our current signs blight, rather than adorn, the countryside. The plea for beautification is directed at our roadside signs as well as highway billboards and smoldering dumps. While they may never become objects d'art, signs can be made more aesthetically pleasing without sacrificing their efficiency. For reasons which we discuss elsewhere, symbols and pictographs have been proposed to achieve this end.

To repeat, proposals for increased symbology are not directed solely at improving the extraction of information by our own driving public. For this reason, and others discussed below, this project did not undertake, in many cases, to compare the effectiveness of a proposed symbol versus a currently-used word legend. Lest this be thought a shortcoming to the study, let us examine, in general, what such a comparison would involve.

To carry out such a comparison we must define a test procedure – a method for presenting the stimuli, control over the relevant parameters, a means of collecting responses from test subjects and a criterion for scoring those responses. A first thought might be to run such tests in the field under actual driving conditions. In this case, two locations would be isolated where such a sign function is warranted, and one of the signs erected at each. The relevant parameters would be the matching of location according to roadway geometrics, traffic volume, warranting conditions, trip purposes over the road, sign placement and so forth. Because many signs do not properly lead to overt, observable driving behavior (DEER CROSSING, for example), the research might involve stopping cars and questioning drivers about the sign just passed.

Alternatively, the tests might be run under more controlled conditions – stimuli might be presented for very brief exposure durations or at varying sign distances. The question is, "What question do we ask the observers?" Typically, there are three categories of questions: (1) detection, (2) absolute identification or (3) recognition.

To ask an observer "Did you just see a sign? Yes? or No?" is to investigate detection. As we shall see, to be able to evaluate the responses properly, the question must be asked not only in cases where a sign had in fact been presented, but also in cases where no sign was presented. The whole concept of detection, however, is fraught with problems and, as a consequence, not vitally interesting. Suppose, for example, we are testing in the field with naive observers — passing motorists stopped at random after having driven by a test location. Because the subjects were not especially prepared for the detection task (other than the normal demands of motoring), we run the risk of confounding detection with recall. To ask "Did you see a sign?" may be to ask "Do you remember seeing a sign?" and this may serve to prejudice the results. That is, a novel sign (such as a new pictograph) may be more easily recalled even though no more detectable.

To ask for absolute identification — "What sign *did* you just see?" "What was the meaning of the sign you just passed?" may be to prejudice the results in the opposite direction. Most naive observers, with their tremendous overfamiliarity with words of the English language and relative unfamiliarity with a particular pictograph, might well do better at absolute identification. Certainly, soliciting from the observers a verbal response about meaning prejudices the case in favor of word legends inasmuch as the word legend is the response as well as the stimulus. The correspondence is exact. In the case of a pictograph or symbol, the observer must select an appropriate verbal response from among a large unstructured set, thus presenting a problem both for the observer and the experimenter (who has to judge the correctness of the verbal response). Suppose that to avoid this problem we give the observer a name to use for the symbol or pictograph. The name might reflect the intended meaning like "do not enter"; it might be more descriptive of the symbol, "meatball," for example; or it might be completely arbitrary, like "x" or "y." Giving the observer this name to work with means (in general) again presenting the symbol in contiguity with the name. With naive subjects, this must be done after the test presentation, and now it turns out we are testing recognition (in addition to recall). The name is, in fact, irrelevant. We are, in effect, asking "Was this the sign you just saw?".

Under more controlled conditions (in the laboratory, for example) we can properly prepare the observers by giving them names for the test items before the actual test. We can, moreover, ask the question before the test presentations of the stimuli, thereby reducing the risk of contaminating recognition with recall. For these reasons, among others, we chose to use a recognition test paradigm. Still one might inquire as to why direct comparisons between, say, a word legend and a symbol or pictograph were not undertaken. Let us pursue this point.

Suppose we actually carried out such a simple and direct comparison — two stimuli, say, a current DO NOT ENTER sign and the DO NOT ENTER symbol, a white horizontal bar upon a red circular field. Suppose further that we chose to control (as the independent parameter) the duration of exposure. Numerous trials would then be run, the observer being instructed to indicate which sign was presented on each trial. As discussed below, a recognizability score could be computed for each sign. But what would these scores tell us?

If both recognition scores were very low, we could conclude: (a) the exposure durations were too brief for adequate processing, such that the observers were simply guessing, or (b) the two signs were actually highly confusable, one with the other. Increasing the exposure durations rules out the former alternative and, assuming the scores remained low, we are left to conclude that the signs are highly confusable. This information would be beneficial if we were considering using the two signs interchangeably. We would know, too, that a proposed change from one to the other would not make things worse than they formerly were. Interesting though these things may be, they do not help to determine whether such a change might be of any benefit.

On the other hand, if both recognition scores are high (for appropriately short durations) — meaning that the two signs are quite easily distinguishable, one from the other — then is this of interest? Probably not. The point is, we wish to know how easily distinguishable a sign is from among the entire set of signs with which it is likely to be used! If it is at all correct to assume that a move toward pictographs will be made for "external" reasons, the appropriate question is "whether a proposed symbol or pictograph is satisfactorily distinguishable from others with which it must work." This last point underscores the approach which has been used generally through the course of the study. In some cases, cross comparisons might be made from a legend set to a pictograph set on the basis of minimum exposure necessary for acceptable recognition within the set. It should be emphasized that as the word legends become familiar in the course of testing, they might be treated as quasi-abstract symbology, not as legends to be read. This process probably pertains — or should — for the more frequently used word-legend signs on the highway today, and highlights the requirement *that* where word messages are used they be exactingly uniform, and stylized in layouts different from one another.

3.2 Choice of Independent Variable

Evolution of the automobile-roadway system is placing increasing demands upon the driver, particularly in the case of dense, high-speed traffic. When demands upon an operator become critical, a factor of prime importance is the speed with which an appropriate response can be made. One way of relating a study of traffic control devices to such time constraints is to measure an observer's "reaction time" to a control device. Time would then be a dependent variable of the study. Alternatively, time may be used as the independent variable in the study, thereby sidestepping the problem of having to trade off reaction time against error rate (a second dependent variable).

As an independent variable, time may be used to constrain both the presentation and processing of information – where the experimenter controls the rate of presentation and the observer tries to "keep up" – thereby confounding the presentation and processing times. Instead, this study uses exposure duration – the length of the presentation interval – as the basic independent variable in the laboratory. Processing and responding were allowed to proceed apace.

Exposure duration has several nice properties which champion its use in experiments of this type. It is easily controllable over a sufficiently wide range so as to produce a measurable error rate in the observer's performance. Its use as an independent, rather than a dependent, variable simplifies enormously the collection and analysis of data. Moreover, exposure duration has a meaningful correlation in the actual driving task – the amount of time a driver need spend looking at, say, a sign. While the processing time (the amount of time a driver must spend thinking about what he just looked at) has been left uncontrolled, we feel that we have abstracted the more essential feature of the task within the driving context. Psychologists do not universally agree that thinking about one thing necessarily precludes thinking concurrently about something else. There is little disagreement, however, that looking at one thing may indeed remove other things from your field of view. Head-turning movements, refocusing, and fixating and tracking a target moving relative to you accentuate the problem. Thus, a sign requiring an overly long look may take its toll in damage risked. Poor signs and other devices can wreak havoc with traffic flow. Imagine a driver, anxious to obtain some specific information, who races up to the next sign, then crawls along (or stops!) to read it. The amount of time which must actually be spent in viewing a sign, as opposed to a later processing of its information, can be related to sight distance (for a given traffic flow rate) and thereby translated into sign size, and thus dollars.

3.3 The Principles of the Data Analyses

In addition to asking which of a set of stimuli was presented on a given trial, the experimenter asks also for a rating of confidence on a four- or an eight-point scale. Acquiring raw data of this type allows the analysis to receive the benefits of recent advances in decision theory. While decision theory has heretofore been little exploited in such applied problems, its concepts have become firmly entrenched in more idealized investigations of signal detection and recognition by human observers [see, e.g., *Signal Detection and Recognition by Human Observers: Contemporary Readings,* J.A. Swets (ed.), 1964; and *Signal Detection Theory and Psychophysics,* D.M. Green and J.A. Swets, 1966].

The chief advantage of an analysis in terms of decision theory is that it yields a pure measure of recognizability, uncontaminated by the biases or predispositions of the observers. To give a concrete example, the costs and values of driving on the highway may predispose one to give a "STOP sign" response with the slightest of provocations. That is, a driver may have a strong "stop signal" bias. As we shall show below, decision theory allows us to assess separately the recognizability of a stop sign, and the bias toward responding "STOP sign." Moreover, the index of recognizability which we arrive at is a pure number and, as such, allows comparison of different stimuli.

In brief, decision theory, or signal detectability theory, applies as follows. When the observer is presented with a stimulus (e.g., a picture of a STOP sign), we can consider his choice as a binary one between the response "STOP sign" and the set of all other permissible response alternatives. In fact, we could put precisely this question to the observer, namely, "Was that a STOP sign you just saw? Yes or no?". Because we could have asked this question about any one of the response alternatives, no loss of generality is implied. Moreover, we could have questioned the observer about whether a STOP sign was presented, when in actuality some other stimulus had been presented. In this example, then, there are four, and only four, possible combinations of events. With repeated trials we can estimate the probability of each event and tabulate the data as shown below.

TABLE 3-1.

Stimulus	Observer's Response	
	"STOP Sign"	"Other"
STOP sign	p_1	$1-p_1$
Other	p_2	$1-p_2$

As indicated, all the information in Table 3-1 can be summarized by the two probabilities p_1 and p_2. These are conditional probabilities, the former being the probability of response "STOP sign" given that a STOP sign was presented – $p(S|s)$ – and the latter is the probability of response "STOP sign" given that some other stimulus was presented – $p(S|o)$.

Now if an observer suddenly increased his predisposition to respond "STOP sign," we would expect *both* $p(S|s)$ and $p(S|o)$ to increase. We would not, however, be willing to say that the stop sign had suddenly become more recognizable. What we need to know is how $p(S|s)$ and $p(S|o)$ can be expected to change in concert with each other for a constant level of recognizability of the stimulus. This is where decision theory helps us.

The theory tells us that if we plot $p(S|s)$ as a function of $p(S|o)$ for various biases, then we can draw a smooth curve through the points as shown below in Fig. 3-1.

This smooth curve, or "operating characteristic" could be called an "iso-recognizability" curve. If another experimental stimulus under identical conditions yielded a curve above the one shown, we could conclude that it was more recognizable. In short, we need to know what the curves for two stimuli look like in order to compare them. It is the ratings of confidence, solicited with each response, which allows a fairly complete curve to be obtained for a given stimulus (see, e.g., Egan, Schulman, and Greenberg, 1959; or Markowitz, 1967). The theory defines an absolute scale for the height of a curve, which is an index of recognizability.

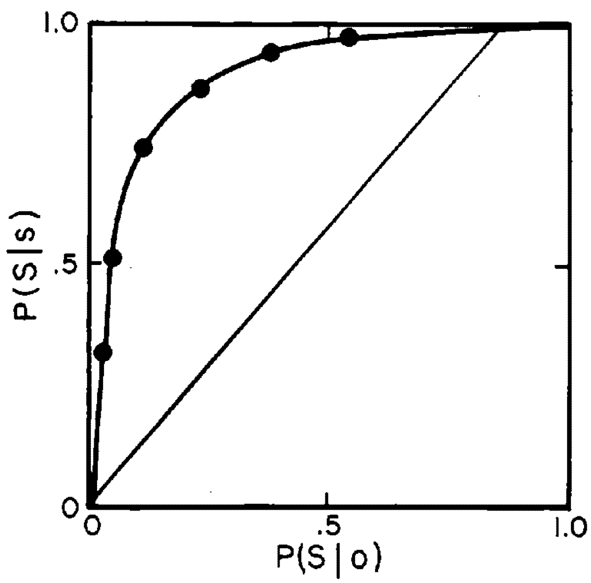


FIG.3-1 OBSERVER'S OPERATING CHARACTERISTIC.

Basic to the model is the assumption that all the available information in the stimulus is processed by the observer and eventually reduced to a single quantity — say, the odds that the stimulus was s rather than o. Because the system is presumed noisy, this quantity is a random variable, x. Moreover, any value of x can arise contingent on either an s or an o presentation. Thus there are two conditional probability density functions $f(x|s)$ and $f(x|o)$ that describe the likelihood that a given value of x will be computed by the observer for each type of presentation. Figure 3-2 below illustrates these functions.

Then, for any computed value of x, the observer can assess ratio of the two likelihoods. This is compared with some preset criterion value of likelihood ratio, denoted c in Fig. 3-2. If a computed value exceeds c then the observer responds "STOP sign." If the value falls short of c, then the response is "other." The coordinates of a point in Fig. 3-1 are related to this figure as follows.

The abscissa value $p(S|O) = \int_c^\infty f(x|o)dx$, the area under the leftmost curve of Fig. 3-2 which is to the right of c; the ordinate value, $p(S|s) = \int_c^\infty f(x|s)dx$, the area under the rightmost curve of Fig. 3-2 which is to the right of c.

If we assume that the underlying distributions are vaguely normal (Gaussian), then it makes sense to replot Fig. 3-1 on a normal-normal coordinate system where the operating characteristic is approximately linear, and thus the curve fitting task is simplified. If a further assumption — the equality of the variances of the two underlying distributions — is made, values of the index of recognizability, denoted d' can be obtained from tables (Swets, 1964). This then is the general data analysis procedure which we have used in the current study.

3.4 The Choice of Stimuli

In addition to myriad other considerations entailed in well controlled and well executed experiments in the area, just what specimens to test must be decided. Certainly currently used signs and signals are good candidates. Testing these alone, however, would hardly lead to much progress. So, what alternatives should we consider?

One way to approach the problem is simple, sound, scientific, and prohibitively expensive in both time and dollars — parametric investigation of each possibly relevant dimension and all interactions. Another approach is to use proposed and currently used signs of all countries as specimens. The basic problem is that people qualified to pursue experimental testing are not often qualified to choose meaningfully among the multitude of sign alternatives. The approach for this study was to create an interdisciplinary team combining the skills of experimental psychology and graphic design.

The graphic designer is schooled to manipulate visual elements so as to maximize the desired effects of these elements, or of the totality of which they are a part, on human perception. His primary functions are to expedite communication through visual messages and, at the same time, to insure a level of aesthetic quality in these messages. Traffic control devices must communicate efeffectively and efficiently, controlled by the manipulation of the various visual elements which make up individual signs and sign systems. In a traffic control device, these elements may include size, shape, color, typography, composition and lighting characteristics. Each of these elements and their relationships within single signs and sign systems are critical to the ultimate effectiveness of the entire system. Even within the protocols established by the current *United States Manual on Uniform Traffic Control Devices* and similar publications of other countries and international groups, there are many potential variations of each of these elements.

To maximize the potential of the proposed study, these elements must be isolated and varied in a meaningful fashion. This isolation and manipulation must be based on a thorough understanding of the design phenomena involved. A problem such as this cannot be effectively solved by trial-and-error arrangements. Rather, it requires a continuing interrelationship between those who understand the principles of design and those who are expert in the testing, measurement and analysis.

The potential contribution of the graphic designer to such a problem was first recognized in Great Britain when a designer was made a part of the motorways advisory committee that determined signage for the British Motorways System. This was followed by more extensive involvement in the committee headed by Sir Walter Worboys which was appointed in 1961 to review signs on all-purpose roads in Great Britain, as discussed in Chapter 2.

3.5 Experiment I – Shape

The term shape here refers to the background shape. In the context of road signs then we are referring to the shape described by the border.

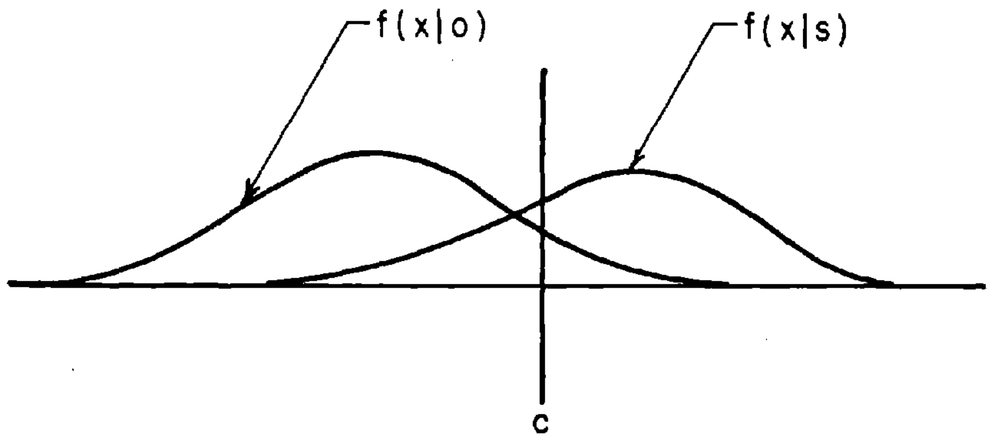


FIG.3-2 DISTRIBUTIONS PRESUMED TO UNDERLIE THE OBSERVER'S DECISION.

Shape can carry a small amount of information quite effectively. In part its effectiveness is high because it is not easily degraded. No portion of the population seems to be afflicted with a shape processing weakness analogous to color "blindness." Shapes retain their identity over an extreme range of ambient illumination intensities and spectral characteristics (as generated by selective absorption of various meteorological conditions, or color-temperatures of illumination sources). Shapes of the type under discussion are not easily affected by contrast with nearby shapes. Background shape can (and should) be congruent with silhouette and therefore its identity can be preserved when covered with dirt, snow or condensation. Finally, border effectively carries all the shape information, so that, for example, only the border need be reflective if cost is an overwhelming consideration.

A disadvantage of shape in comparison to color is that its information cannot be contained in a point source. In order to be recognized, a shape must subtend some minimum visual angle. On the other hand, if the visual angle subtended is too large, then considerable scanning must be employed. This is, of course, a serious drawback, but the successful use of shape in the current U.S. system attests to the fact that a useable range of visual angles does exist. The use of shape in this country must be considered a plus in contrast to other systems. To compromise with other systems by giving up a potentially useful coding dimension does not seem to be indicated.

Sign shape in this country generally conveys gross information about the more detailed information carried by the sign. According to the 1961 edition of the *Manual on Uniform Traffic Control*

Devices, the significance of sign shapes is standardized as follows:

- The **octagon** shall be reserved exclusively for the STOP sign.
- The **equilateral triangle**, with one point downward, shall be reserved exclusively for the YIELD sign.
- The **round shape** shall be used for the advance warning of a railroad crossing, and for the civil defense Evacuation Route Marker. It is also used for some State Route Markers.
- The **diamond shape** shall be used only to warn of existing or possible hazards either on the roadway or adjacent thereto.
- Regulatory signs, with the exception of STOP signs and YIELD signs, shall be **rectangular**, ordinarily with the longer dimension **vertical**.
- Guide signs, with the exception of certain route markers, shall be **rectangular**, ordinarily with the longer dimension **horizontal**.
- Other shapes are reserved for special purposes; for example, the shield or other characteristic design for route markers on Interstate, U.S., and State highway routes, and the crossbuck for railroad crossings.

Method

Out of fourteen shapes shown on Figs. 3-3 and 3-4, ten were selected for testing. Eliminated because of their highly specialized current uses were the two shields, the U.S. route marker (#13) and the interstate shield (#14), as well as the star (#7). The equilateral triangle was shown only vertex downward (#4) and not vertex upward (#1).

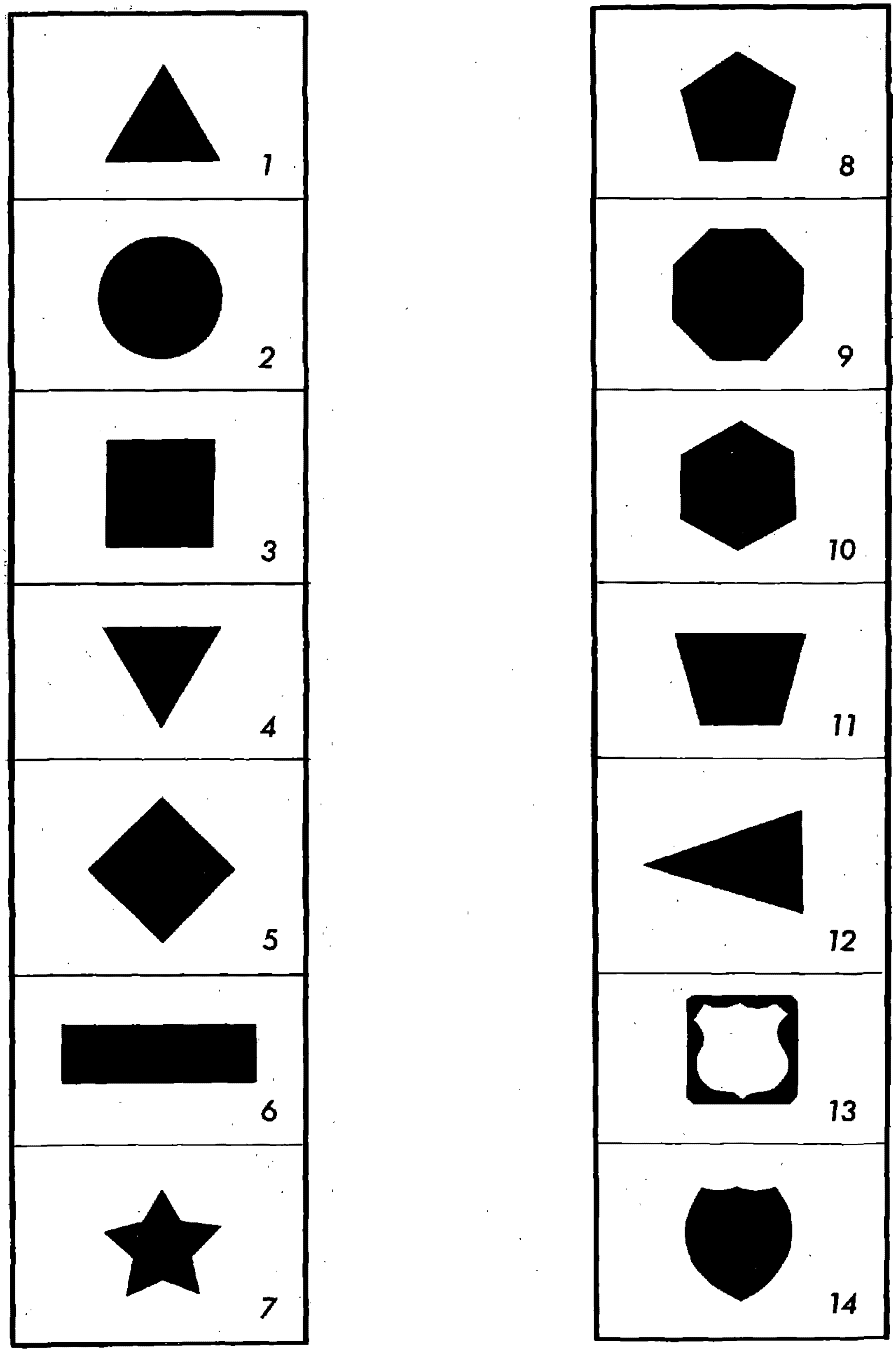


FIG. 3-3 SPECIMEN SHAPES — BLACK FIGURE ON A WHITE SURROUND. (POSITIVE IMAGE)

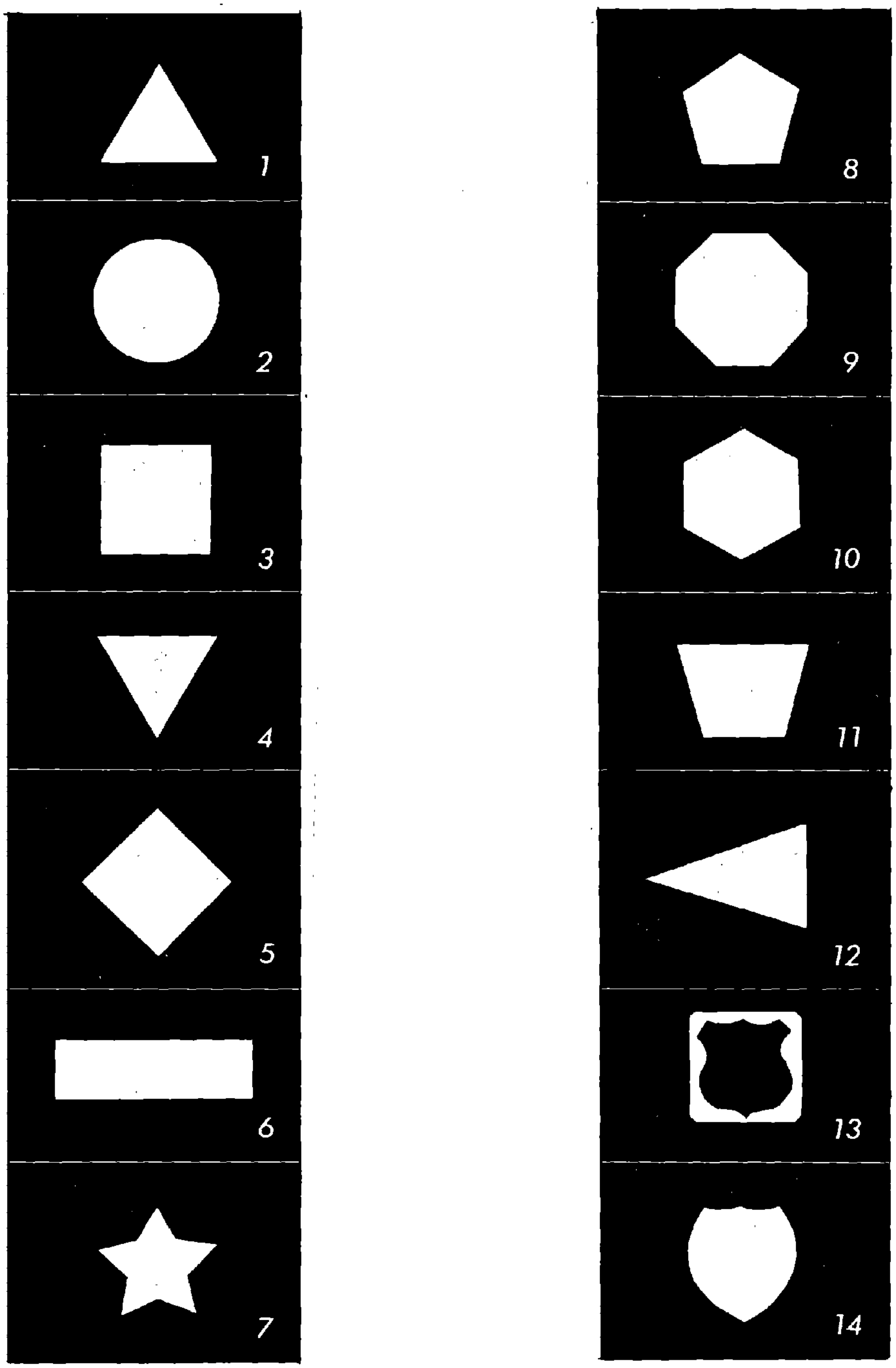


FIG. 3-4 SPECIMEN SHAPES — WHITE FIGURE ON A BLACK SURROUND. (NEGATIVE IMAGE)

Approximately thirty observers were used, each for at least ten daily sessions. Each session lasted two hours, during which time a subject was exposed to eighty tachistoscopic stimulus presentations. Four exposure durations were used and each of the ten stimulus shapes was presented at each exposure duration in both positive (black shape on white surround) and negative (white shape on a black surround). The exposure durations used in this series of experiments were 0.015, 0.020, 0.025 and 0.030 seconds. Each stimulus presentation was both preceded and followed in time by masking fields, visual noise of slightly higher energy. In general terms, both the pre-stimulus and post-stimulus presentations of visual noise were designed to limit the effective stimulus presentation to no more than the actual exposure duration. The pre-stimulus visual noise served also as a warning signal to the observers. The action of the pre-stimulus visual noise fits into the conceptual framework of both "masking" and the "psychological refractory period," the action of the post-stimulus visual noise being related to "backward temporal masking" and the "erasure" phenomena of Sperling and Averbach.

The task put to the observer was to tell which of the ten shapes occurred on a given trial, and to attach to his answer a numerical rating of from one to four, to indicate the confidence he felt in his judgment. The observer was provided with a suitable answer sheet upon which to record his responses, as well as copies of Figs. 3-3 and 3-4 to assist in identification and to limit the set of responses. Observers were required to answer on each and every trial. When they were unsure, they were instructed to choose the most likely alternative shape, and to accord it a suitable confidence rating.

Results

Data in this experiment were analyzed according to the principles set forth in Sec. 3.3. With respect to any shape, two things could have actually been presented, that shape (s), or some other (o). The observer could have responsed either with the name for that shape "S" and a numerical rating of confidence, or some other "O" and a rating. These "O" responses were in a sense regarded as "S" responses, but of even less certainty and such that the more sure the observer was about "O," the less sure we consider him to have been about "S." That is, for a particular sign under consideration, an observer's response can be described by the pair:

$$\langle t,x\rangle \text{ where } t \supset T = \{\text{"S"}, \text{"O"}\}$$

$$\text{and} \quad x \supset X = \{1, 2 \ldots n\} \, ,$$

The set T representing the set of shape types, and the set X representing the set of confidence ratings, where $n=4$ in our case. Then the transformation made is

$$\langle \text{"O"},x\rangle = \langle \text{"S"}, n + (n+1) - x\rangle$$

$$= \langle \text{"S"}, 2n + 1 - x\rangle$$

and inasmuch as n in this case is equal to four

$$\langle \text{"O"},x\rangle = \langle \text{"S"}, 9 - x\rangle$$

Finally, then, we can think of any response as

$$\langle \text{"S"},c\rangle \text{ where } c \supset C = \{1, 2 \ldots 8\}$$

Because either s or o could have been presented we are interested in the two conditional probabilities

$$p(\langle\text{"S"}, c\rangle | s)$$

and

$$p(\langle\text{"S"}, c\rangle | o)$$

or more precisely we are interested in the cumulative conditional probabilities,

$$P(\text{"S}_i\text{"} | s) = \sum_{c=1}^{i} p(\langle\text{"S"}, c\rangle | s)$$

and

$$P(\text{"S}_i\text{"} | o) = \sum_{c=1}^{i} p(\langle\text{"S"}, c\rangle | o)$$

Thus, the primary data reduction is to a 2×8 table of the form

TABLE 3-2.

	i	$P(\text{"S}_i\text{"}\|s)$	$P(\text{"S}_i\text{"}\|o)$
"very sure"	1		
	2		
	3		
	4		
	5		
	6		
	7		
"very unsure"	8	1.00	1.00

Table 3-3 represents data pooled over observers, exposure durations and positive and negative images, broken down according to shape. The eighth row is omitted inasmuch as it is constrained to be 1.00.

The data in Table 3-3 were plotted to obtain the ten operating characteristics shown in Fig. 3-5. One estimate of recognizability, d_c, was abstracted from the operating characteristics themselves, at their intersection with the negative diagonal, and is given in Table 3-3. Another index, d', was taken using the middle data point and assuming that the underlying distributions are of equal variance. Fulfillment of this condition would be operating characteristics of unit slope. As can be seen from Fig. 3-5, the assumption is not quite accurate as the slopes are generally less than unity. Nonetheless, ranking the shapes according to either index gives reasonably good agreement with the other as shown in Fig. 3-6.

Now let us separate the data according to whether the positive (black shape on a white surround) or negative (white shape on a black surround) was shown. These data are presented in Table 3-4 and plotted in Fig. 3-7. As before, the data are pooled over observers and exposure durations. For purposes of comparison, d' values are shown. A rank-ordering according to d' values is given separately for positive and negative presentations in Fig. 3-8.

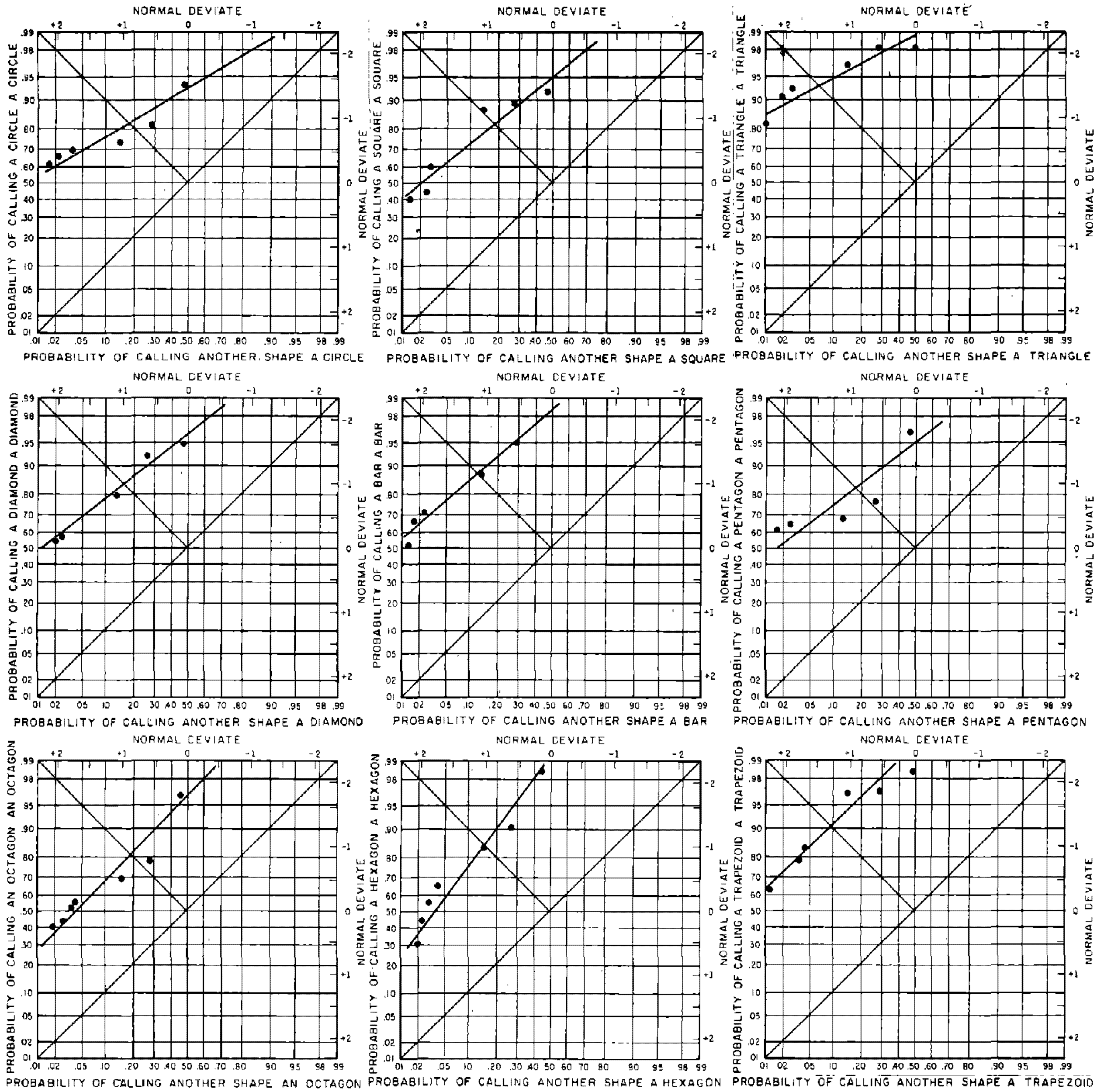
Discussion

The shapes that appear to be most distinct and recognizable from the set, irrespective of whether positive or negative, are those with the most acute angles — triangle, pennant and trapezoid.

TABLE 3-3. Reduced data for shape, pooled over positive and negative images, all durations and observers. d' for the middle point is given, as is d_e taken from the plots of the data.

Circle		Square		Triangle		Diamond		Bar	
.516	.004	.149	.010	.685	.001	.447	.005	.433	.001
.612	.017	.403	.014	.815	.010	.500	.009	.516	.013
.661	.022	.446	.025	.907	.017	.552	.020	.667	.015
.693	.036	.596	.029	.925	.027	.578	.025	.715	.022
.738	.145	.873	.135	.962	.142	.789	.131	.871	.137
.818	.286	.888	.276	.981	.285	.921	.267	.950	.284
.935	.485	.920	.467	.981	.500	.947	.473	.999	.501
d'	= 2.32	d'	= 2.14	d'	= 3.38	d'	= 2.15	d'	= 2.56
d_c	= 1.92	d_e	= 1.90	d_e	= 3.00	d_e	= 2.0	d_e	= 2.30

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.372	.000	.400	.018	.301	.019	.482	.009	.550	.003
.559	.003	.427	.027	.444	.022	.633	.012	.685	.013
.610	.015	.518	.035	.555	.029	.783	.034	.716	.015
.644	.025	.554	.040	.666	.037	.833	.042	.716	.025
.672	.130	.690	.150	.841	.150	.966	.149	.866	.147
.762	.265	.781	.282	.904	.270	.966	.291	.966	.294
.966	.461	.963	.465	.985	.432	.933	.487	.984	.500
d'	= 2.34	d'	= 1.89	d'	= 2.26	d'	= 2.69	d'	= 2.53
d_e	= 1.84	d_e	= 1.75	d_e	= 2.06	d_e	= 2.60	d_e	= 2.46



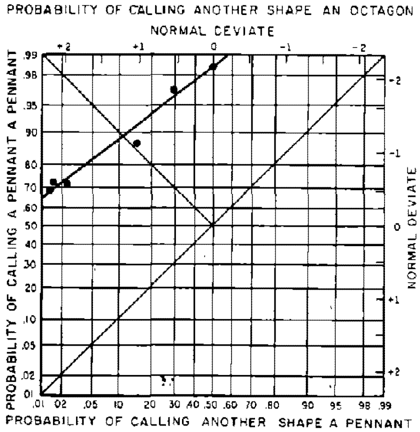


FIG. 3-5 OPERATING CHARACTERISTICS — SHAPE.
DATA FROM TABLE 3-3.

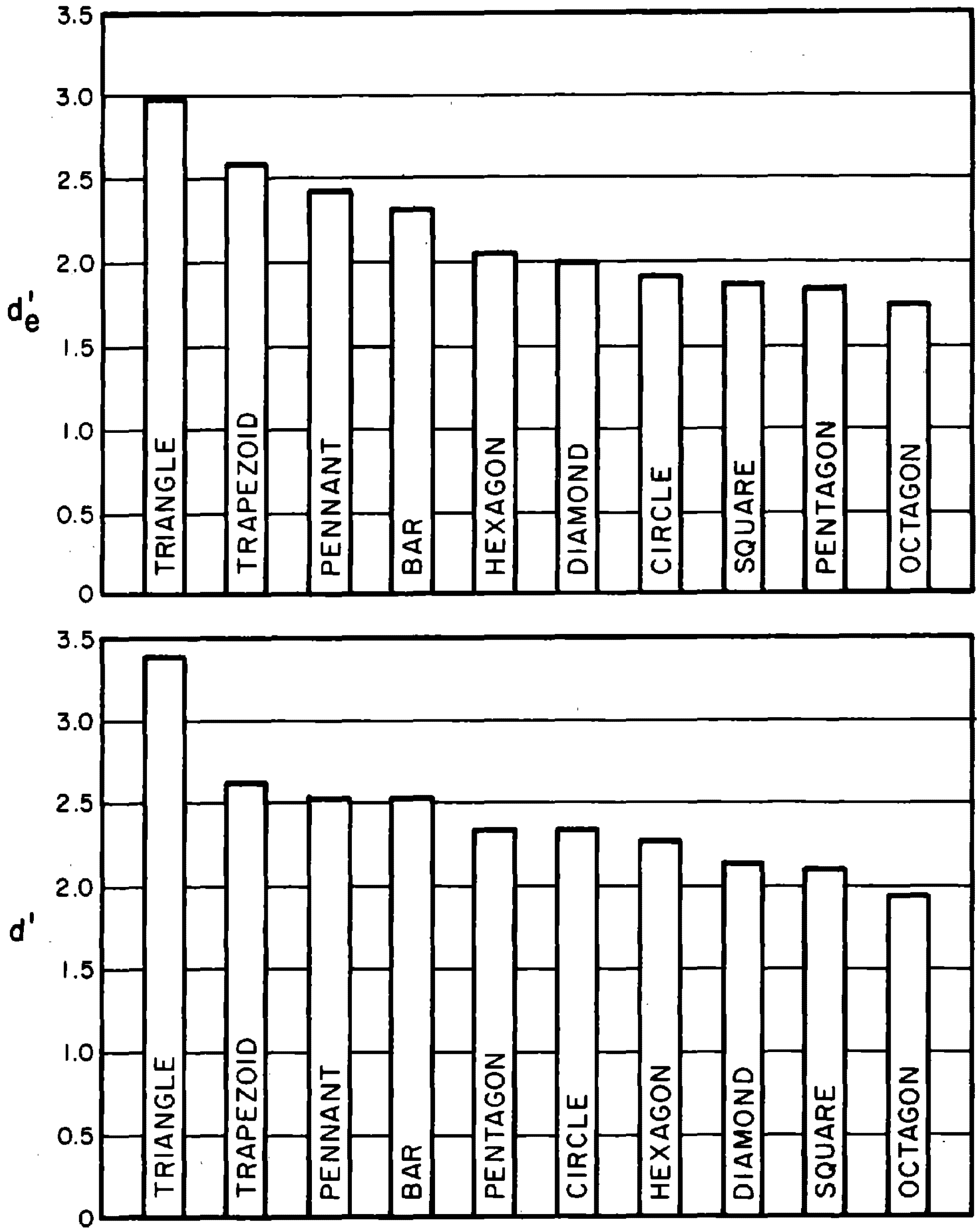


FIG.3-6 INDEX OF RECOGNIZABILITY - SHAPE
DATA FROM TABLE 3-3 AND FIGURE 3-5

TABLE 3-4.

POSITIVE IMAGE (BLACK SHAPE ON WHITE)

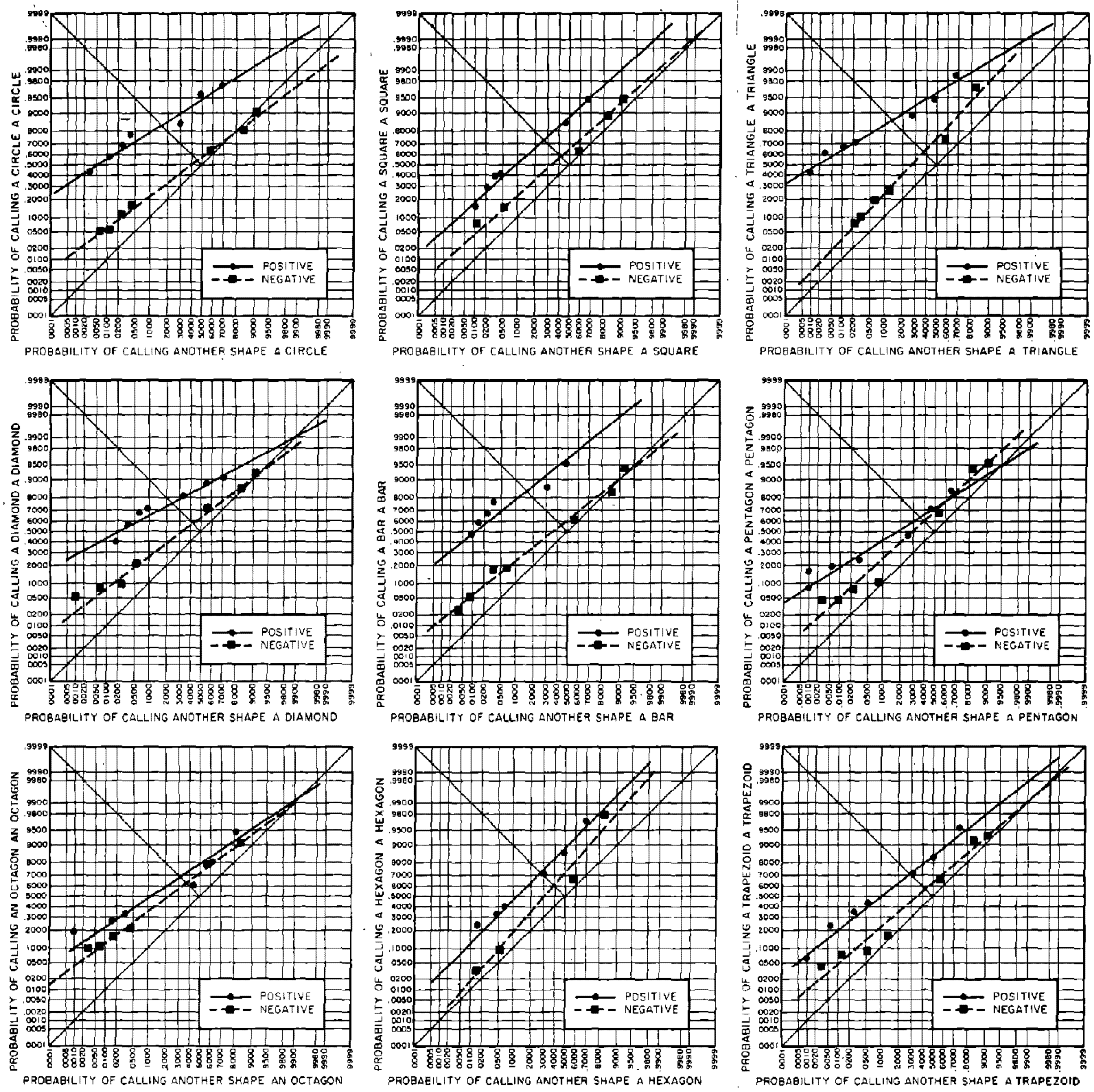
Circle		Square		Triangle		Diamond		Bar	
.422	.003	.154	.011	.422	.001	.397	.019	.461	.009
.577	.012	.281	.022	.605	.003	.575	.039	.584	.014
.690	.026	.394	.031	.647	.011	.671	.063	.676	.021
.774	.040	.408	.049	.704	.022	.712	.097	.769	.034
.845	.298	.704	.275	.873	.276	.808	.336	.861	.311
.957	.491	.850	.475	.943	.474	.876	.553	.953	.497
.971	.693	.943	.670	.985	.679	.904	.701	1.00	.699
d' = 2.49		d' = 1.41		d' = 2.58		d' = 1.84		d' = 2.62	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.084	.001	.121	.000	.117	.000	.062	.001	.541	.006
.169	.001	.187	.001	.235	.016	.234	.006	.639	.014
.197	.066	.266	.016	.323	.048	.344	.029	.680	.014
.239	.032	.333	.031	.397	.070	.421	.056	.763	.019
.464	.263	.600	.436	.705	.300	.703	.303	.930	.273
.704	.460	.800	.624	.867	.482	.828	.498	.986	.489
.854	.650	.946	.815	.970	.688	.953	.743	1.00	.707
d' = 1.18		d' = 1.44		d' = 1.22		d' = 1.35		d' = 2.76	

NEGATIVE IMAGE (WHITE SHAPE ON BLACK)

Circle		Square		Triangle		Diamond		Bar	
.051	.007	.038	.000	.071	.022	.052	.001	.027	.004
.051	.012	.038	.000	.100	.030	.078	.007	.054	.008
.115	.025	.078	.011	.185	.063	.092	.027	.178	.032
.167	.043	.155	.052	.257	.122	.223	.057	.191	.066
.641	.587	.623	.586	.742	.578	.723	.578	.616	.581
.821	.850	.883	.829	.971	.833	.855	.844	.835	.861
.897	.921	.948	.905	1.00	.907	.934	.908	.945	.920
d' = .80		d' = .65		d' = .54		d' = .78		d' = .59	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.044	.003	.100	.003	.000	.000	.041	.003	.067	.011
.044	.009	.110	.007	.000	.003	.055	.013	.148	.022
.074	.021	.159	.017	.031	.015	.083	.057	.243	.057
.104	.086	.217	.041	.093	.054	.166	.137	.337	.117
.686	.541	.782	.568	.671	.576	.652	.575	.743	.610
.940	.816	.942	.842	.984	.828	.916	.837	.932	.855
.955	.897	1.00	.914	1.00	.898	.930	.909	.972	.914
d' = .06		d' = .98		d' = .30		d' = .13		d' = .76	



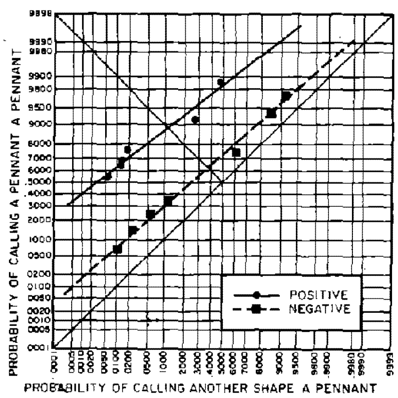


FIG. 3-7 OPERATING CHARACTERISTICS — SHAPE.
DATA FROM TABLE 3-4.

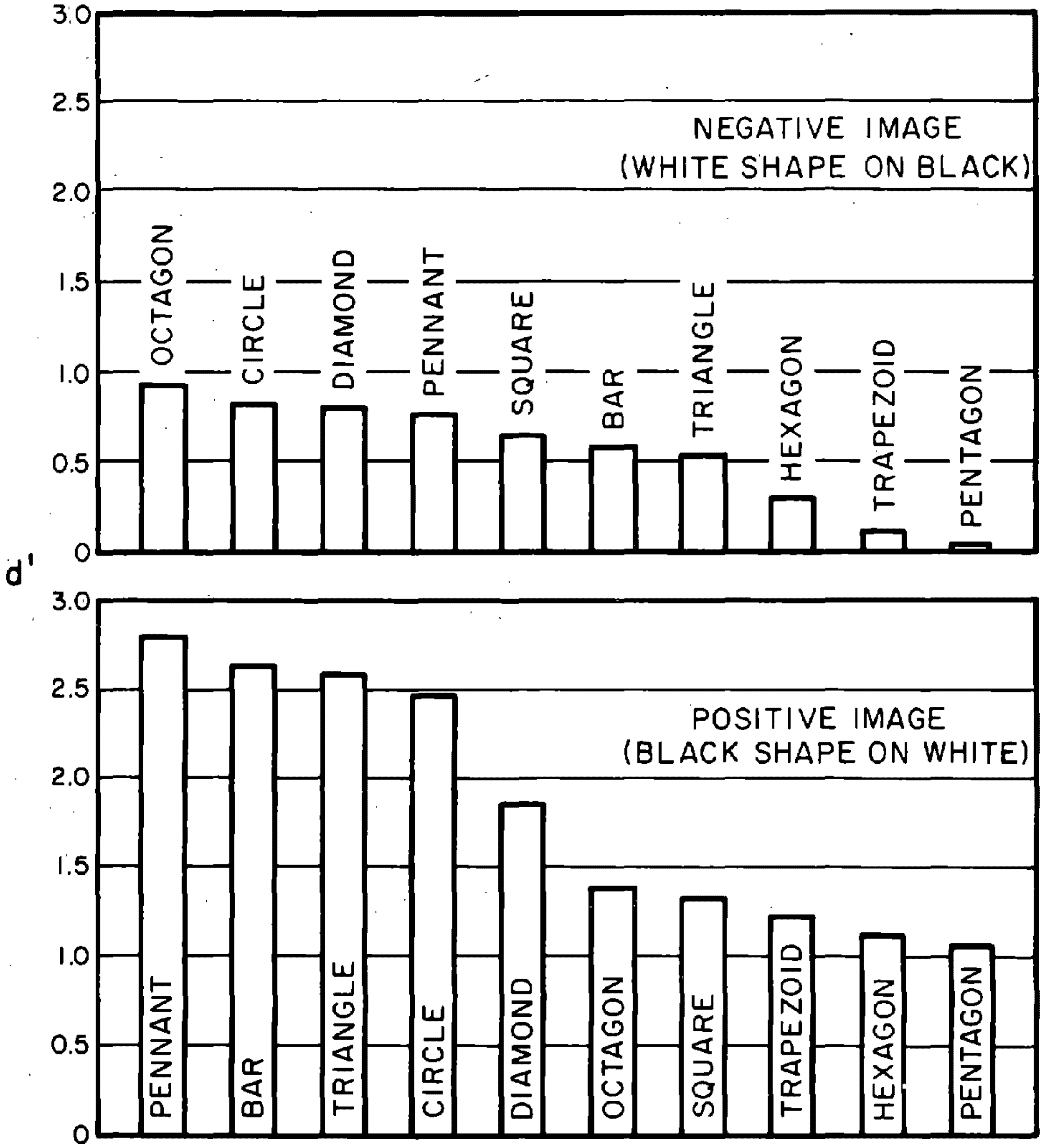


FIG.3-8 INDEX OF RECOGNIZABILITY.
DATA FROM TABLE 3-4, FIGURE 3-7.

Figures with more obtuse angles — octagon, pentagon, square and diamond, as well as the circle — fare relatively more poorly. Quite reasonably, a slim figure, the bar, does well and in a sense is similar to the acute angle figures. One way of describing the difference between the better and poorer performance is that the former have small visual areas with two edges and thus high local contrast definition.

Separating out the data according to negative and positive presentations is quite revealing. Most prominent is the superiority of the positive (black figure on white surround) images. As can be seen in Fig. 3-7, this holds true for every shape, without exception. Figure 3-8 is also quite revealing. It shows that the superiority of the acute angle figures is dominated by the positive presentation data. Reversing the figure-ground relationship appears to reverse the trend, an interesting and little remarked upon relationship. The question of whether highway signs are positive or negative against their varied and uncontrollable backgrounds is a difficult one, compounded by the possibility of day-night reversals, particularly with dark-colored, background-reflectorized signing. The use of a border, reversed from the background shape, undoubtedly mitigates the problem and is to be recommended.

The reader should not overlook the dominant finding that all the shapes can in fact convey their information effectively in extremely brief observation intervals. The total set then constitutes an acceptable medium for coding of limited information and shape coding should most certainly be continued. Each shape constitutes a reasonable field in which legend or symbolic information can be placed. The pennant provides the least amenable field for messages, but its proposed singular usage for the "keep right" message, whether by legend or symbol should be effective.

Because of various suggestions that a circular shape supplant the octagon for the STOP sign, a special analysis of the errors to circular stimuli was made. As might be guessed, a greater number of errors to the circle were octagon responses although the disproportion was not inordinate — 16.3% as against an expected 11.1%. The direction of the errors does then mitigate slightly the transitional problems which would be encountered. There are, of course, other difficulties in that the circle is currently reserved for railroad crossings.

3.6 Experiments — Arrows

The use to which arrows are put in traffic-control devices is straightforward and needs virtually no detailed explication here. On guide signs, arrows serve to indicate direction destination; on warning signs, arrows have been suggested to show that the warning is an advance one — i.e., up ahead; likewise their use with route shields indicate the message is in advance. Such uses as the latter two do not constitute as pressing a problem as the former. The reason is that in the latter cases, there is seldom a choice of driving maneuver — turn right, veer left, etc. The use of arrows on guide signs is the more critical application inasmuch as they occur at a choice point, where often there is time pressure. To make matters worse, there is almost always more information to be processed, some of it highly uncertain. Time left for processing the information contained by the arrow may then be minimal.

The experiments with arrow type are in response to the operational situation which contains a choice point — a set of alternative directions — and immediacy. As the set of alternative directions, we chose the four cardinal ones: up, down, right and left. The initial feeling was that to answer questions about arrow type, four would suffice. The downward pointing arrow was included basically for completeness and balance although it does, in fact, see service in overhead lane-control signing.

While no great prior expectations about the superiority of one or another arrow type existed, the results were, as will be shown, extremely gratifying. The experiment might, of course, have included arrow types deliberately poorly designed — "straw" arrows, as it were — but in fact it did not. The seven arrow types tested appeared to be *a priori* effective and pleasing.

Method

Seven types of arrows were selected for study. They are shown in Fig. 3-9 below. While there does not exist a really good language for describing arrow types, there is a fair lexicon for aircraft configurations which might be helpful. Accordingly, five of the arrows are delta-winged, two of them unswept deltas (Nos. 1 and 6), and three of them swept-back deltas (Nos. 3, 5, and 7) of varying severity; two are simple swept wing arrows (Nos. 2 and 4). Note that one of them (No. 1) has a wasp-waisted fuselage, a slightly smaller arrow head and a slightly longer shaft.

Five observers were run continuously over ten daily sessions. Each session lasted two hours, during which time each observer was exposed to eighty tachistoscopic stimulus presentations.

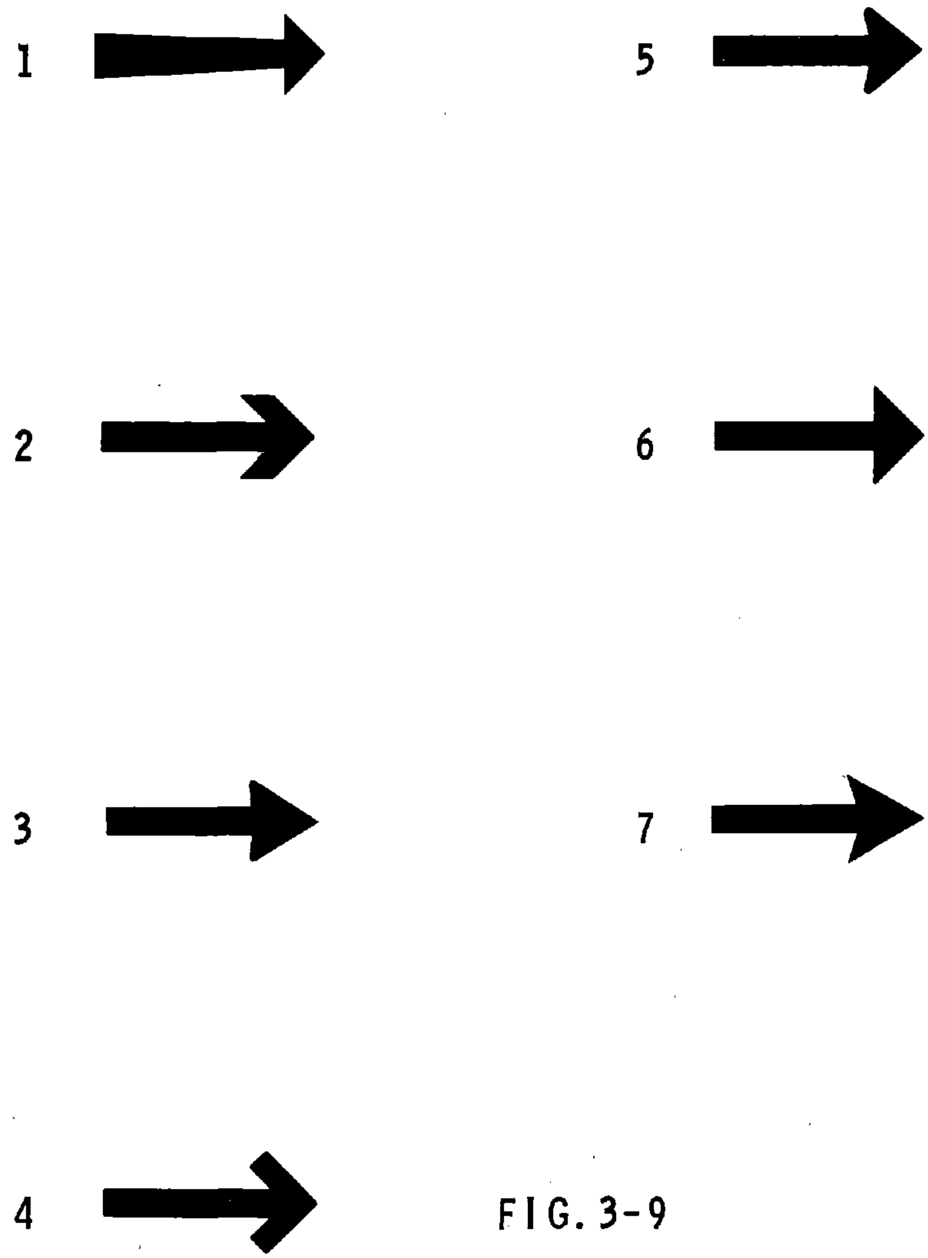


FIG. 3-9

STIMULUS SET FOR EXPERIMENTS WITH DIRECTIONAL ARROWS

The exposure durations used during this series of experiments were 0.015, 0.020, 0.025 and 0.030 seconds, as in the previous series. Again, each stimulus presentation was both preceded and followed in time by masking fields (visual noise of slightly higher energy), for reasons explained in the previous experiment.

A stimulus presentation entailed one of the seven arrow types oriented in one of the four cardinal directions, up, down, right and left. Choice of arrow type and orientation were determined randomly and counter-balanced appropriately over days and exposure durations.

The observers were instructed to indicate in which orientation the arrow had been displayed, and to rate their confidence in the decision on a four-point numerical scale ranging from very sure to very unsure. Note that the observers were not required to identify the arrow types, but merely to abstract information about direction from the presentation, as they would be required to do at a real choice point in the field.

Results

The data were analyzed according to the principles set forth in Sec. 3.3 above. Points on a given operating curve were adduced from the data as described in the method section of the previous experiment, reported in Sec. 3.5. Insofar as the operating characteristics obtained appeared reasonably well-described by linear functions on normal-normal probability coordinates as seen in Fig. 3-10, tabular values of d' were abstracted from the data.

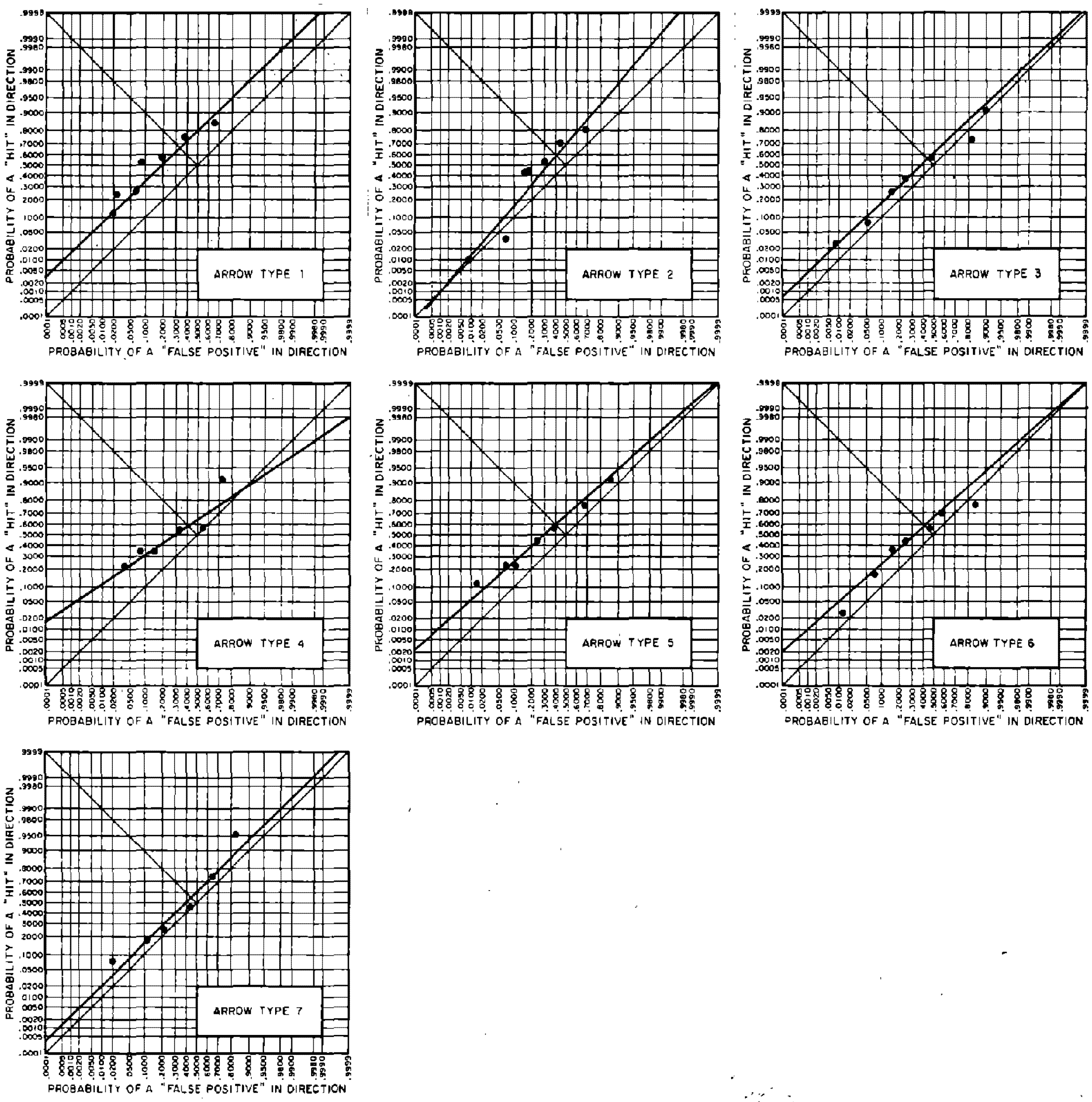


FIG. 3-10 OPERATING CHARACTERISTICS — ARROW TYPES

Looking first at accuracy in judging orientation, independent of arrow type, a substantial difference is found between up and down, on the one hand, and right and left, on the other. The supporting data are given in Table 3-5 below. The table entries are d' values and are given as a function of both orientation and exposure duration. For each exposure duration, the up and down orientations produce superior performance. This is seen more easily in Fig. 3-11, which shows average d' values for the vertical and horizontal orientations as a function of exposure duration in milliseconds.

TABLE 3-5. d' Values for each orientation, as a function of exposure duration and pooled for all arrow types.

	ORIENTATION			
Exposure Duration	Up	Down	Left	Right
30 ms	.87	.92	.42	.68
25	.72	.60	.20	.51
20	.57	.51	.08	.14
15	-.10	.20	-.20	.13

To give the reader some notion of how much more accurate the observers were in the vertical orientations (up and down) as opposed to the horizontal orientations (right and left), we have extrapolated the data of Fig. 3-11 to a convenient d' value of 1.00. While this performance would be reached on the vertical orientations at an exposure of slightly more than thirty milliseconds, it would take an exposure duration of more than forty milliseconds to produce the same accuracy.

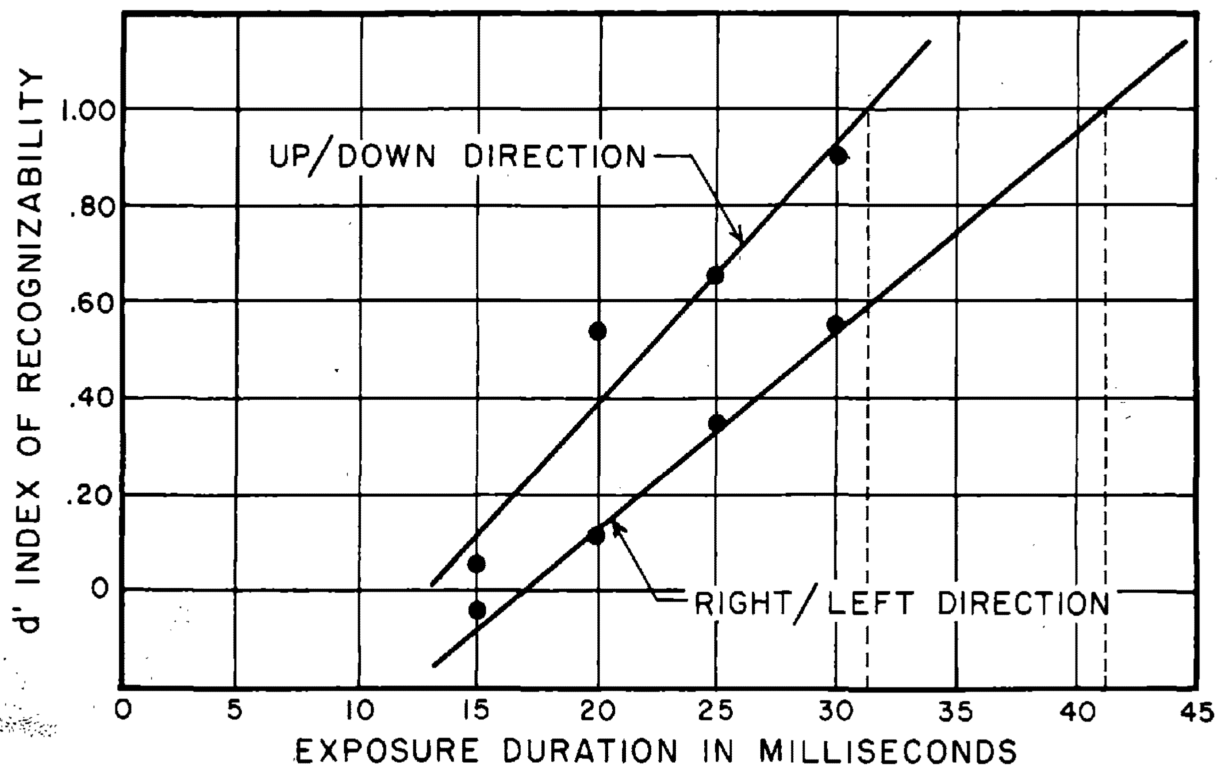


FIG.3-11 AVERAGE d' VALUES FOR VERTICAL AND HORIZONTAL ORIENTATIONS OF DIRECTIONAL ARROWS AS A FUNCTION OF THE EXPOSURE DURATION IN MILLISECONDS. DATA ARE POOLED OVER ARROW TYPE.

Now let us consider arrow types. Table 3-6 below gives data from the experiments, pooled over observers and exposure durations, and broken down according to arrow type. These same data are plotted as operating characteristics in Fig. 3-11. The rank ordering of arrow types is depicted graphically in Fig. 3-12.

Discussion

Two interesting findings of the experiments on directional arrows and arrow types are the superiority of the vertical orientations, and the clear superiority of one arrow type. While the latter finding is the more applicable to highway signing problems, it is also the more explicable, and we shall defer it for the moment. Why the vertical orientations should lead to the best performance is a perplexing one. Our observers did, of course, view the stimuli binocularly and, inasmuch as human beings are side-by-side (rather than one above the other), there is an overlapping central portion which is elongated in the vertical direction. It is then conceivable that arrows in the vertical orientation can be thought of as going along two channels rather than a single one. To rely on such an assumption we are forced also to assume a degree of information processing at a very peripheral level – highly speculative, but our only speculation to date.

To return to the superiority of arrow types, arrow type 1 is clearly the best. No doubt its advantage lies in the fact that directional information is carried not only by the arrow head but by the shaft as well. As a consequence, necessary processing of the figure is reduced. For example, it is no longer necessary to "find" where the arrow head is located – any small slice is sufficient to tell exactly the orientation.

TABLE 3-6. Arrow Shapes.

1	
.118	.020
.230	.025
.262	.065
.521	.089
.559	.190
.755	.389
.850	.673

d' = 1.39

2	
.010	.009
.033	.070
.433	.160
.445	.189
.525	.300
.700	.445
.800	.692

d' = 0.74

3	
.027	.008
.088	.050
.260	.154
.380	.233
.589	.487
.736	.835
.912	.889

d' = 0.44

4	
.000	.010
.222	.038
.333	.080
.355	.150
.545	.322
.581	.550
.933	.717

d' = 0.66

5	
.110	.015
.206	.070
.244	.110
.422	.233
.595	.393
.784	.673
.916	.868

d' = 0.54

6	
.025	.015
.156	.073
.386	.167
.425	.256
.562	.486
.700	.591
.750	.843

d' = 0.46

7	
.000	.009
.089	.020
.188	.125
.263	.205
.454	.430
.734	.630
.950	.814

d' = 0.16

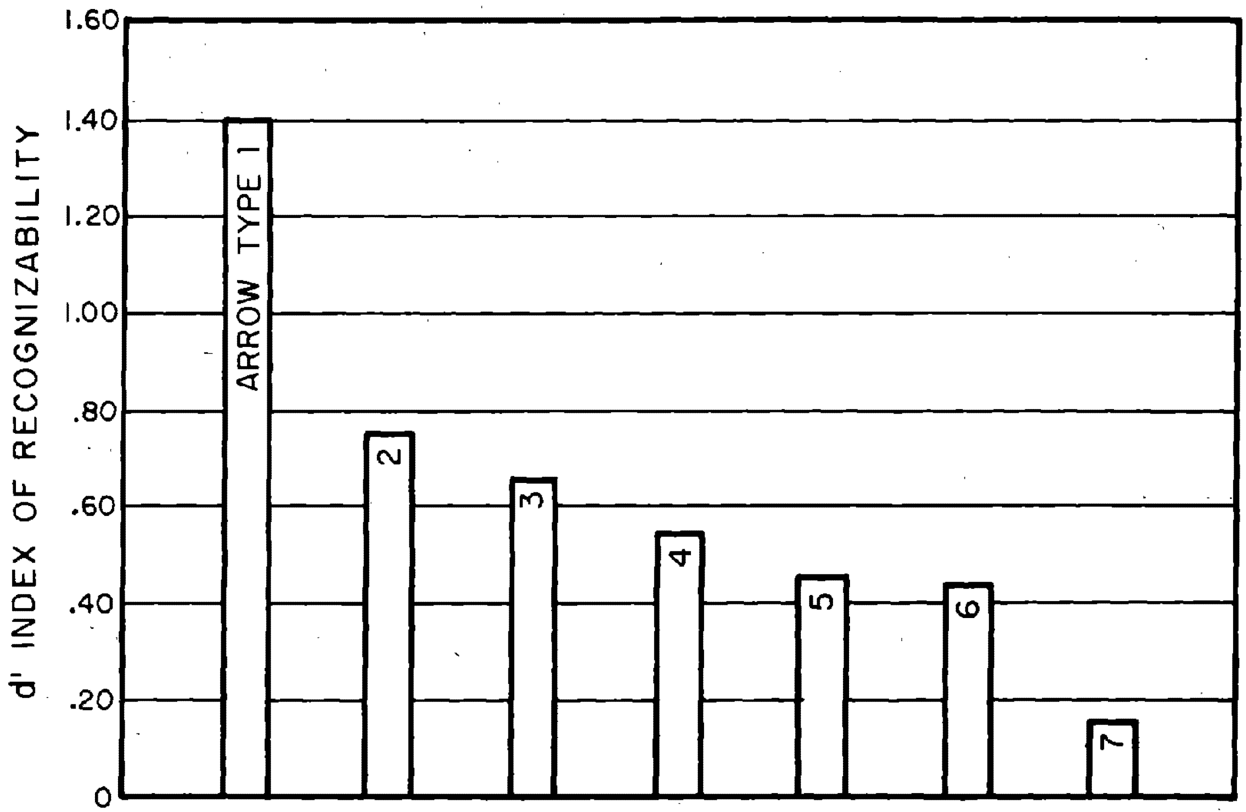


FIG.3-12 RANK ORDERING OF ARROW TYPES. DATA FROM TABLE 3-6

3.7 Borders

The function of a border on a highway sign is to convey redundantly the information coded in the shape, as discussed in Sec. 3.5. Proper borders, colored in contrast to the background color and *inset from the shape's silhouette edge,* can serve to offset reversals or ambiguities which may arise about whether a shape is positive (dark shape on a light surround) or negative (light shape against a dark background). A proper border ensures that there are both positive and negative representations of the shape; thus, there is always a positive representation of the shape.

There is, in fact, relatively little to the design of a border. Inasmuch as it is to follow sign shape, the only degree of design freedom is border width.

Because the information transmitted by a sign border is that of shape, the meaningful question to be asked of observers is, quite simply, "what shape did you see?" and, of course, "How confident were you?". In many respects, then, these experiments were quite similar to those discussed in Sec. 3.5.

Method

Three shapes only were used in this series of experiments, diamond, circle and square. These shapes were represented by borders of four different widths. The set of stimuli used are shown in Fig. 3-13 below.

Five observers were run continuously over ten daily sessions. Each session lasted two hours, during which time any observer

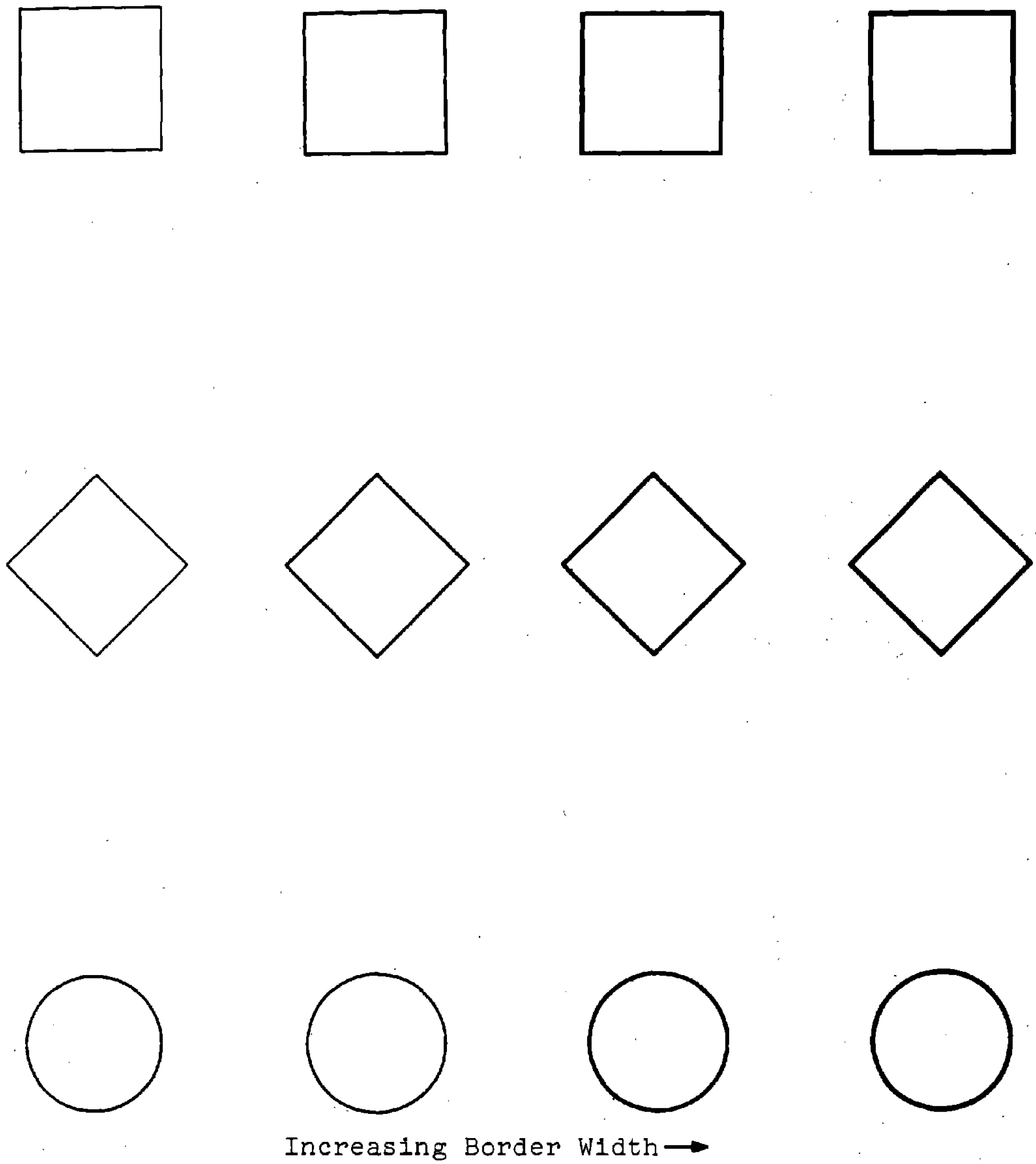


FIG 3-13 STIMULUS SET USED IN EXPERIMENT ON BORDERS.

was exposed to eighty tachistoscopic stimulus presentations. The exposure durations used were 0.015, 0.020, 0.025 and 0.030 seconds, as in the previous series. Again, each stimulus presentation was both preceded and followed in time by masking fields.

A stimulus presentation entailed one of the four shapes represented by one of the four border widths. Choice of shape and border were determined randomly and counter-balanced appropriately over days and exposure durations.

The observers were instructed to indicate which shape had been displayed, and to rate their confidence in the decision on a four-point numerical scale ranging from very sure to very unsure. Note that the observers were not required to identify the border widths, but merely the shapes, as they would be required to do on the road.

Results

The data were analyzed according to the principles set forth in Sec. 3.3 above. Points on a given operating curve were adduced from the data as described in the method section of the experiments on shape, reported in Sec. 3.5. Insofar as the operating characteristics obtained appeared reasonably well described by linear functions on normal-normal probability paper, as shown in Fig. 3-14, tabular values of d' were abstracted from the data.

Table 3-7, below, gives these data broken down by shape and border width, and pooled over observers and exposure durations. Because the primary questions were about border width, quite

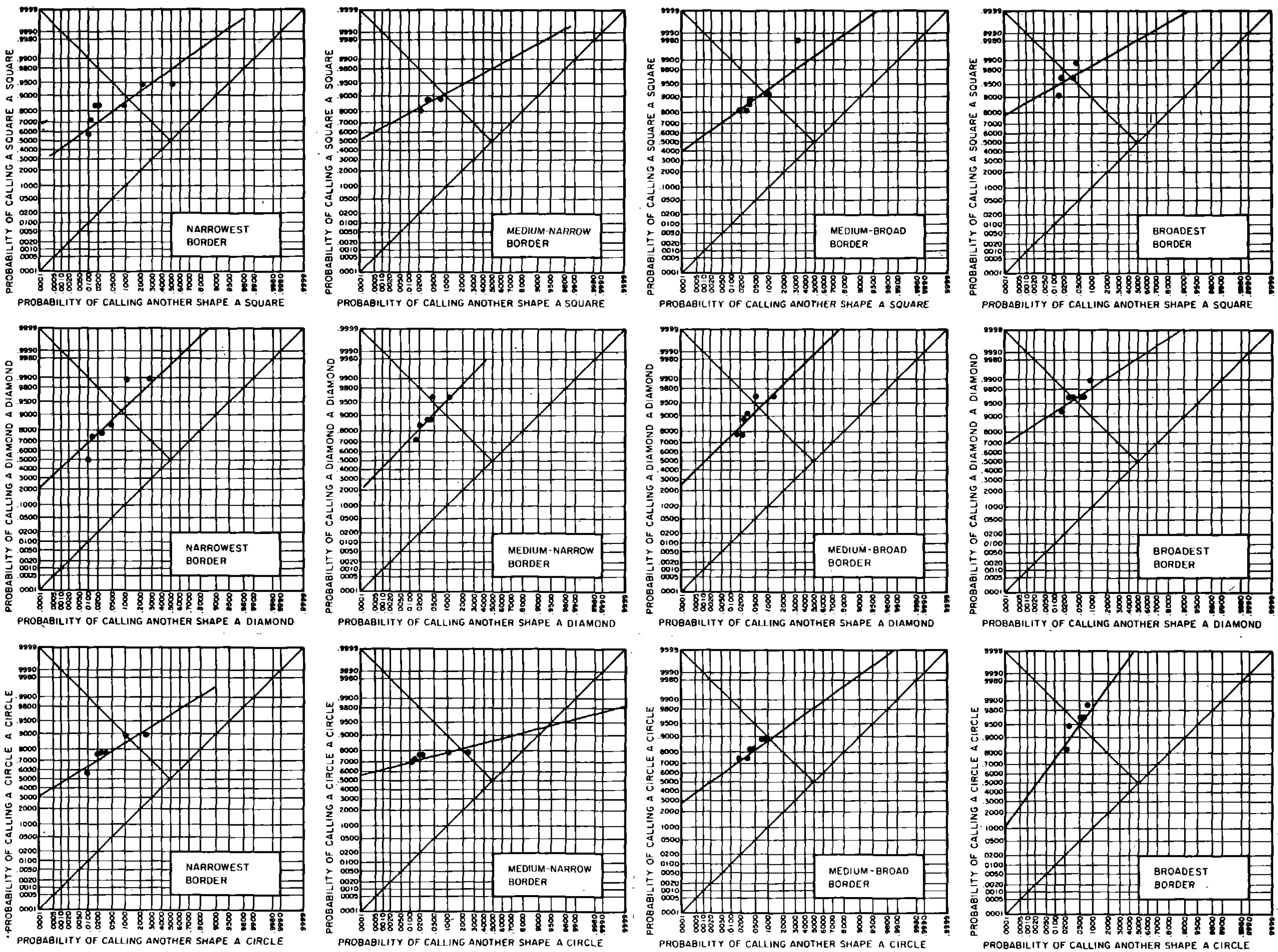


FIG. 3-14 OPERATING CHARACTERISTICS — BORDERS. DATA FROM TABLE 3-7.

TABLE 3-7. Border, 3 shapes, 4 widths.

	A		B		C		D	
Diamond	.500	.010	.720	.018	.778	.017	.933	.019
	.750	.014	.850	.020	.778	.025	.956	.027
	.775	.028	.885	.033	.789	.028	.956	.033
	.840	.049	.885	.043	.901	.035	.978	.056
	.989	.117	.955	.049	.955	.057	.948	.067
	.989	.278	.955	.121	.955	.140	.990	.095
	1.00	.536	.989	.578	1.00	.483	1.00	.303
	d' = 2.63		d' = 2.98		d' = 3.03		d' = 3.60	
Circle	.575	.010	.700	.012	.455	.020	.833	.022
	.778	.020	.722	.015	.755	.035	.956	.028
	.789	.026	.777	.020	.833	.040	.975	.055
	.789	.036	.777	.022	.833	.047	.975	.063
	.895	.110	.777	.118	.889	.077	.987	.075
	.955	.253	.792	.240	.889	.097	1.00	.101
	1.00	.570	1.00	.670	1.00	.520	1.00	.250
	d' = 2.56		d' = 2.82		d' = 2.87		d' = 3.60	
Square	.577	.010	.818	.022	.833	.019	.922	.015
	.722	.012	.818	.022	.833	.029	.967	.017
	.845	.017	.878	.032	.855	.032	.967	.034
	.845	.020	.878	.034	.889	.032	.989	.041
	.845	.093	.878	.078	.933	.089	1.00	.078
	.944	.203	1.00	.110	.933	.098	1.00	.095
	.944	.510	1.00	.500	.998	.307	1.00	.303
	d' = 3.04		d' = 3.06		d' = 3.11		d' = 4.07	

independent of shape, the observers' responses were pooled to yield Table 3-8 and these data are plotted in Fig. 3-15.

As can be seen from Table 3-8, within the limits of border widths that were used in this series, the wider the border, the better it conveys its shape information. As can be confirmed in Table 3-7, this holds for each individual shape without exception.

TABLE 3-8. Border width, A, B, C, D.
A is narrowest, D is broadest.

A		B		C		D	
.818	.000	.902	.012	.933	.010	.980	.020
.818	.008	.973	.014	.933	.012	.985	.026
.892	.020	.973	.020	.933	.012	.985	.026
.892	.032	.973	.050	.955	.020	.985	.040
.892	.040	.973	.062	.955	.055	.989	.051
.899	.040	1.00	.076	.955	.078	.989	.051
1.00	.051	1.00	.076	.989	.222	1.00	.067
d' = 3.11		d' = 3.52		d' = 3.80		d' = 4.07	

Discussion

The finding that broader borders convey shape information better is not a surprising one and needs little discussion here. What is pleasantly surprising is that such subtle differences in width produce measurably different performances.

This experiment did not, of course, explore the entire range of possible border widths. At one extreme, the border becomes increasingly thin and "disappears," while at the other extreme the border gets so thick as to "disappear" (becomes the shape). Inasmuch as broader borders are superior, there would be no need to explore finer ones than were used. Exploring borders quite

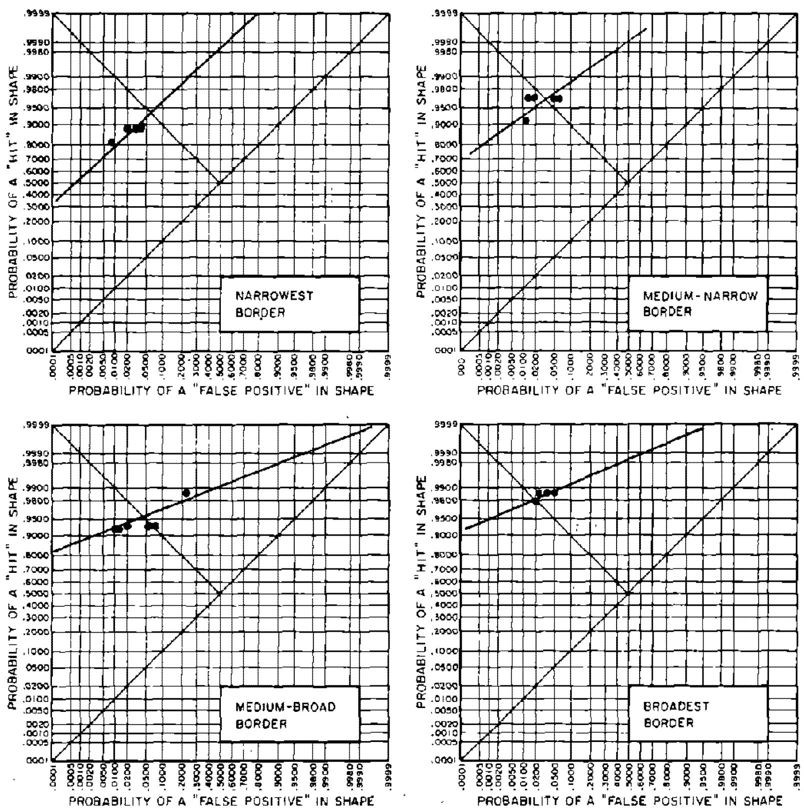


FIG. 3-15 OPERATING CHARACTERISTICS — BORDERS. DATA FROM TABLE 3-8, POOLED FOR ALL SHAPES.

a bit thicker would eventually mean studying a compromise between message field size (and thus message size) and border width. There is the definitional question of when a border ceases to be a border and becomes a symbol in its own right.

3.8 Colors and Colored Shapes

Color plays an important role in our current system of traffic control devices and the use of color is being expanded and made more systematic. According to a proposed draft of the 1970 *U.S. Manual on Uniform Traffic Control Devices:*

- **Red** shall be used as a background color for stop and do not enter messages, and as a legend color for parking prohibition and yield right of way messages.
- **Black** shall be used as a background on one-way, and night-speed-limit signs. Black is used as a message on white, yellow and orange signs.
- **White** shall be used as a background color on all regulatory signs not using red or black backgrounds, and for miscellaneous information signs. White is used as a message on brown, green, blue, purple and red signs.
- **Orange** shall be used as a background color for construction, maintenance and emergency signs, and shall not be used for any other purpose.
- **Purple** shall be used as a background color for school signs, and shall not be used for any other purpose.
- **Yellow** shall be used as a background color for warning signs not using orange.

- **Brown** shall be used as a background color for guide and information signs related to points of recreational, scenic or cultural interest.
- **Green** shall be used as a background color for guide signs and route shields, other than those using brown and mileposts and as legend color on white background for permissive parking regulations.
- **Blue** shall be used as a background color for information signs related to motorist services including police services and rest areas.
- Three other colors — **gray, buff,** and **brilliant yellow-green** — have been identified as suitable for highway use, and are being reserved for future needs.
- Wherever **white** is specified herein as a sign color, it is understood to include silver-colored reflecting coatings or elements that reflect white light.

In some cases, then, color carries its information redundantly with shape; in other cases, it carries a message of its own. In order to appreciate the effects of color, there are, then, really three sets of questions which need to be asked about colored shapes: which shape? which color? and which colored shape?

The first question allows the investigator to assess whether the introduction of color affects the recognition of shape. The second question allows him to assess whether color recognition is affected by shape. The third question allows him to explore cases where color and shape together might uniquely determine the message.

As a result, three distinct series of experiments were performed using the same set of stimuli – the ten basic shapes as discussed in Sec. 3.5 in four basic colors: red, blue, green, and yellow.

3.8.1 Recognition of shape as a function of color

Method

From among the fourteen shapes shown on Figs. 3-3 and 3-4, ten were selected for testing as in our previous experiments on shape as described in Sec. 3.5. Eliminated were the two shields and the star as before, and the equilateral triangle was shown vertex downward and not vertex upward.

Nine observers were used, each for fifteen daily sessions. Each session lasted two hours, during which time an observer was presented tachistoscopically with one-hundred-and-twenty stimuli in four groups of 30 apiece. Each group was shown at a different exposure duration, 0.030, 0.025, 0.020 and 0.015 seconds, the slowest presentation at the beginning of a session and the briefest last. Each group of thirty contained randomly selected colored shapes, the colors being red, yellow, blue, and green. As in previous experiments each stimulus presentation was both preceded and followed in time by masking fields, visual noise of slightly higher energy. The visual noise was whites and grays, and thus achromatic, or fairly uniformly distributed over the visual spectrum, as you will.

The task put to the observer was to tell which of the ten shapes occurred on a given trial, and to attach to his answer a numerical rating of from one to four, to indicate the confidence he felt in his judgment. The observer was provided with a suitable answer sheet upon which to record his responses, as well as copies of Figs. 3-3 and 3-4 to assist in identification and to limit the set of responses. Observers were required to answer on each and every trial. In cases where they were unsure they were instructed to choose the most likely alternative shape, and accord it a suitable confidence rating reflecting how unsure they were.

Results

As in previous experiments, the data were analyzed according to the principles set forward in Secs. 3.3 and 3.5 above. Table 3-9 below gives data broken down according to shape, and pooled over the observers and the four exposure durations. The data were plotted as operating characteristics on normal-normal coordinates and are shown in Fig. 3-16 below. Insofar as the operating characteristics appeared reasonably fit by linear functions, tabular values of d' were abstracted from the data and are given in Table 3-9.

Figure 3-17 shows the rank ordering of shapes according to their recognizability when shown in one of four basic colors, red, blue, yellow, and green.

The data were further broken down to consider the recognition of shape, color by color. Table 3-10 gives data by shape, considering only the presentation of red stimuli, Table 3-11 similarly for yellow, Table 3-12 for blue, and Table 3-13 for green. These data are plotted as operating characteristics in Figs. 3-18, 3-19, 3-20 and 3-21, respectively. Rank orderings by shape, broken down by color are shown in Fig. 3-22.

TABLE 3-9. Shape, pooled over 4 exposure durations.

Circle		Square		Triangle		Diamond		Bar	
.173	.004	.148	.005	.191	.005	.116	.005	.185	.003
.300	.012	.444	.014	.361	.013	.271	.013	.391	.012
.436	.022	.626	.027	.552	.016	.429	.025	.614	.022
.586	.034	.793	.079	.669	.045	.601	.051	.645	.042
.643	.229	.869	.225	.830	.191	.624	.196	.870	.223
.952	.388	.885	.411	.922	.390	.967	.395	.924	.414
.966	.675	.948	.712	.957	.664	.984	.670	.945	.693
d' = 2.11		d' = 2.20		d' = 2.08		d' = 1.90		d' = 2.14	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.151	.004	.193	.006	.142	.004	.135	.004	.270	.002
.315	.011	.343	.013	.332	.010	.300	.015	.436	.014
.525	.021	.508	.024	.463	.020	.450	.029	.621	.030
.659	.057	.558	.037	.576	.031	.625	.052	.810	.047
.867	.152	.790	.227	.831	.169	.760	.222	.843	.346
.918	.485	.928	.481	.858	.489	.865	.472	.891	.731
.960	.700	.950	.674	.963	.714	.911	.735	.962	.901
d' = 1.96		d' = 1.90		d' = 2.08		d' = 1.97		d' = 2.52	

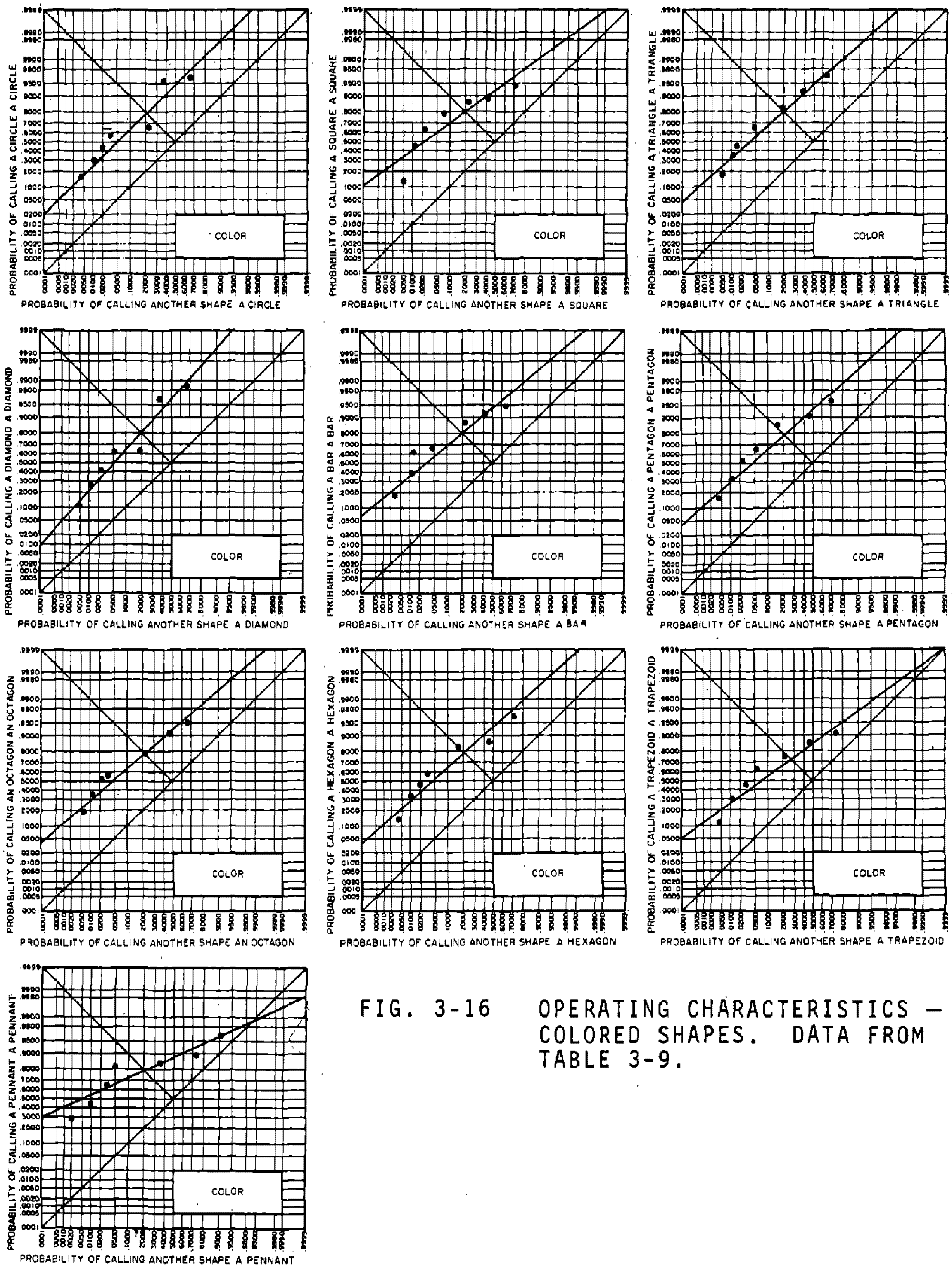


FIG. 3-16 OPERATING CHARACTERISTICS – COLORED SHAPES. DATA FROM TABLE 3-9.

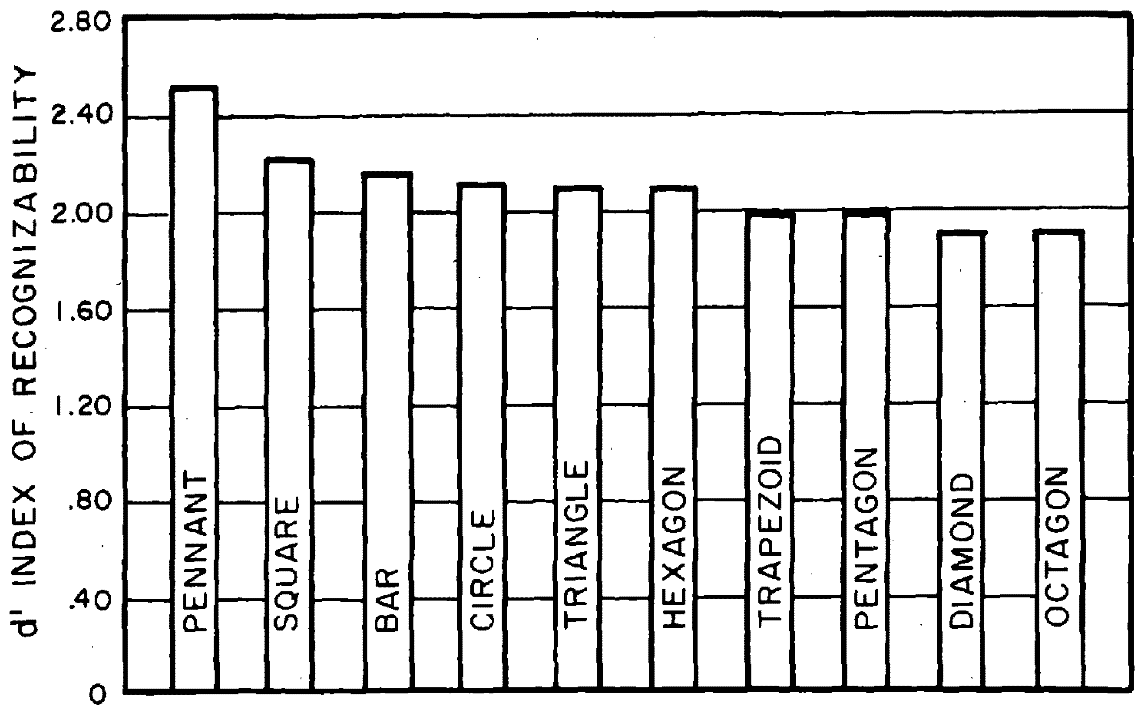


FIG. 3-17 RANK ORDERING OF SHAPES DISPLAYED IN COLOR (RED, BLUE, GREEN, OR YELLOW).

TABLE 3-10. Red Shape - Recognition of Shape.

Circle		Square		Triangle		Diamond		Bar	
.304	.010	.171	.000	.246	.002	.157	.000	.231	.006
.464	.027	.357	.014	.410	.019	.353	.006	.365	.008
.638	.048	.471	.017	.557	.029	.608	.007	.558	.013
.826	.065	.786	.019	.405	.046	.745	.015	.673	.022
.841	.349	.829	.316	.803	.269	.882	.242	.788	.214
.884	.400	.929	.362	.918	.497	.922	.484	.865	.416
.899	.720	.971	.676	.934	.752	1.00	.737	.981	.634
d' = 2.42		d' = 2.86		d' = 2.20		d' = 2.72		d' = 2.49	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.129	.002	.189	.008	.184	.006	.174	.005	.377	.000
.371	.010	.391	.011	.469	.011	.391	.009	.493	.009
.516	.018	.472	.021	.551	.019	.607	.021	.652	.022
.694	.021	.660	.038	.673	.022	.739	.025	.826	.024
.726	.220	.830	.248	.796	.256	.826	.312	.869	.320
.871	.416	.906	.488	.837	.508	.848	.378	.928	.381
.968	.479	.981	.750	.878	.757	.869	.697	.986	.708
d' = 2.56		d' = 2.16		d' = 2.49		d' = 2.52		d' = 2.83	

TABLE 3-11. Yellow Shape — Recognition of Shape.

Circle		Square		Triangle		Diamond		Bar	
.282	.008	.185	.016	.139	.002	.230	.019	.155	.000
.423	.017	.463	.028	.316	.019	.385	.028	.276	.018
.592	.032	.519	.034	.557	.028	.538	.040	.586	.027
.732	.048	.740	.062	.671	.049	.708	.087	.690	.080
.831	.312	.925	.251	.747	.269	.908	.286	.759	.290
.930	.573	.963	.481	.911	.638	.969	.559	.914	.546
.958	.808	.963	.664	.911	.824	1.00	.805	.983	.785
d' = 2.25		d' = 2.19		d' = 2.08		d' = 1.90		d' = 1.90	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.141	.002	.167	.008	.192	.005	.156	.007	.122	.002
.250	.009	.300	.008	.327	.011	.356	.016	.243	.002
.470	.015	.433	.022	.423	.029	.444	.031	.419	.007
.641	.032	.633	.035	.635	.038	.667	.045	.541	.015
.688	.297	.833	.284	.846	.285	.800	.302	.650	.288
.844	.555	.883	.554	.962	.561	.844	.573	.703	.556
.969	.782	.983	.790	1.00	.792	.978	.789	.757	.787
d' = 2.24		d' = 2.08		d' = 2.11		d' = 2.08		d' = 2.15	

TABLE 3-12. Blue Shape — Recognition of Shape.

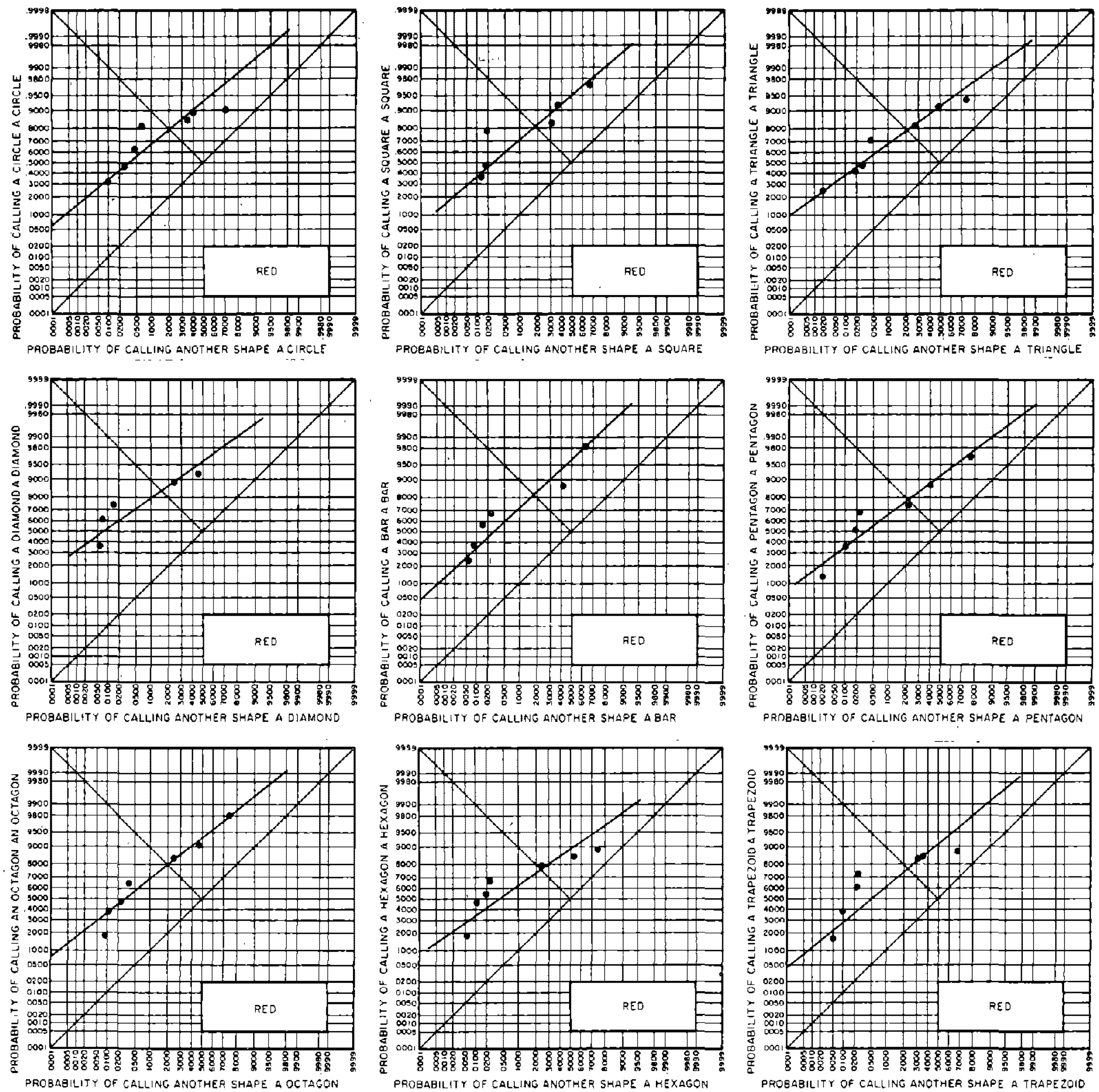
Circle		Square		Triangle		Diamond		Bar	
.141	.008	.153	.000	.152	.000	.111	.000	.132	.008
.282	.022	.288	.014	.271	.008	.259	.008	.264	.020
.451	.040	.303	.018	.337	.020	.358	.020	.472	.024
.602	.045	.398	.024	.467	.040	.456	.043	.584	.042
.845	.383	.797	.355	.870	.349	.878	.388	.666	.375
.930	.649	.915	.633	.944	.369	.987	.638	.857	.570
.958	.838	.966	.826	1.00	.837	.995	.827	.864	.868
d' = 1.90		d' = 1.80		d' = 1.68		d' = 1.62		d' = 1.95	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.146	.002	.140	.000	.120	.004	.130	.009	.160	.004
.231	.013	.195	.010	.202	.008	.205	.011	.363	.010
.339	.021	.300	.025	.375	.012	.289	.024	.597	.034
.493	.043	.566	.052	.484	.033	.445	.050	.816	.045
.750	.298	.733	.633	.667	.410	.637	.670	.829	.323
.798	.569	.816	.694	.801	.643	.743	.735	.943	.546
.940	.838	.908	.808	.849	.837	.818	.893	.969	.853
d' = 1.72		d' = 1.82		d' = 1.83		d' = 1.51		d' = 2.56	

TABLE 3-13. Green Shape — Recognition of Shape.

Circle		Square		Triangle		Diamond		Bar	
.128	.008	.138	.000	.141	.003	.098	.000	.108	.000
.240	.020	.277	.009	.266	.028	.246	.009	.246	.002
.444	.029	.430	.011	.391	.043	.409	.021	.400	.011
.595	.043	.462	.022	.531	.057	.525	.032	.492	.034
.940	.371	.662	.293	.625	.403	.672	.284	.554	.296
.971	.450	.769	.570	.719	.472	.738	.559	.677	.571
.990	.780	.815	.816	.750	.778	.836	.809	.813	.812
d'	= 2.00	d'	= 1.95	d'	= 1.62	d'	= 1.93	d'	= 1.86

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.118	.002	.121	.002	.148	.000	.096	.004	.154	.000
.235	.013	.212	.009	.279	.002	.194	.013	.323	.000
.397	.027	.333	.015	.410	.013	.339	.015	.431	.007
.559	.040	.485	.026	.540	.053	.500	.037	.523	.022
.603	.313	.545	.335	.590	.310	.580	.252	.570	.297
.721	.577	.621	.586	.623	.568	.613	.469	.631	.579
.824	.815	.667	.820	.738	.811	.661	.843	.677	.819
d'	= 1.90	d'	= 1.86	d'	= 1.74	d'	= 1.75	d'	= 2.10



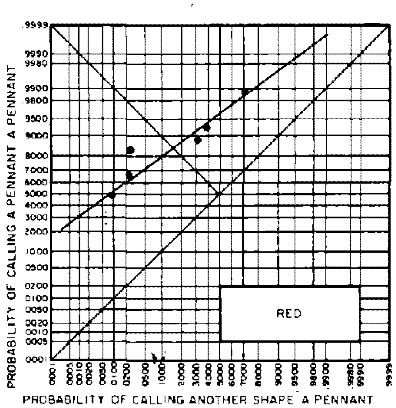
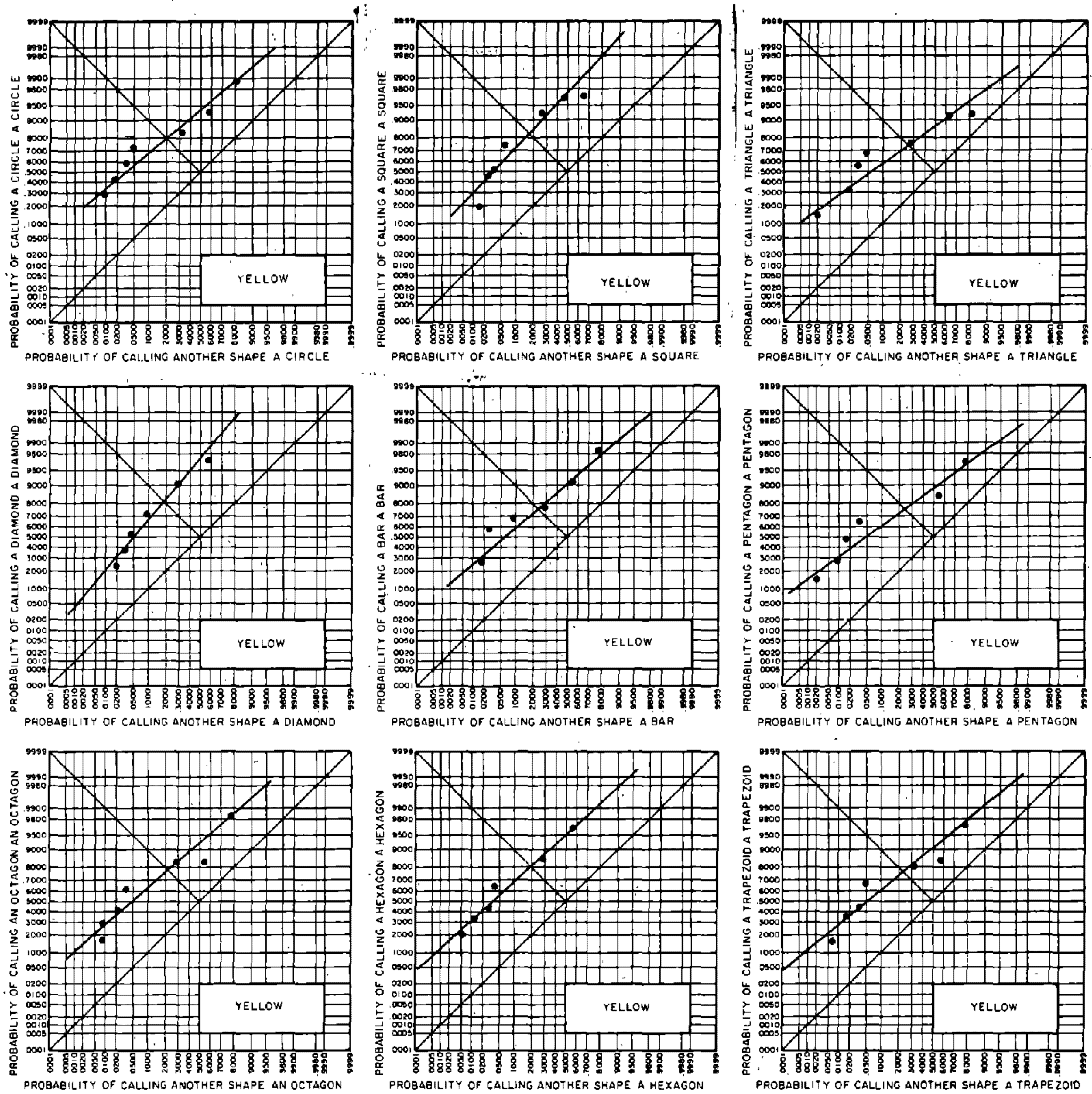


FIG. 3-18 OPERATING CHARACTERISTICS – RED SHAPES. DATA FROM TABLE 3-10.



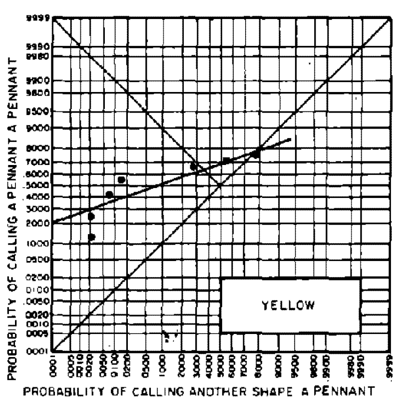


FIG. 3-19 OPERATING CHARACTERISTICS — YELLOW SHAPES. DATA FROM TABLE 3-11.

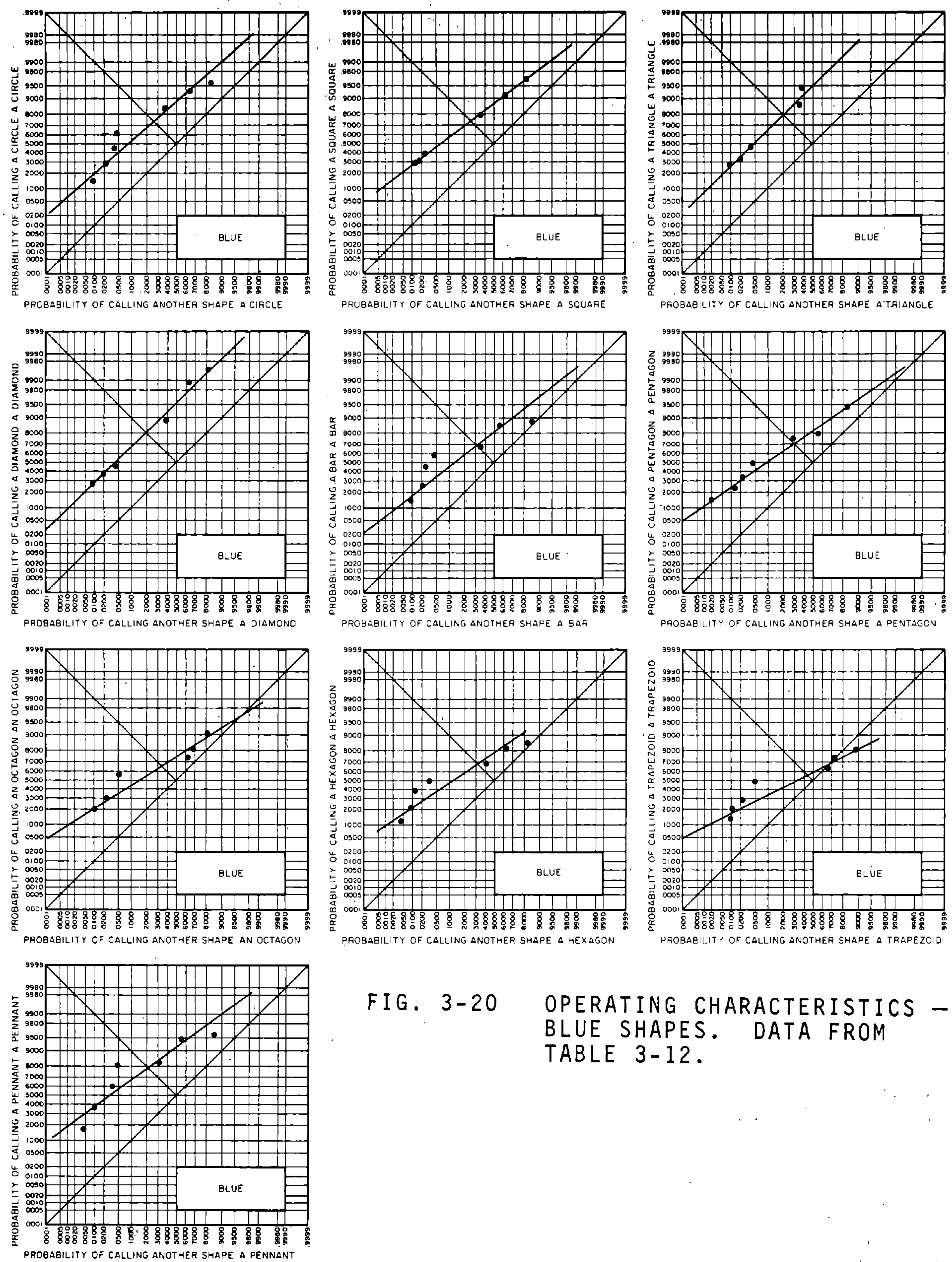
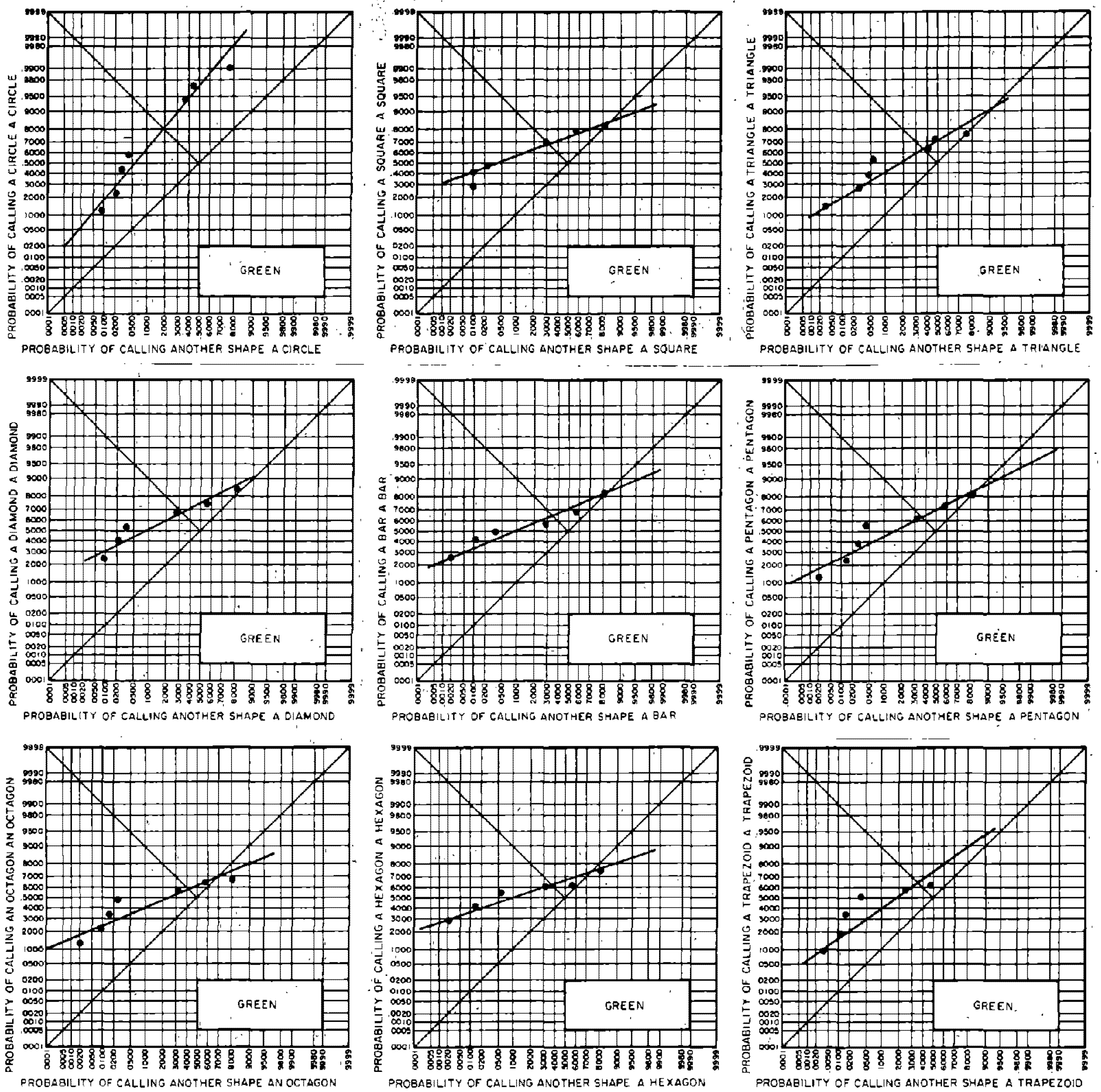


FIG. 3-20 OPERATING CHARACTERISTICS — BLUE SHAPES. DATA FROM TABLE 3-12.



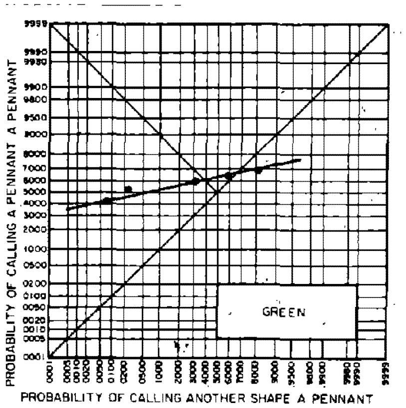


FIG. 3-21 OPERATING CHARACTERISTICS — GREEN SHAPES. DATA FROM TABLE 3-13.

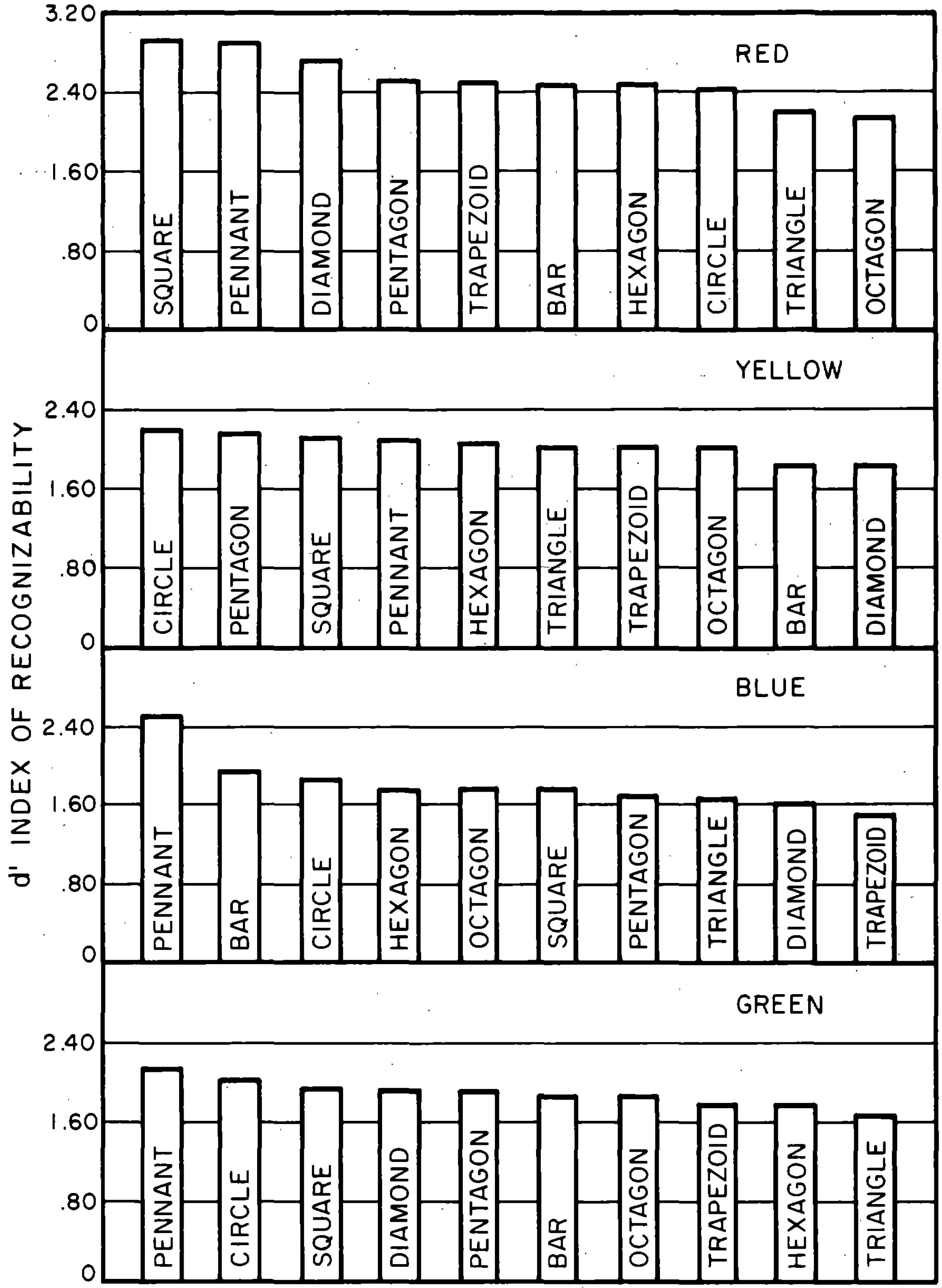


FIG.3-22 RANK ORDERING OF SHAPES.

Discussion

The basic question to which this series of experiments is addressed is that of whether the introduction of color drastically or adversely affects the recognition of shape. The overall answer to the question is a straightforward negative. The introduction of color effects no drastic changes in the recognition of shape. The basis for this answer rests in a comparison of Fig. 3-22 and Fig. 3-8. As with any answer, there are, of course, certain reservations. While all the shapes achieve quite good recognition scores when shown in color, even at the brief exposure durations we have used, color may introduce a few idiosyncrasies. The square seems to improve upon being presented in color, particularly in red. The triangle undergoes some degradation in blue and green. The triangle is good in yellow – the present arrangement for the YIELD sign – and even a trifle better in red, reinforcing the proposed change in YIELD signs from yellow to red. The pennant and bar hold their places quite well, being relatively better in red and blue.

When discussing shape in prior experiments, we were emphatic in pointing out that all the shapes can, in fact, convey their information effectively in extremely brief observation intervals. We concluded that the total set constituted an acceptable medium for coding of limited information and that coding by shape should most certainly be continued. Inasmuch as the introduction of color does not drastically reduce the recognition of any of the shapes, we see no reason to change these conclusions.

In order to make use of certain of the more detailed findings, a rather complete re-evaluation of the role of both shape and color would have to be undertaken. A coherent policy would have to be arrived at, settling whether shape and color should be used for categories of messages or for particular messages, and whether they should be used redundantly or as independent coding dimensions. This point will be discussed again in later chapters.

3.8.2 Processing color information from colored shapes

Method

From among the fourteen shapes shown on Figs. 3-3 and 3-4, ten were selected for testing as in the previous experiment. In nearly every respect, the procedure was identical with that of the previous experiment.

As before, nine observers were used, each for fifteen daily sessions. Each session lasted two hours, during which time an observer was presented tachistoscopically with one-hundred-and-twenty stimuli in four groups of 30 apiece. Each group was shown at a different exposure duration, 0.030, 0.025, 0.020 and 0.015 seconds, the slowest presentation at the beginning of the session, and the briefest last. Each group of thirty contained randomly selected colored shapes, the colors being red, yellow, blue, and green. As in previous experiments each stimulus presentation was both preceded and followed in time by masking fields, visual noise of slightly higher energy. The visual noise was whites and grays, and thus achromatic, or fairly uniformly distributed over the visual spectrum, as you will.

Observers were instructed to respond with the color which they judged most likely to have been presented on a given trial. Observers were also instructed to attach to each answer a numerical rating of confidence on a four-point scale. A simple answer sheet was provided for this purpose. Inasmuch as only four basic colors, red, green, blue, and yellow were used, and inasmuch as these most surely constitute a well learned set, no cue sheet of specimens was given the observers.

Results

The raw data were analyzed as in previous experiments and are summarized in Table 3-14 below. The table is broken down according to color and exposure duration, and d' values are given.

In Fig. 3-23 we have plotted values of d' for each color as a function of the exposure duration in milliseconds.

Discussion

Data involving color judgments about briefly presented stimuli must be approached with some caution. The human eye in some respects behaves as if it were composed of discrete populations of receptor elements uniquely sensitive to different portions of the color spectrum — different "eyes" for different colors, as it were. Among the parameters peculiar to each of these "color-eyes" is what amount of energy need be integrated over what period of time in order to produce a given magnitude of sensation. As a consequence, certain colors can "disappear" at quite brief exposure durations, while other colors may be still apparent. In certain experimental cases, such a disappearance can provide a troublesome artifact. Witness Fig. 3-23.

Note the extremely high value of d' for yellow at the briefest of the exposure durations. More importantly note that the recognizability of yellow apparently declines with more prolonged

TABLE 3-14. Color, 4 exposures - .030, .025, .020, .015 seconds.

Red	.030	Blue	.030	Yellow	.030	Green	.030
.517	.028	.022	.022	.225	.024	.120	.052
.724	.065	.130	.143	.350	.037	.280	.110
.862	.065	.348	.154	.600	.055	.400	.162
.931	.083	.587	.209	.925	.073	.550	.165
.931	.290	.739	.308	.950	.250	.660	.377
.931	.564	.848	.440	1.00	.500	.820	.597
1.00	.850	.957	.692	1.00	.799	.940	.812
d'	= 2.84	d'	= 1.03	d'	= 2.85	d'	= 1.10

Red	.025	Blue	.025	Yellow	.025	Green	.025
.318	.006	.022	.010	.029	.009	.000	.009
.500	.019	.089	.095	.088	.051	.258	.038
.636	.050	.289	.200	.265	.154	.323	.085
.772	.056	.533	.286	.382	.231	.355	.181
.818	.288	.533	.495	.588	.487	.548	.321
.909	.544	.667	.705	.735	.735	.581	.509
1.00	.806	.833	.867	.921	.889	.935	.717
d'	= 2.33	d'	= 0.64	d'	= 0.44	d'	= 0.54

Red	.020	Blue	.020	Yellow	.020	Green	.020
.118	.018	.025	.015	.152	.088	.029	.009
.206	.069	.187	.073	.212	.124	.088	.051
.294	.112	.375	.161	.303	.150	.265	.154
.421	.190	.425	.234	.394	.186	.382	.231
.559	.387	.525	.482	.667	.416	.588	.487
.794	.673	.700	.591	.788	.735	.735	.734
.912	.871	.850	.781	.967	.929	.912	.889
d'	= 0.68	d'	= 0.53	d'	= 0.63	d'	= 0.44

Red	.015	Blue	.015	Yellow	.015	Green	.015
.156	.031	.000	.019	.379	.000	.000	.009
.188	.093	.109	.075	.621	.000	.079	.045
.406	.116	.236	.104	.793	.000	.184	.134
.438	.240	.400	.311	.931	.009	.263	.205
.594	.535	.618	.472	.966	.200	.447	.420
.875	.791	.782	.783	.966	.463	.737	.625
.938	.946	.909	.896	1.00	.806	.947	.813
d'	= 0.55	d'	= 0.25	d'	= 3.79	d'	= 0.17

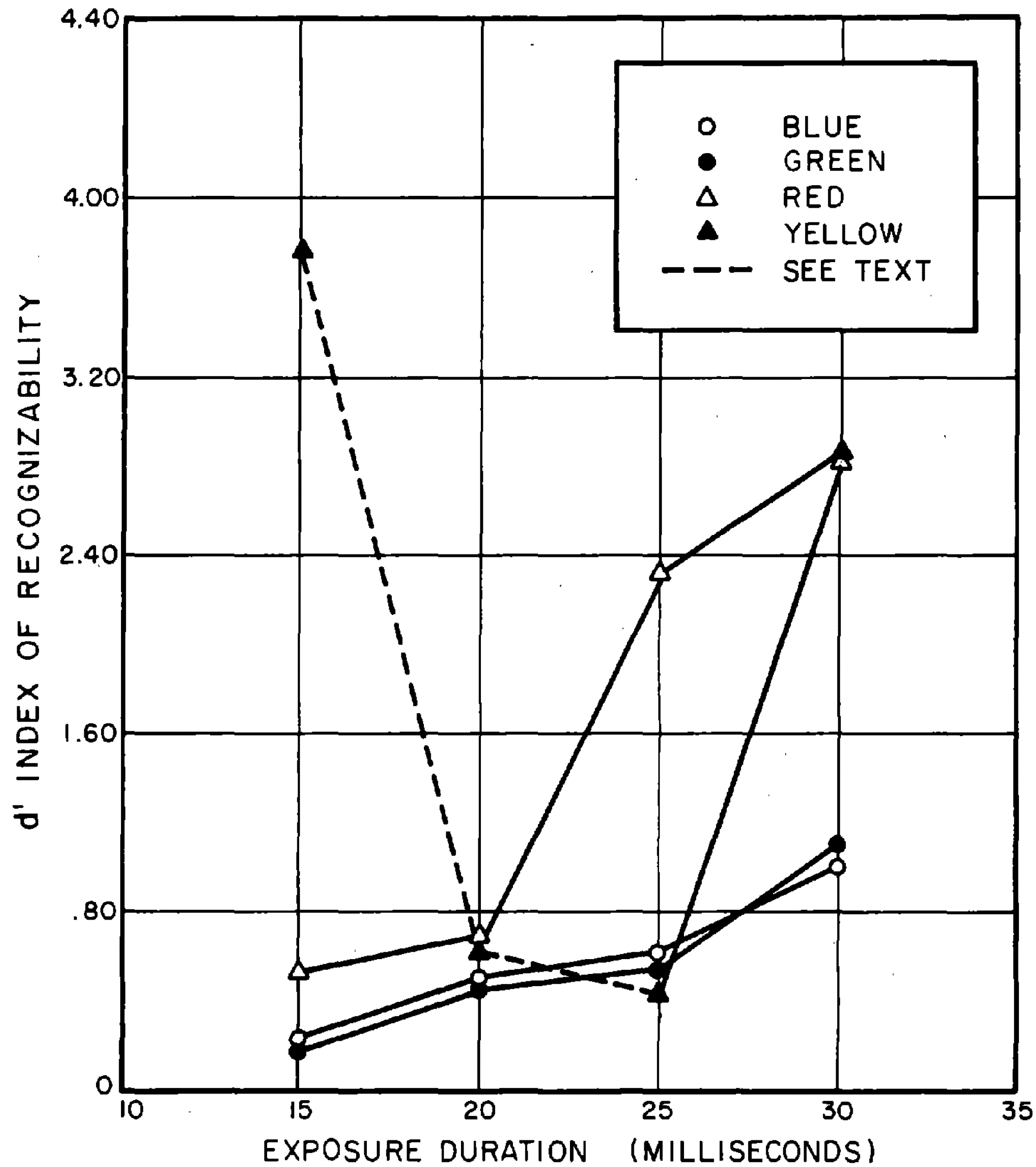


FIG.3-23 d' AS A FUNCTION OF EXPOSURE DURATION FOR COLOR JUDGMENTS.

exposure durations, the decline being denoted by the dashed line. In order to understand so curious a result, recall that the experimental usage of recognizability means recognizability from among a finite set of alternatives. In this case the set is quite small – four colors – and there are truly three and not four completely independent pieces of data. A most pertinent example will make this clear.

Suppose red, blue, and green shapes such as ours all disappear completely at exposure durations of, say, 15 milliseconds. Then, if an observer "sees" anything, he can with assurance call it "yellow." Seeing nothing, an observer must choose virtually at random among the alternatives red, green, and blue. Thus they will be unrecognizable one from the other, and distinct only from yellow. On the other hand, yellow will be highly recognizable.

Alternatively, suppose it is the yellow stimuli only that disappear at the briefest exposure durations. Yellow would still appear highly recognizable – an artifact – inasmuch as an observer can respond "yellow" with assurance when he "sees" nothing. The other three stimuli colors, red, green, and blue will be only slightly recognizable one from the other (as befits a fifteen-millisecond exposure), but, of course, quite distinct from yellow.

Of the two alternative hypotheses, we favor the latter. First of all it is *a priori* more likely. The experiment did use pre- and post-stimulus masking fields of higher energy than the stimulus. Then, too, the background, which while neutral in hue, was on the lightish side, provided slightly less apparent contrast with the yellow stimuli as opposed to the others. Finally, both the subjects and the experimenter reported precisely such a phenomenon – a quarter of the stimuli "disappearing" at the briefest duration. The experimenter could, of course, verify that the disappearances were of yellow stimuli. And while we would be among the last to place unswerving faith in such subjective reports, it would be gratuitous to overlook them, particularly in the absence of other evidence.

It must be pointed out that this finding bears on the data in this section and does not alter the results or conclusions of the previous experiment on colored shapes, where the recognition of shape only was at issue. While seeing "no shape," the data tell a lot about the color; it tells naught about the shape.

Recognizing the spurious nature of the datum for yellow at a 15-millisecond duration, as shown on Fig. 3-23, it is apparent that of the set, the red of our stimuli was the most distinct color and required the briefest exposure duration for processing. Yellow, too, is quite distinct (considering only the unbroken portion of the curve), but requires several more milliseconds' exposure. Blue and green are less distinct, being reasonably confusable, one with the other. It did not appear efficient at the time to run a more extended range of exposure durations. Indeed, if one were limited to four, a more judicious choice could hardly have been made. Shorter exposure durations might have allowed one to intuit which color "disappears" next. Longer durations would allow one to watch the growth in distinctiveness of green and blue. Forced to speculate about the true nature of the curves, one can hypothesize those shown in Fig. 3-24 below.

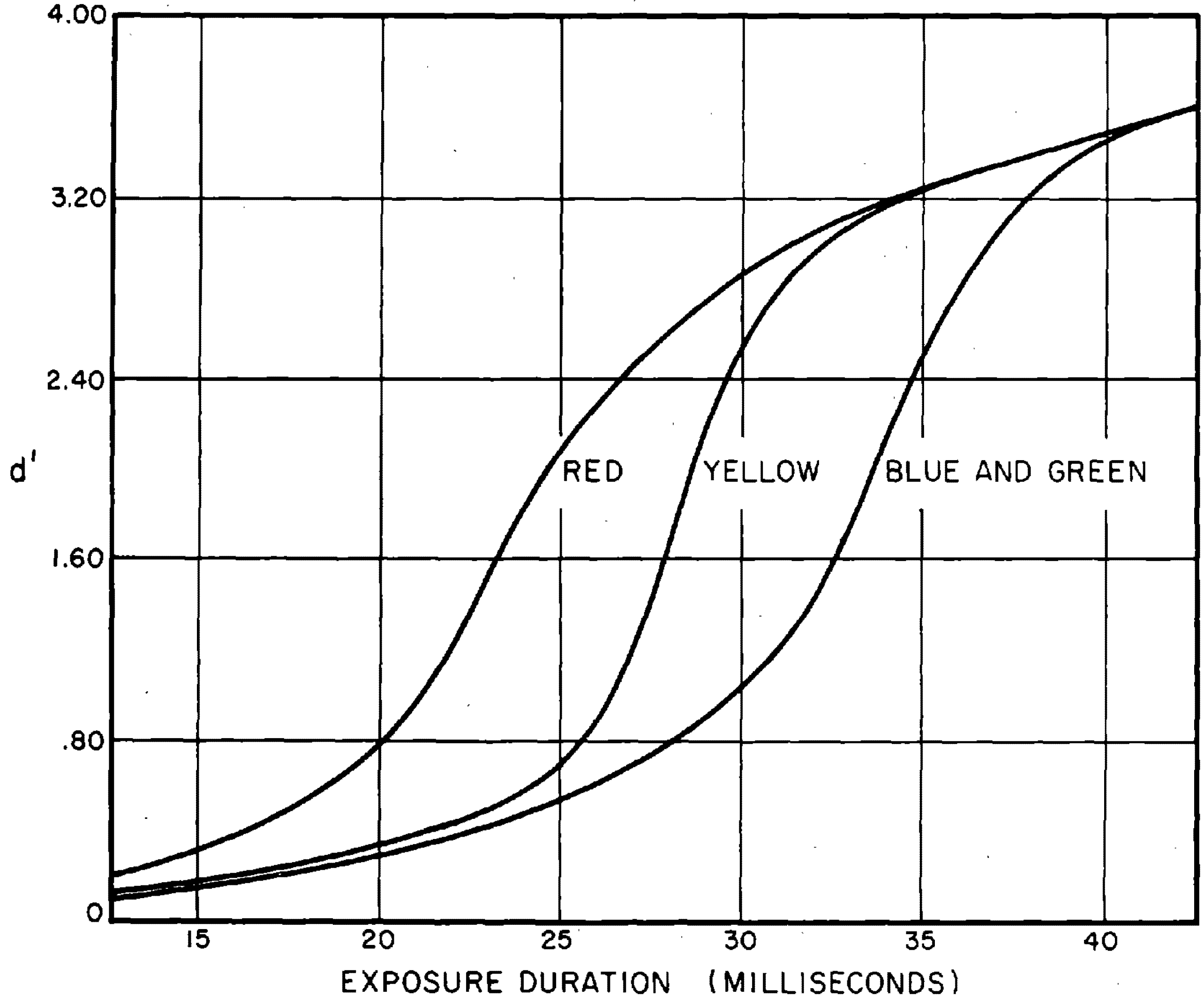


FIG.3-24 HYPOTHETICAL BEHAVIOR OF COLOR JUDGMENT.

3.8.3 Recognizing both shape and color

Method

Again, ten shapes were used as in the previous two experiments, as was an almost identical procedure. The number of observers was increased, from nine to twelve, and each served for fifteen daily sessions. As before, each session lasted two hours during which time an observer was presented tachistoscopically with one-hundred-and-twenty stimuli in four groups of 30 apiece. Each group was shown at a different exposure duration, .030, .025, .020, and .015 seconds, the slowest presentation at the beginning of the session, and the briefest last. Each group of thirty contained randomly selected colored shapes, the colors being red, yellow, blue, and green. As in previous experiments each stimulus presentation was both preceded and followed in time by masking fields, visual noise of slightly higher energy. The visual noise was whites and grays, and thus achromatic, or fairly uniformly distributed over the visual spectrum, as you will.

In this experiment, however, observers were required to respond by giving the most likely shape, and color, as opposed to just one, or the other as in the two preceding experiments. Numerical ratings of confidence, on a four-point scale, were also solicited from the observers.

Results

The data from this series of experiments were analyzed as in all previous experiments. These data are given in Table 3-15 below broken down according to both shape and color, but pooled over observers and exposure durations. Values of d' are given in Table 3-15 as well.

TABLE 3-15. Color and Shape, all four exposures.

SHAPE #2 CIRCLE

2.	Red	2.	Blue	2.	Green	2.	Yellow
.071	.000	.036	.000	.000	.000	.000	.000
.214	.002	.316	.012	.214	.003	.050	.000
.286	.006	.316	.025	.214	.012	.050	.002
.286	.011	.368	.037	.214	.021	.050	.005
.286	.311	.368	.333	.214	.317	.050	.309
.429	.632	.421	.655	.571	.631	.100	.639
.500	.994	.605	.991	.929	.983	.450	.998
d'	= 1.75	d'	= 1.46	d'	= 1.26	d'	= 0.68

Shape #3 Square

3.	Red	3.	Blue	3.	Green	3.	Yellow
.143	.000	.000	.000	.000	.000	.000	.000
.571	.001	.273	.011	.176	.005	.063	.003
.714	.004	.333	.023	.235	.012	.063	.010
.714	.006	.333	.028	.235	.012	.125	.010
.714	.306	.333	.337	.235	.318	.125	.311
1.00	.626	.424	.657	.706	.629	.188	.634
1.00	.984	1.00	.997	1.00	.982	.375	.997
d'	= 2.90	d'	= 1.45	d'	= 1.60	d'	= 1.16

Shape #4 Triangle

4.	Red	4.	Blue	4.	Green	4.	Yellow
.000	.000	.000	.001	.000	.006	.000	.000
.267	.005	.295	.022	.214	.008	.000	.000
.267	.011	.364	.030	.286	.017	.143	.004
.267	.018	.386	.038	.286	.024	.286	.016
.267	.316	.386	.347	.286	.321	.286	.305
.533	.635	.568	.668	1.00	.626	.286	.626
.800	.986	.818	.995	1.00	.983	.571	.987
d'	= 1.47	d'	= 1.48	d'	= 1.38	d'	= 1.61

TABLE 3-15 (continued)

Shape #5 Diamond

5.	Red	5.	Blue	5.	Green	5.	Yellow
.000	.000	.000	.000	.000	.001	.000	.000
.100	.002	.286	.006	.287	.007	.000	.002
.100	.005	.286	.009	.287	.019	.000	.004
.100	.009	.286	.016	.287	.022	.144	.015
.200	.158	.286	.315	.287	.319	.144	.305
.550	.630	.524	.643	.857	.630	.144	.629
.800	.989	.810	.988	1.00	.984	.570	.987
d'	= 1.04	d'	= 1.61	d'	= 1.48	d'	= 1.12

Shape #6 Bar

6.	Red	6.	Blue	6.	Green	6.	Yellow
.000	.000	.000	.000	.000	.000	.000	.000
.556	.007	.286	.005	.445	.000	.000	.000
.667	.010	.457	.008	.667	.004	.000	.002
.889	.013	.486	.011	.667	.012	.286	.012
.889	.310	.486	.321	.667	.317	.286	.301
1.00	.632	.486	.648	1.00	.628	.286	.626
1.00	.982	.686	.998	1.00	.984	.429	.988
d'	= 3.46	d'	= 2.27	d'	= 2.71	d'	= 1.72

Shape #8 Pentagon

8.	Red	8.	Blue	8.	Green	8.	Yellow
.100	.001	.026	.000	.000	.000	.000	.000
.600	.004	.308	.008	.000	.001	.000	.001
.600	.007	.333	.017	.000	.009	.000	.004
.600	.013	.385	.025	.167	.018	.143	.012
.600	.311	.410	.329	.167	.309	.143	.305
.700	.635	.615	.640	.667	.623	.143	.629
.700	.980	.795	.995	1.00	.982	.714	.991
d'	= 2.49	d'	= 1.67	d'	= 1.15	d'	= 1.22

TABLE 3-15 (continued)

Shape #9 Octagon

9.	Red	9.	Blue	9.	Green	9.	Yellow
.000	.001	.000	.000	.000	.000	.000	.000
.400	.004	.063	.008	.267	.006	.000	.001
.600	.007	.188	.020	.400	.009	.000	.004
.800	.013	.188	.023	.467	.010	.143	.012
.800	.312	.250	.323	.467	.312	.143	.305
.900	.630	.438	.637	.667	.631	.143	.629
.900	.987	.813	.986	.933	.984	.714	.985
d'	= 3.07	d'	= 1.12	d'	= 2.24	d'	= 1.20

Shape #10 Hexagon

10.	Red	10.	Blue	10.	Green	10.	Yellow
. 43	.000	.000	.000	.000	.000	.000	.000
.286	.004	.072	.003	.143	.004	.000	.000
.286	.007	.143	.012	.143	.010	.000	.005
.286	.009	.179	.014	.143	.013	.072	.012
.286	.309	.197	.322	.143	.312	.072	.308
.714	.629	.321	.644	.571	.629	.072	.944
.857	.985	.643	.997	1.00	.982	.214	.999
d'	= 1.75	d'	= 1.26	d'	= 1.17	d'	= 0.81

Shape #11 Trapezoid

11.	Red	11.	Blue	11.	Green	11.	Yellow
.067	.000	.000	.000	.000	.000	.000	.000
.133	.000	.071	.005	.071	.006	.000	.000
.200	.011	.250	.014	.421	.020	.063	.008
.200	.024	.250	.025	.421	.035	.125	.030
.200	.316	.250	.324	.421	.324	.125	.312
.333	.632	.429	.640	.500	.632	.188	.633
.867	.986	.750	.992	.786	.986	.313	.999
d'	= 1.16	d'	= 1.29	d'	= 1.61	d'	= 0.73

Shape #12 Pennant

12.	Red	12.	Blue	12.	Green	12.	Yellow
.000	.000	.000	.000	.000	.000	.000	.000
.067	.003	.424	.011	.000	.001	.143	.001
.200	.003	.515	.017	.000	.003	.143	.019
.267	.009	.515	.019	.125	.014	.143	.303
.333	.305	.515	.331	.125	.308	.571	.625
.467	.630	.667	.652	.875	.630	.571	.625
.933	.983	.848	.989	1.00	.982	.714	.985
d'	= 1.70	d'	= 2.10	d'	= 1.09	d'	= 0.56

Because the data must be broken down according to both dimensions, thus yielding a matrix composed of forty cells, an individual cell contains rather less data than would be liked. For this reason, as well as for economy of space, the forty operating characteristics are not displayed.

Discussion

Out of respect for the variability inherent in these data all shape-color combinations have been broken into three groups, the best, the worst, and the in-between. d' values of 1.00 and 2.00 serve as convenient cut-points.

Most distinct colored shapes are:

RED	BLUE	GREEN
Bar	Bar	Bar
Octagon	Pennant	Octagon
Square		
Pentagon		

Least distinct colored shapes are:

YELLOW
Hexagon
Trapezoid
Circle
Pennant

Recall the words of caution in the discussion of the results of the previous experiment (Sec. 3.8.2), with respect to color data obtained under very brief visual exposures.

If we are correct in our hypothesized color recognition functions (for our stimuli) shown in Fig. 3-24, then it is only at the longest exposure duration, thirty milliseconds, where errors due to color are not unduly emphasized. For this reason the data from thirty- and twenty-five-millisecond exposures, has been broken out separately. These data are given in Tables 3-16 and 3-17.

As can be seen from the data broken down according to exposure duration, different length exposures impose different weights on the relative effect of errors due to shape confusion and errors due to color confusions. Recall that observers had to identify both shape and color. An obvious way to ease the dilemma is, of course, to utilize color coding and shape coding redundantly rather than as independent coding dimensions. In the probable eventuality that this is too restrictive, they can be used as intelligently correlated dimensions; using a red triangle, octagone, and circle for yield, stop, and do not enter; for example.

3.9 Guide Signs

It seems that most proposals for change and improvement in uniform traffic control devices treat things other than directional signing. Yet, perhaps, a majority of incidents, provocative of complaint by the driving public about signing practice, deal with guide, or directional, signing. The majority of such complaints refer to the information such signing might convey. Particularly appropriate to guide signs are the previously discussed three categories: misinformation, missing information, and inextractable information.

This is not to say that strides have not been taken toward alleviating certain of the problems associated with guide signs. The need for larger signs to be read at greater distances to allow for adequate processing at today's higher speed has been

TABLE 3-16.

RED 30 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.257	.021	.160	.009	.163	.000	.149	.000	.197	.000
.543	.030	.272	.019	.293	.002	.270	.011	.344	.012
.667	.041	.415	.020	.350	.015	.303	.015	.590	.019
.729	.045	.696	.027	.564	.026	.510	.027	.704	.025
.826	.391	.896	.563	.878	.753	.788	.815	.793	.750
.930	.564	.989	.649	.900	.890	.943	.892	.897	.889
.959	.825	.998	.917	.973	.940	.998	.956	.941	.915
d'	= 2.25	d'	= 2.40	d'	= 2.03	d'	= 1.90	d'	= 2.40

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.151	.002	.142	.002	.144	.000	.172	.000	.260	.000
.283	.019	.296	.017	.260	.010	.290	.000	.397	.011
.405	.022	.393	.019	.400	.016	.336	.010	.596	.022
.566	.037	.601	.036	.575	.029	.507	.014	.736	.036
.729	.556	.741	.869	.778	.700	.890	.756	.838	.777
.881	.789	.895	.884	.833	.739	.955	.880	.973	.840
.929	.921	.975	.956	.977	.899	.983	.956	.980	.899
d'	= 1.93	d'	= 2.00	d'	= 2.08	d	= 2.08	d'	= 2.39

TABLE 3-16 (continued)

YELLOW 30 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.130	.000	.188	.000	.171	.000	.133	.000	.178	.000
.196	.000	.209	.009	.260	.000	.170	.008	.219	.009
.293	.002	.299	.017	.293	.009	.218	.011	.316	.015
.462	.031	.533	.025	.379	.019	.490	.027	.622	.039
.866	.509	.826	.489	.877	.600	.890	.472	.790	.555
.941	.822	.953	.671	.960	.872	.977	.780	.883	.750
.968	.913	.966	.890	.981	.933	.989	.853	.980	.900
d'	= 1.78	d'	= 1.96	d'	= 1.74	d'	= 1.86	d'	= 2.06

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.150	.000	.135	.000	.156	.000	.160	.000	.173	.000
.228	.000	.160	.009	.199	.000	.211	.002	.222	.010
.444	.015	.283	.020	.293	.021	.377	.025	.389	.022
.550	.037	.490	.035	.560	.036	.576	.050	.611	.036
.818	.616	.816	.577	.807	.609	.710	.577	.853	.588
.875	.779	.940	.868	.966	.889	.856	.725	.893	.740
.970	.884	.987	.940	.975	.971	.956	.909	.970	.898
d'	= 1.88	d'	= 1.72	d'	= 1.90	d'	= 1.84	d'	= 2.03

TABLE 3-16 (continued)

BLUE 30 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.150	.000	.170	.000	.139	.000	.143	.001	.173	.000
.211	.005	.281	.008	.271	.019	.206	.005	.193	.008
.363	.009	.373	.015	.361	.026	.350	.020	.244	.018
.410	.027	.500	.028	.483	.047	.473	.027	.516	.028
.880	.773	.861	.740	.840	.787	.810	.811	.832	.757
.960	.798	.937	.838	.898	.878	.973	.898	.951	.828
.990	.935	1.00	.970	.934	.909	.993	.980	.978	.963
d'	= 1.65	d'	= 1.88	d'	= 1.59	d'	= 1.80	d'	= 1.93

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.155	.001	.160	.002	.173	.000	.161	.000	.171	.000
.197	.012	.210	.013	.191	.010	.210	.015	.380	009
.297	.030	.310	.022	.243	.029	.333	.052	.463	.022
.566	.045	.490	.047	.556	.045	.555	.066	.569	.041
.817	.770	.893	.775	.787	.789	.898	.709	.715	.680
.960	.809	.970	.811	.961	.829	.970	.852	.860	.792
.948	.958	.992	.914	.990	.934	.988	.920	.933	.915
d'	= 1.82	d'	= 1.62	d'	= 1.79	d'	= 1.62	d'	= 1.93

TABLE 3-16 (continued)

GREEN 30 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.143	.000	.166	.001	.159	.010	.160	.000	.163	.000
.270	.012	.289	.013	.191	.019	.270	.019	.250	.000
.304	.027	.415	.028	.288	.029	.361	.027	.340	.017
.440	.039	.516	.037	.468	.047	.560	.036	.522	.026
.820	.737	.818	.761	.898	.795	.747	.795	.786	.817
.990	.818	.940	.888	.955	.837	.856	.887	.853	.889
.998	.908	.963	.919	.989	.950	.937	.933	.960	.931
d' = 1.60		d' = 1.80		d' = 1.56		d' = 1.90		d' = 1.93	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.141	.019	.129	.001	.159	.002	.160	.001	.142	.000
.204	.025	.133	.010	.170	.012	.190	.009	.195	.002
.279	.036	.241	.026	.259	.030	.255	.015	.360	.021
.600	.050	.409	.036	.488	.036	.444	.035	.475	.029
.718	.703	.898	.813	.700	.793	.789	.773	.817	.826
.850	.875	.963	.970	.850	.889	.889	.818	.930	.900
.920	.909	.990	.989	.988	.977	.933	.908	.986	.925
d' = 1.90		d' = 1.52		d' = 1.72		d' = 1.60		d' = 1.83	

TABLE 3-17

RED 25 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.184	.010	.190	.011	.180	.009	.188	.008	.194	.005
.224	.022	.272	.036	.292	.020	.240	.023	.388	.009
.380	.033	.427	.044	.350	.036	.374	.033	.454	.024
.520	.041	.626	.049	.450	.040	.398	.042	.580	.039
.795	.515	.700	.590	.800	.535	.808	.575	.719	.600
.880	.738	.853	.818	.833	.674	.970	.838	.820	.795
.980	.797	.977	.889	.989	.780	.998	.927	.033	.885
d' = 1.80		d' = 1.97		d' = 1.62		d' = 1.50		d' = 1.95	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.135	.020	.131	.007	.216	.009	.132	.011	.277	.002
.264	.028	.264	.011	.333	.012	.297	.025	.388	.005
.380	.035	.388	.027	.390	.028	.336	.035	.420	.010
.482	.045	.444	.038	.464	.037	.475	.045	.498	.025
.825	.599	.775	.603	.733	.666	.698	.708	.600	.630
.920	.680	.844	.721	.821	.722	.834	.811	.478	.777
.993	.822	.967	.831	.955	.853	.978	.878	.944	.933
d' = 1.59		d' = 1.60		d' = 1.65		d' = 1.59		d' = 1.88	

TABLE 3-17 (continued)

YELLOW 25 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.146	.002	.145	.002	.115	.002	.125	.009	.186	.010
.197	.020	.199	.009	.150	.009	.170	.025	.286	.012
.253	.033	.266	.016	.222	.022	.230	.029	.379	.022
.366	.039	.332	.027	.267	.030	.278	.034	.419	.040
.866	.575	.900	.496	.970	.500	.866	.601	.808	.667
.919	.710	.989	.700	1.00	.628	.988	.799	.890	.808
1.00	.830	.960	.737	1.00	.938	.997	.898	.986	.889
d'	= 1.42	d'	= 1.44	d'	= 1.27	d'	= 1.30	d'	= 1.55

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.129	.002	.118	.005	.148	.004	.127	.005	.177	.009
.258	.020	.176	.011	.192	.006	.186	.007	.209	.011
.284	.033	.259	.030	.242	.017	.221	.017	.277	.015
.355	.039	.294	.035	.275	.025	.256	.029	.360	.026
.888	.616	.912	.530	.747	.437	.863	.570	.579	.710
.919	.830	.976	.667	.852	.700	.917	.614	.785	.793
.990	.870	1.00	.919	.934	.844	.966	.847	.936	.860
d'	= 1.39	d'	= 1.20	d'	= 1.30	d'	= 1.24	d'	= 1.52

TABLE 3-17 (continued)

BLUE 25 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.150	.014	.189	.010	.111	.001	.116	.010	.192	.011
.222	.022	.235	.015	.130	.003	.135	.020	.256	.023
.267	.030	.307	.027	.211	.015	.227	.029	.321	.039
.333	.040	.350	.045	.233	.027	.300	.045	.359	.048
.880	.555	.877	.633	.985	.611	.850	.616	.833	.619
.935	.800	.980	.715	.997	.833	.950	.777	.923	.723
.990	.872	.989	.770	1.00	.920	.983	.889	.962	.911
d' = 1.31		d' = 1.26		d' = 1.14		d' = 1.12		d' = 1.28	

Pentagon		Octagon		Hexagon		Trapezoid		Pennant	
.121	.010	.117	.003	.019	.002	.129	.007	.175	.005
.199	.013	.170	.013	.157	.005	.170	.011	.196	.007
.301	.025	.186	.027	.196	.008	.260	.023	.217	.019
.349	.046	.271	.040	.239	.024	.277	.041	.290	.025
.843	.633	.938	.515	.696	.407	.819	.615	.616	.653
.904	.797	.960	.680	.796	.733	.909	.711	.700	.740
.964	.883	.994	.877	.930	.875	.956	.822	.909	.819
d' = 1.26		d' = 1.14		d' = 1.18		d' = 1.17		d' = 1.32	

TABLE 3-17 (continued)

GREEN 25 MILLISECONDS

Circle		Square		Triangle		Diamond		Bar	
.141	.009	.181	.009	.122	.002	.120	.008	.191	.009
.200	.015	.204	.011	.134	.005	.142	.015	.293	.016
.273	.031	.260	.035	.215	.010	.155	.023	.319	.026
.309	.042	.293	.044	.240	.025	.265	.037	.346	.045
.960	.490	.936	.606	.978	.610	.936	.625	.828	.620
.985	.676	.988	.711	.980	.799	.960	.709	.955	.737
1.00	.920	1.00	.854	.993	.909	.988	.775	.994	.929
d'	= 1.24	d'	= 1.20	d'	= 1.18	d'	= 1.14	d'	= 1.26

Pentagon		Octagon		Hexagon		Diamond		Pennant	
.140	.008	.112	.011	.117	.003	.109	.003	.160	.002
.180	.011	.185	.020	.181	.004	.133	.005	.191	.005
.264	.020	.225	.036	.240	.010	.205	.015	.220	.010
.299	.036	.253	.044	.253	.032	.236	.026	.267	.025
.862	.613	.843	.636	.602	.387	.880	.610	.705	.633
.928	.785	.955	.717	.791	.740	.950	.770	.855	.716
.958	.900	.978	.914	.860	.850	.995	.815	.933	.889
d'	= 1.22	d'	= 1.08	d'	= 1.20	d'	= 1.18	d'	= 1.27

recognized. The drawbacks of having successive signs referring to the same choice point be orthogonal in meaning to one another, rather than confirming of what the driver has abstracted from the previous ones, have likewise been recognized. The need for information sufficiently in advance of the choice point has been underscored, and a system such as that used on our westernmost freeways – always giving, in order of appearance, the destinations of the next three exits – appears as a considerable improvement. Finally, well motivated authorities have decided that no more than three (or four) destination names may appear on the same guide sign. The arguments underlying such a limitation are that too many destination names make a sign too hard to read...too confusing...too lengthy to read in the short period of time safely allowable. While not about to dispute such claims, we might suggest that not everyone "reads" a sign – certainly not everyone "reads" it in the same way. Not everyone reads a guide sign in the same way because not everyone has the same goal. The variety of goals leads to a variety of strategies, at least two of which are of interest here. To give them names, we designate one strategy as "searching," the other as "discovering."

"Search," as used here, refers to a situation where an observer, approaching a choice point, has a well defined destination and he fully expects to find the name of that destination on the sign. The observer has, moreover, a good guess as to what alternatives of the choice point are (e.g., straight ahead, right or left). His job, then, is to search through the words on the guide sign until he comes to the one he is looking for and find the direction associated with it.

Discovery, as we use it here, applies when the observer either has no well defined destination, or does not expect to find his destination on the sign. He, too, we shall assume, can guess some things about the choice point. Yet his task is quite different. He must discover which destination names go with which directions, and then, finding the named destination most properly related to his destination, he will know in which direction to proceed.

Restricting the number of place names a guide sign can contain is of benefit to those employing a "discover" strategy. The restriction is quite possibly detrimental to those who would "search." To give a compelling illustration, suppose that an observer approaches a guide searching for a particular destination name. If his target is one that has been left off in compliance with a number restriction, his search must terminate unsuccessfully. He must then search for an alternate, or change to a "discover" strategy.

There is not sufficient information at the moment to decide to which strategy one should cater. Perhaps a compromise is indicated — not simply adding a few more destination names, and making neither strategy workable, but by giving primary, and secondary information, identifiable as such. If these were to go on separate signs, note that the secondary information must appear first, according to the analysis above.

A discussion of such strategies, however meaningful it might be to changes in guide signs, was introduced to explain why two different series of guide sign experiments were conducted. In all cases, the stimuli were identical, consisting of three destination names, permuted randomly in both order and direction. In one case, however, observers were required to give the direction corresponding to a given destination. In the other case, observers gave the destination which lay in a particular direction.

3.9.1 Searching for a destination

Method

The stimuli used in this series of experiments consisted of a set of guide signs containing three destination names — Salem, Dayton and Richmond — one presumed lying to the right, one to the left, and one straight ahead. Each of the destination names could occur in any one of the three positions on the sign (top, middle or bottom) and be associated with any one of the three directions of travel (right, left or straight ahead). The arrows representing the direction of travel could be either all to the left of the destination names, all to the right, or staggered; in the first two cases, the names were left justified. Finally, a sign could be either positive (black legend on a white surround) or negative (white legend on a black surround). All possible combinations of these variables were used. Representative selections of the signs are reproduced in Fig. 3-25 below.

Twenty-one observers were tested for approximately seven days, which included a day or two of practice inasmuch as a range of exposure durations different from previous experiments had to be selected. The exposure durations selected were 0.075, 0.080 and 0.090 seconds. These durations were considerably longer than those required in previous experiments, as you might

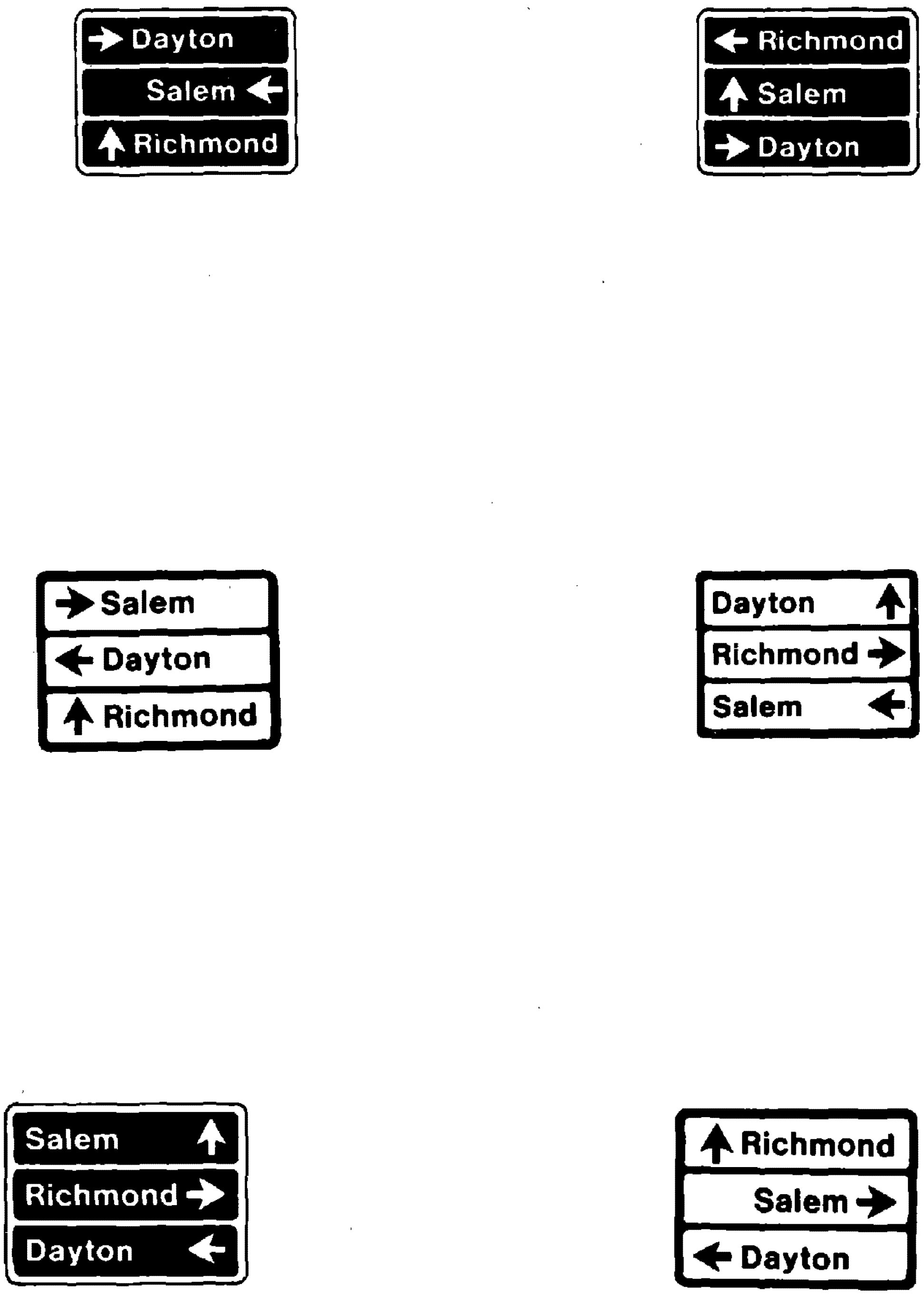


FIG. 3-25 SOME SPECIMEN GUIDE SIGNS USED IN EXPERIMENT.

expect. Even then, the data from the 75-millisecond exposure were not utilized because the duration was insufficient.

Daily sessions lasted for two hours, during which time an observer was exposed to a random selection of 90 of the stimuli presented tachistoscopically, 30 at each of the three exposure durations. On each trial, observers were required to give the direction of travel associated with a particular destination name. The particular destination name was changed for each block of ten trials. In addition to responding with the direction of travel associated with a particular place name, observers were also required to assign a numerical rating of confidence to their answers. As in previous experiments a four-point scale was utilized. Again, as in previous experiments, each stimulus presentation was both preceded and followed in time by masking fields of visual noise.

Results

Because of the insufficiency of the 75-millisecond exposure duration, the data from these presentations are not included. The remaining data were treated in accord with the principles set forward in Sec. 3.3 above.

The data were first analyzed to look at the effect of arrow placement. Table 3-18 shows the data broken down according to placement of the directional arrows, and pooled over observers and each of the other variables. Values of d' are given in the table. The data are plotted in Fig. 3-26 below. As can be seen from both the table and the figure, arrow placement to the right of the destination name is inferior to placement to the left, or staggered — these last two leading to about equal performance.

TABLE 3-18. Guide Signing — "Search"

Arrows to RIGHT of Destination Name		Arrows to LEFT of Destination Name		Arrows STAGGERED	
.002	.003	.019	.005	.011	.006
.051	.041	.088	.031	.097	.046
.144	.106	.196	.089	.203	.105
.247	.183	.303	.160	.318	.173
.372	.283	.429	.249	.445	.264
.544	.459	.598	.423	.597	.403
.770	.725	.796	.695	.795	.690
d' =	0.24	d' =	0.46	d' =	0.48

To follow up the previous findings regarding the superiority of positive (black legend on a white surround) as opposed to negative images, the data were broken down according to positive or negative presentations, pooled over other variables. These data are presented in Table 3-19 below and plotted in Fig. 3-27. Value of d' abstracted from these data are also given in the table. As is obvious from both the table and the figures, processing of information is superior when the legend is positive as opposed to negative.

One can also investigate which position on the sign is most easily and efficiently processed in a brief visual exposure. Table 3-20 presents data bearing on this question. The data are broken down according to position — top, middle and bottom — and pooled over the other variables. These data are plotted in Fig. 3-28 below. As can be seen in both the table and the figure, the middle position led to the best performance.

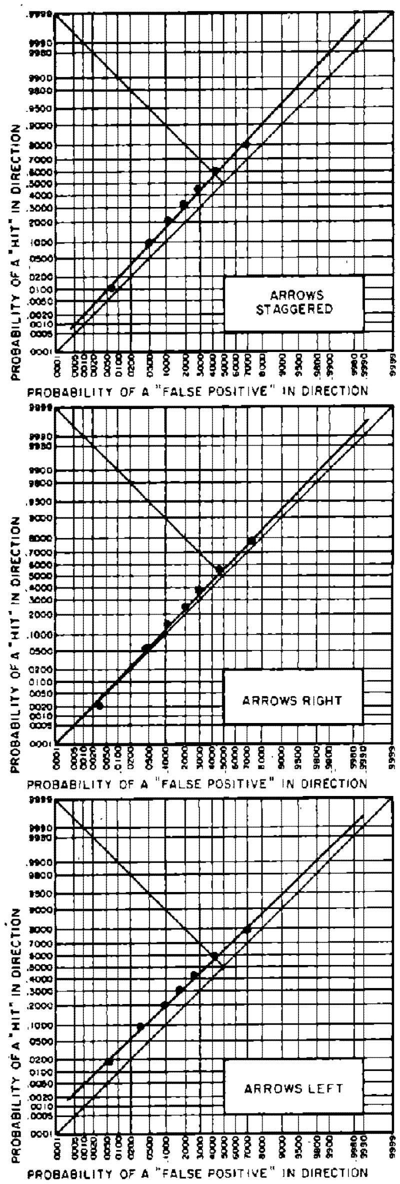


FIG. 3-26 OPERATING CHARACTERISTICS — GUIDE SIGNING, "SEARCH".
DATA FROM TABLE 3-18

TABLE 3-19. Guide Signing - "Search"
Comparison of Negative and Positive Images

Light on Dark (Negative)		Dark on Light (Positive)	
.102	.029	.241	.008
.452	.144	.571	.078
.599	.221	.705	.102
.605	.227	.719	.109
.616	.236	.737	.125
.768	.463	.804	.328
.944	.868	.951	.758
d' = 1.02		d' = 1.81	

TABLE 3-20. Guide Signing - "Search"
Legend Position on Sign

Top		Middle		Bottom	
.120	.000	.373	.020	.100	.000
.161	.018	.534	.043	.120	.022
.161	.049	.609	.048	.250	.040
.333	.080	.714	.048	.400	.055
.645	.270	.815	.372	.550	.280
.700	.392	.850	.550	.600	.465
.950	.604	.910	.666	.765	.590
d' =	.96	d' =	2.20	d' =	1.30

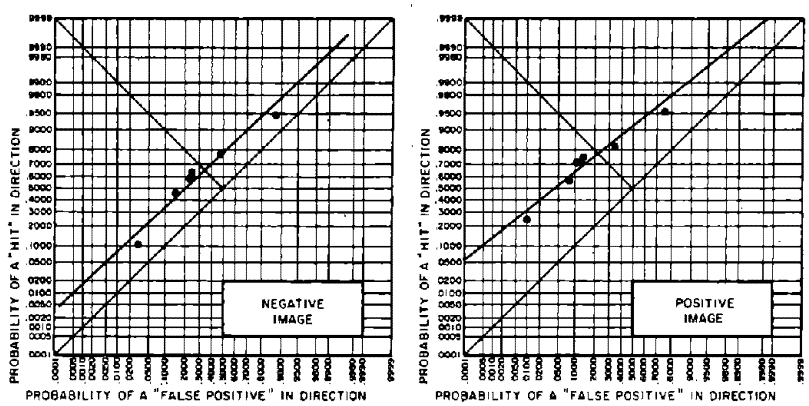


FIG. 3-27 OPERATING CHARACTERISTICS — GUIDE SIGNING, "SEARCH". DATA FROM TABLE 3-19.

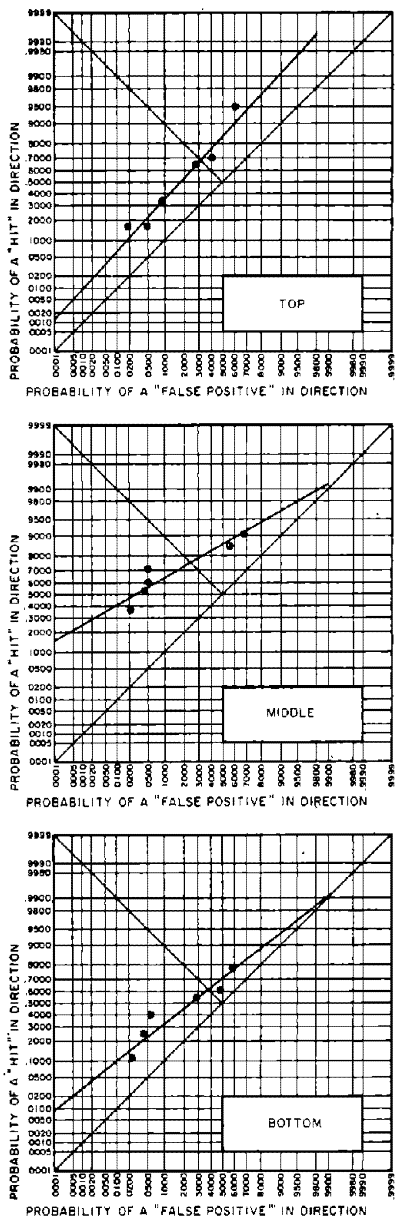


FIG. 3-28 OPERATING CHARACTERISTICS — GUIDE SIGNING, "SEARCH". DATA FROM TABLE 3-20.

A final question is whether a particular direction of travel leads to superior performance. The relevant data are given in Table 3-21 below, and plotted in Fig. 3-29. As can be seen in the figure and table, the straight ahead direction provides the best performance. The data were also broken down according to exposure duration and, as might be expected, the longer duration leads to improved performance.

Discussion

The first thing to be noted is the length of the exposure durations necessary to provide adequate viewing time for this series of tasks. A four- to six-fold increase was necessary, compared with the simple recognition tasks of previous experiments. This important, although not unexpected, finding must be kept in mind in the design and placement of guide signs. Sight distance and size for a given travel speed are, of course, the analogues of our variable of exposure duration and should be adjusted correspondingly as contrasted with the simple warning and regulatory signs. In this connection we should point out that the increase in view time found necessary is, if anything, conservative. In all of these experiments the observers were extremely familiar with the stimulus materials because of the repetition. Such familiarity with particular destination names on a particular guide sign would less likely be on the highway. The more standard warning and regulatory signs would, as in the lab, be relatively familiar.

The individual findings, again not wholly unexpected, can be put to good use on the highway. Left justified names with directional arrows to the right should be avoided in favor of a staggered, or all-left placement.

TABLE 3-21. Guide Signing - "Search"

Direction of Travel

	Right		Left		Straight	
90 MILLISECONDS						
	.014	.000	.050	.000	.200	.000
	.351	.000	.350	.008	.460	.000
	.635	.127	.600	.097	.740	.097
	.730	.164	.683	.121	.820	.112
	.784	.255	.733	.234	.860	.351
	1.00	.591	1.00	.605	.980	.649
	1.00	.882	1.00	.911	1.00	.970
	d' =	1.60	d' =	1.64	d' =	2.14
80 MILLISECONDS						
	.024	.000	.000	.000	.130	.000
	.381	.040	.283	.045	.370	.035
	.524	.189	.457	.170	.609	.198
	.524	.235	.543	.261	.609	.267
	.691	.406	.630	.330	.761	.372
	.952	.615	.957	.614	.935	.674
	1.00	.814	1.00	.930	1.00	.988
	d' =	0.76	d' =	.74	d' =	.89

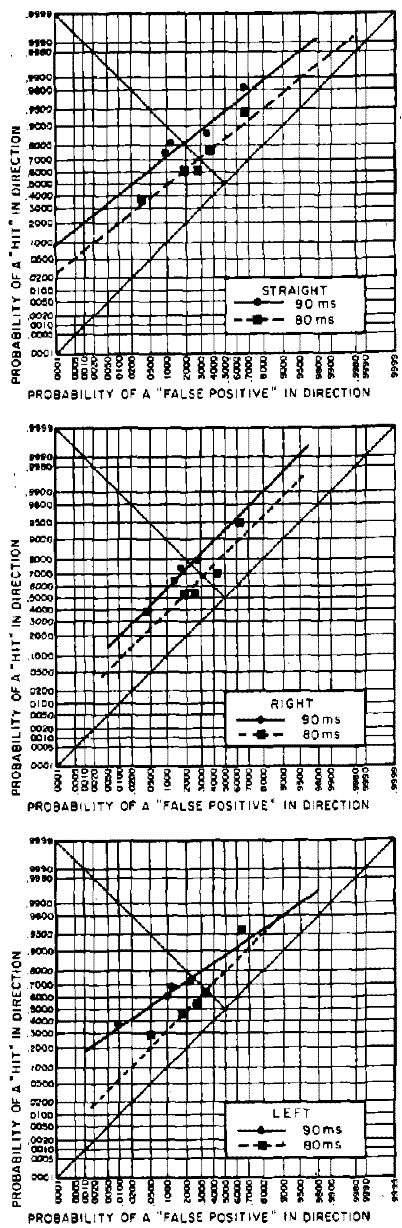


FIG. 3-29 OPERATING CHARACTERISTICS — GUIDE SIGNING, "SEARCH". DATA FROM TABLE 3-21.

The finding that the straight-ahead direction leads to superior performance when compared to left and right arises most probably because in the set of direction there is but one vertical arrow, but two horizontal arrows. One possibility which might be considered is to equalize the three directions by spacing the arrows more uniformly about 360 degrees. Right might then be indicated by 120 degrees (as opposed to 90 degrees), and left by 240 degrees (vs. 270 degrees). Such a solution would, of course, be contra-indicated if the geometrics of a sufficiently large number of choice points actually included such sharp right and left-hand alternatives.

With regard to which of the three positions (top, middle and bottom) provides the best information, our finding of the superiority of the middle position may reflect either the effect of the overall display, or, simply the effects of eye position. To implement such a finding on the highway would entail placing the most frequently sought, or the most troublesome, destination in the middle. This would be in conflict with standards making position redundant with direction. This study did not identify the tradeoffs involved, and so must remain silent on this question.

The finding that improved performance results from a positive (dark message on a light background) as opposed to a negative (light message on a dark background) presentation is consistent with ours, and others' findings. For other reasons, guide signs are now specified to be white messages on a green field — negative. According to this study's equating of view time in the experiments with sight distance and size, these parameters should be adjusted accordingly. Said another way, relevant to a question raised in revising the *Manual on Uniform Traffic Control Devices*, "small" guide signs would be better executed in black on white.

One further point should be made at this time, which concerns the population of observers used in our experiments. Many of our experiments used brighter than average subjects — college students or college-bound high-school students. In previous experiments on simple recognition tasks this was felt to be of minor significance. In the experiments to be described later on the meaning of pictographs, an average or below average population was felt desirable. In this series of experiments on searching for a destination name, it was decided to use *both* populations of observers. Nine of the observers, then, constituted a "bright" group. The remaining twelve observers, an "average" group, were female assembly workers at a nearby industrial plant. Separate analyses were undertaken for each group, which showed that the findings remained the same, independent of "intelligence," but that the bright group could perform better with briefer exposure durations. This is nicely exemplified by the data in Table 3-22 below. The data are broken down to direction and exposure duration, and given separately for the "bright" and the "average" groups. These data are plotted in Fig. 3-30. As was indicated, the finding (superiority of straight ahead) remains the same for each group, but in each case, for a given exposure duration, the "bright" group performs better than their "average" counterpart. Such analyses give confidence that these results do not depend on sampling biases, and reinforce the decision to use the "average" group in investigating questions of meaning in the following section on pictographs.

TABLE 3-22. Guide Signing

"Average" Group - 90 ms Exposure Duration

Straight		Right		Left	
.092	.003	.102	.024	.075	.018
.289	.063	.218	.125	.269	.152
.462	.186	.354	.214	.413	.258
.497	.218	.401	.250	.469	.319
.613	.313	.503	.346	.525	.404
.774	.566	.741	.623	.781	.641
.988	.877	.966	.910	.950	.903
d' =	.77	d' =	.42	d' =	.40

"Bright" Group - 90 ms Exposure Duration

Straight		Right		Left	
.357	.000	.206	.010	.156	.015
.464	.012	.450	.021	.429	.031
.796	.109	.631	.070	.697	.088
.837	.109	.700	.129	.766	.156
.949	.208	.770	.178	.854	.286
.979	.506	.950	.537	.961	.759
.979	.798	00	.726	.981	.989
d' =	2.22	d' =	1.66	d' =	1.73

"Average" Group - 80 ms Exposure Duration

Straight		Right		Left	
.015	.030	.017	.040	.005	.025
.187	.113	.100	.177	.139	.188
.256	.234	.184	.320	.183	.308
.290	.301	.226	.415	.227	.385
.458	.416	.393	.506	.351	.510
.676	.664	.653	.679	.658	.697
.943	.951	.971	.948	.891	.947
d' =	.03	d' =	.54	d' =	.46

"Bright" Group - 80 ms Exposure Duration

Straight		Right		Left	
.202	.034	.224	.033	.226	.021
.436	.075	.471	.070	.454	.059
.616	.114	.666	.109	.637	.098
.788	.152	.778	.150	.780	.150
.840	.300	.836	.239	.831	.303
.908	.510	.899	.472	.884	.520
.968	.755	.951	.736	.935	.761
d' =	1.84	d' =	1.81	d' =	1.81

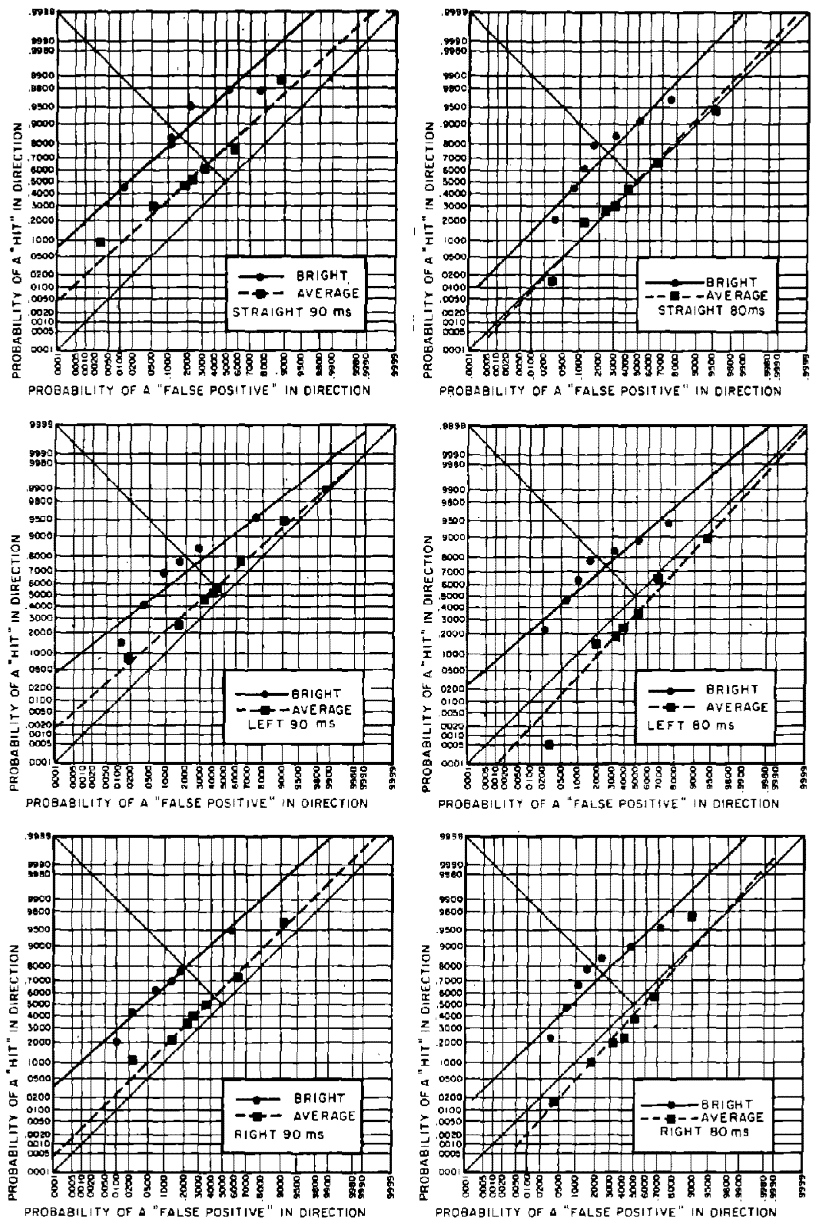


FIG. 3-30 OPERATING CHARACTERISTICS — GUIDE SIGNING. DATA FROM TABLE 3-22.

3.9.2 Discovering a destination

Method

The stimuli used in this series of experiments were identical to those used in the previous series, as discussed in Sec. 3.9.1 above. The stimuli consisted of a set of guide signs with three destinations, each associated arbitrarily with a direction of travel. Name position, travel direction, and arrow placement were all permuted randomly for both the positive and the negative images. A representative selection of stimuli are reproduced in Fig. 3-25 above.

Nine of the observers used in the previous series of experiments on guide signs were continued over into this series. In the previous series the observers had been given a destination name and were required to respond with the associated direction of travel. In this series, however, the observers were given a particular direction of travel and asked to *discover* the name of the destination presumed to be lying in the target direction. As before, the observers attached a numerical confidence rating to their judgments.

The observers were run for four daily sessions, each two hours long. In each daily session, a random selection of 108 stimuli were presented tachistoscopically, each tachistoscopic presentation being of 80 milliseconds' duration. Each of the directions, right, left and straight were used as the target direction for one-third of the trials in a daily session. As in all previous experiments, each stimulus presentation was preceded and followed in time by masking fields of visual noise.

Results

The data from this series of experiments were analyzed in accordance with the principles set forth in Sec. 3.3 above. Analyses were conducted to answer the same questions raised in the previous section.

The data were first analyzed to look at the effect of arrow placement. Table 3-23 shows the data broken down according to placement of the directional arrows, and pooled over observers and each of the other variables. Values of d' are given in the table. These data are plotted in Fig. 3-31 below. As can be seen from both the table and the figure, arrow placement to the right of the destination name is inferior to placement to the left, or staggered. The staggered placement leads to the best performance by a slight margin.

TABLE 3-23. Guide Signing — "Discovery" Position of Arrows

Arrows to RIGHT of Destination Name		Arrows to LEFT of Destination Name		Arrows STAGGERED	
.250	.002	.242	.019	.344	.020
.391	.061	.424	.029	.594	.060
.551	.126	.623	.110	.728	.120
.656	.216	.718	.144	.811	.188
.801	.436	.788	.266	.872	.378
.906	.458	.905	.556	.939	.574
.996	.688	.961	.740	.978	.636
d' =	1.18	d' =	1.66	d' =	1.76

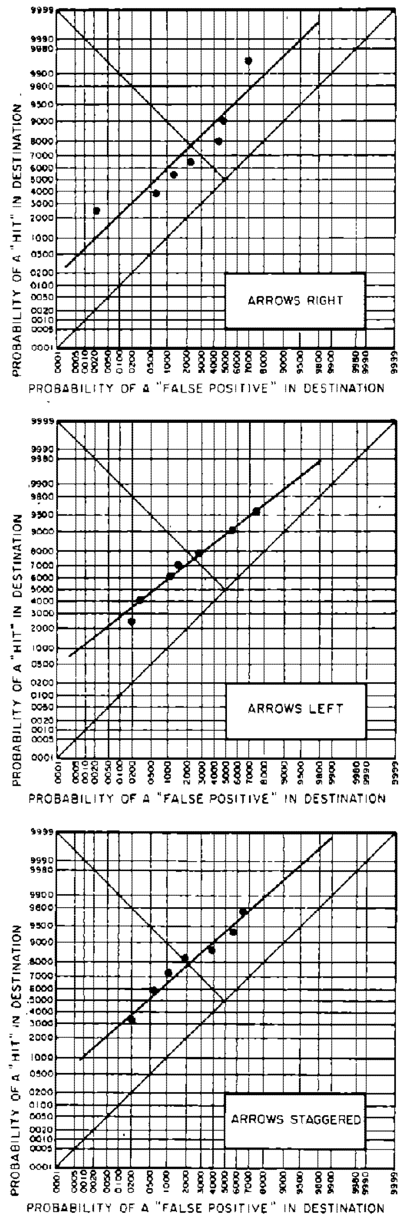


FIG. 3-31 OPERATING CHARACTERISTICS — GUIDE SIGNS, "DISCOVERY". DATA FROM TABLE 3-23.

The data were next analyzed to compare the effect of positive (dark legend on a light surround) as opposed to negative (light legend on a dark surround) stimulus presentations. These data, pooled over the other variables, are presented in Table 3-24 below and plotted in Fig. 3-32. Values of d' abstracted from the data are included in Table 3-24. As these data show, processing of information was superior for the positive legends, compared to the negative legends.

We also investigated which position on the sign was most easily and efficiently processed in brief visual exposures. Table 3-25 and Fig. 3-33 contain these data and respective d' values, and show that the best performance is associated with the middle position.

TABLE 3-24. Guide Signing — "Discovery"
High-School Subjects: 80 ms.
Comparison of Dark on Light and Light on Dark

Light on Dark (Negative)		Dark on Light (Positive)	
.257	.000	.320	.000
.466	.023	.576	.013
.660	.083	.778	.028
.740	.137	.898	.051
.844	.206	.944	.194
.956	.485	.975	.411
1.00	.729	1.00	.680
d' = 1.72		d' = 2.92	

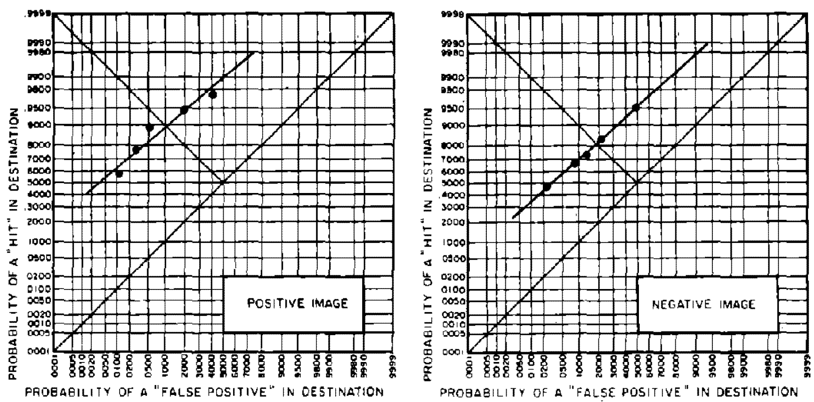


FIG. 3-32 OPERATING CHARACTERISTICS — GUIDE SIGNS, "DISCOVERY". DATA FROM TABLE 3-24.

TABLE 3-25. Position of Place Name

Top		Middle		Bottom	
.181	.034	.549	.006	.126	.000
.363	.101	.780	.019	.472	.022
.543	.171	.829	.044	.753	.058
.601	.799	.878	.050	.851	.079
.657	.285	.891	.106	.890	.204
.796	.536	.941	.182	.958	.539
.928	.786	.988	.438	1.00	.866
1.00	1.00	1.00	1.00	1.00	1.00
d' = 1.10		d' = 2.82		d' = 2.44	

Finally, we asked whether a particular direction of travel led to superior performance. The relevant data are given in Table 3-26, and plotted in Fig. 3-33 below. Reference to the figure and table shows that the straight ahead direction leads to the best performance.

Discussion

The results from this series of experiments are wholly in agreement with those of the preceding series. As before, having all directional arrows to the right of left-justified destination names is contra-indicated, staggered or all-left placement is to be preferred. Again, the straight-ahead direction leads to superior performance, probably for the reasons previously discussed. Finally, as before, positive images and middle name positions provide the best conditions for processing information under brief visual exposure. Inasmuch as the results are in accord with the previous section, the comments contained therein should apply to this series of experiments as well.

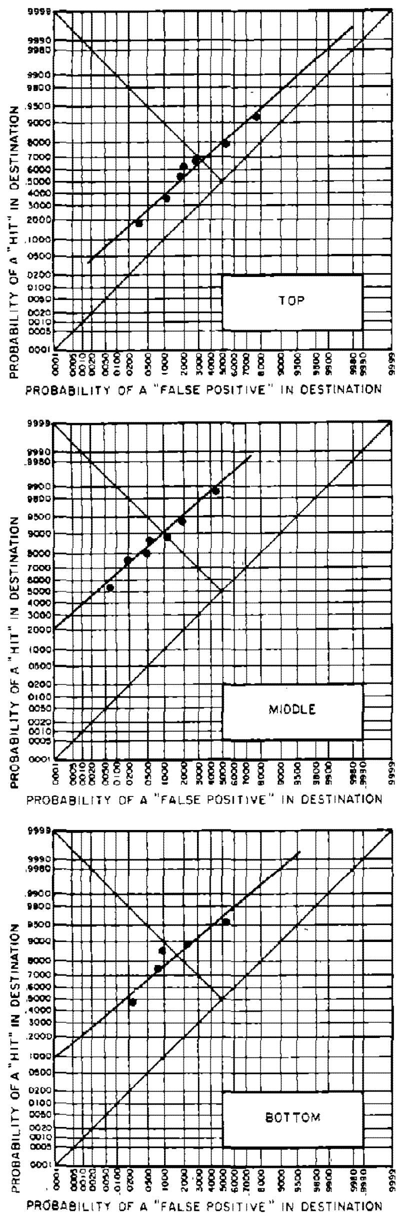


FIG. 3-33 OPERATING CHARACTERISTICS — GUIDE SIGNS. PERFORMANCE BY POSITION OF PLACE NAME. DATA FROM TABLE 3-25.

TABLE 3-26. Guide Signing — "Discovery"
9 High-School Subjects: .080 millisecs
Direction of Travel

Straight		Right		Left	
.370	.021	.360	.009	.311	.005
.624	.051	.548	.045	.513	.022
.788	.100	.712	.080	.663	.044
.874	.120	.786	.098	.773	.069
.907	.239	.918	.211	.818	.124
.946	.430	.918	.398	.904	.335
.996	.650	.971	.646	.961	.606
d' =	2.30	d' =	2.08	d' =	2.21

One further interesting question one can ask is whether there are differences between the two strategies that have been labelled "search" and "discover." The former strategy refers to the series of experiments reported in Sec. 3.9.1, wherein observers are given a destination name as a "target," must search for that destination name, and respond with its associated direction. The latter strategy covers the present series of experiments wherein observers have a direction as their "target" and must discover the destination which lies in that direction.

Inasmuch as the discovery experiment employed only the "bright" group of nine observers, and only an 80 millisecond exposure duration, it must be compared with the equivalent data for the same subjects in the search experiments.

Table 3-27 below shows the relevant data from both series of experiments contrasted. These data are plotted in Fig. 3-35, and, as can be seen from either, there is marginally superior

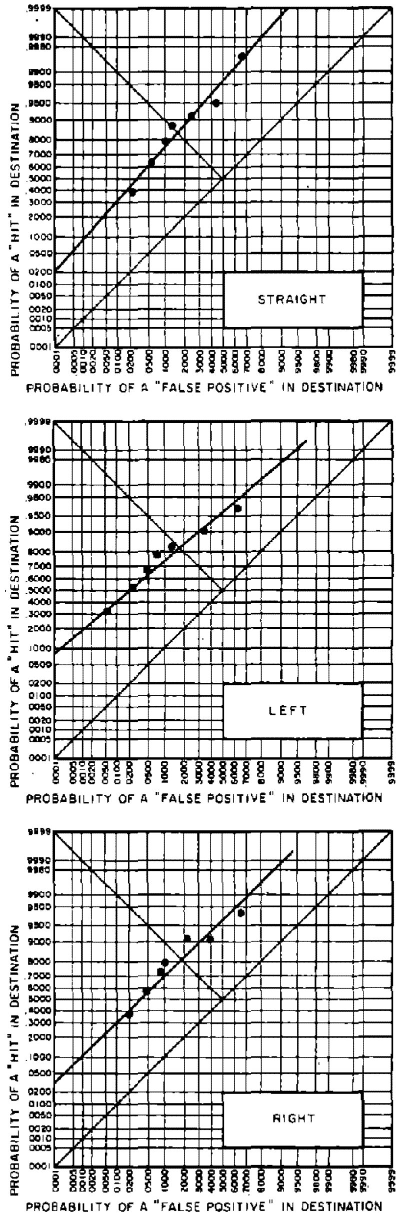


FIG. 3-34 OPERATING CHARACTERISTICS — GUIDE SIGNS, "DISCOVERY". PERFORMANCE BY DIRECTION OF TRAVEL. DATA FROM TABLE 3-26.

TABLE 3-27. Guide Signing. Data from two series of experiments using "bright" group of observers only, and a single exposure duration of 80 milliseconds. Data are pooled over other variables.

"SEARCH" Strategy		"DISCOVER" Strategy	
.205	.013	.298	.008
.427	.038	.505	.038
.639	.079	.735	.064
.773	.117	.806	.089
.845	.291	.858	.185
.926	.524	.933	.455
.975	.776	.985	.691
d' = 1.92		d' = 2.22	

performance in the discovery series. It must be borne in mind that the data are pooled over all the experimental variables, and that, moreover, the discovery series of experiments was run subsequent to the search series, and there remains the possibility that any differences may merely reflect order effects.

3.10 Pictographs

As mentioned previously, suggestions for increased use of pictographs probably rival public complaints about guide signs in frequency. The arguments most generally made in favor of the increased use of pictographic information are uniformity, decreased dependence on literacy in a given language, and improved aesthetic appeal. It would be hard to try and evaluate any of these arguments in the laboratory. Nor can one evaluate the relative efficiency of pictographic and word legends by direct test (see Sec. 3.1). It appears, moreover, that changes to pictographic message representation will come about because of

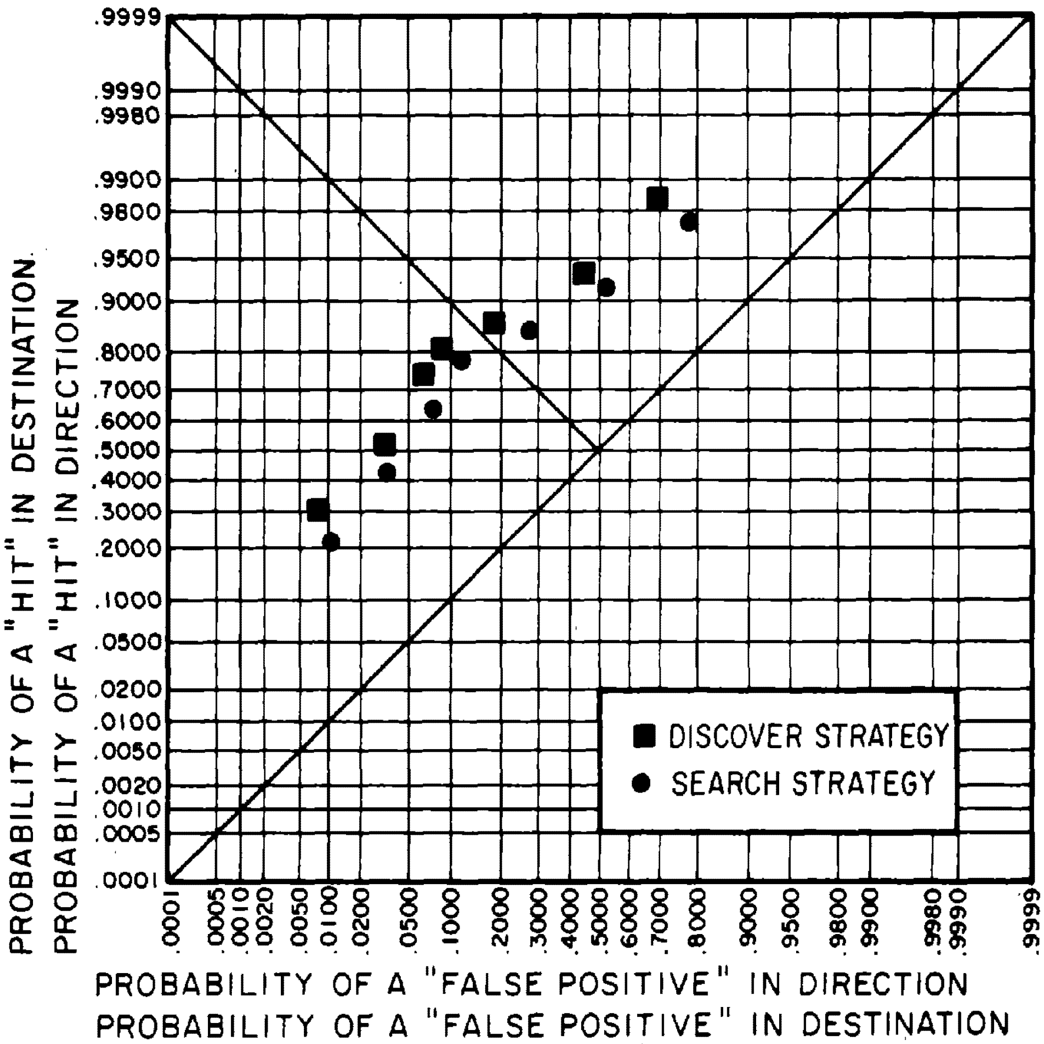


FIG.3-35 OPERATING CHARACTERISTICS-GUIDE SIGNING. COMPARISON OF "SEARCH" AND "DISCOVERY" STRATEGY. DATA FROM TABLE 3-27.

other pressures. What these experiments have tried to do, then, is to discover which of a large set of pictographs are most easily recognizable from amongst that set. The problem is, what response alternatives should be allowed the observers? When previously dealing with relatively simple "geometric" shapes, observers were allowed to refer to shapes by arbitrary indications (numbers) with the aid of a code sheet that reproduced the stimulus set. There are, of course, reasonably accurate semantic labels for each such simple shape, and they were used in the discussion. Using either designation interchangeably was felt justified because the (geometric) "name" was not the (sign's) "meaning." The intended meaning in the highway operational context was not inherent in the geometric name. On the other hand with pictographs, the situation is quite different. Any economical name (other than arbitrary alpha-numeric designation, which would be difficult to learn for a large set) for a pictograph is nearly synonomous with its intended meaning. In a very real sense, it is this property which defines a pictograph.

The dilemma was resolved in favor of giving the observers a list of intended meanings as the set of response alternatives. That is, the names by which observers referred to the stimuli were quite close to the intended meaning of the pictograph.

To further bear on this problem, a second series of experiments were run to ascertain meanings assigned *a priori* to the same pictographs by a naive population of observers.

3.10.1 The recognition of pictographs

Method

A set of forty-four pictographs was used in this series of experiments. The stimuli are shown in Fig. 3-36 below.

Nine observers were run continuously over fifteen daily sessions. Each session lasted two hours, during which time an observer was exposed to one hundred tachistoscopic stimulus presentations, twenty-five at each of four exposure durations. The exposure durations used were 0.012, 0.015, 0.020, and 0.025 seconds. As in previous experiments, and for reasons previously described, each stimulus presentation was both preceded and followed in time by masking fields (visual noise of slightly higher energy).

Each observer was provided with an appropriate answer sheet and a list of the forty-four response alternatives. In addition to choosing that response alternative most likely on a given trial, observers were required to attach to their responses a numerical rating of confidence on a four-point scale.

The list of response alternatives is given in Table 3-28 below.

Results

As in previous experiments, the raw data were reduced in accordance with the principles set forth in Sec. 3.3 above. The reduced data for each pictograph are shown in Table 3-29, below, along with the respective values of d'. The values are presented again in Table 3-30, which gives a rank ordering, best to worst, of the recognizability of the various pictographs.

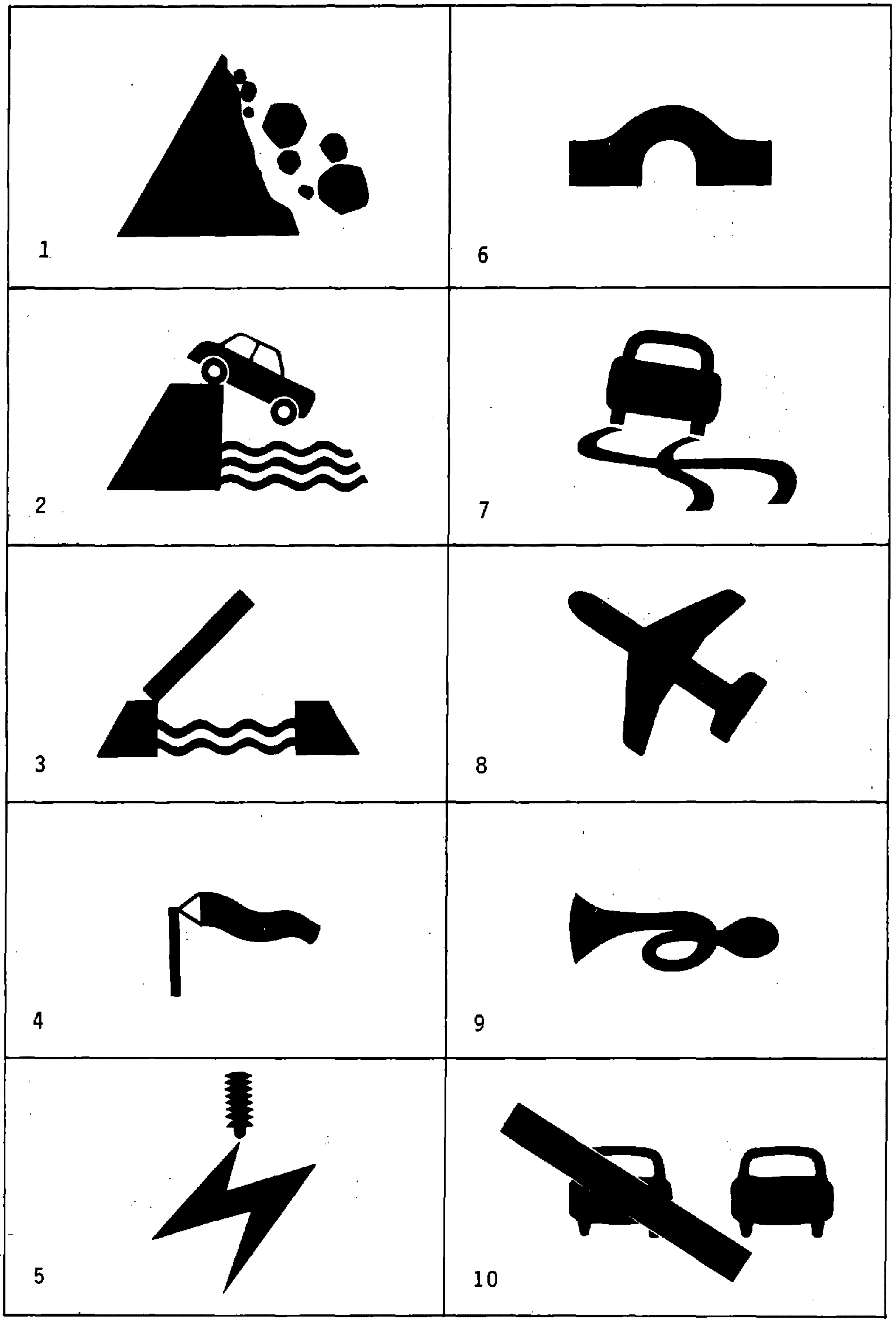


FIG. 3-36a SPECIMEN PICTOGRAPHS

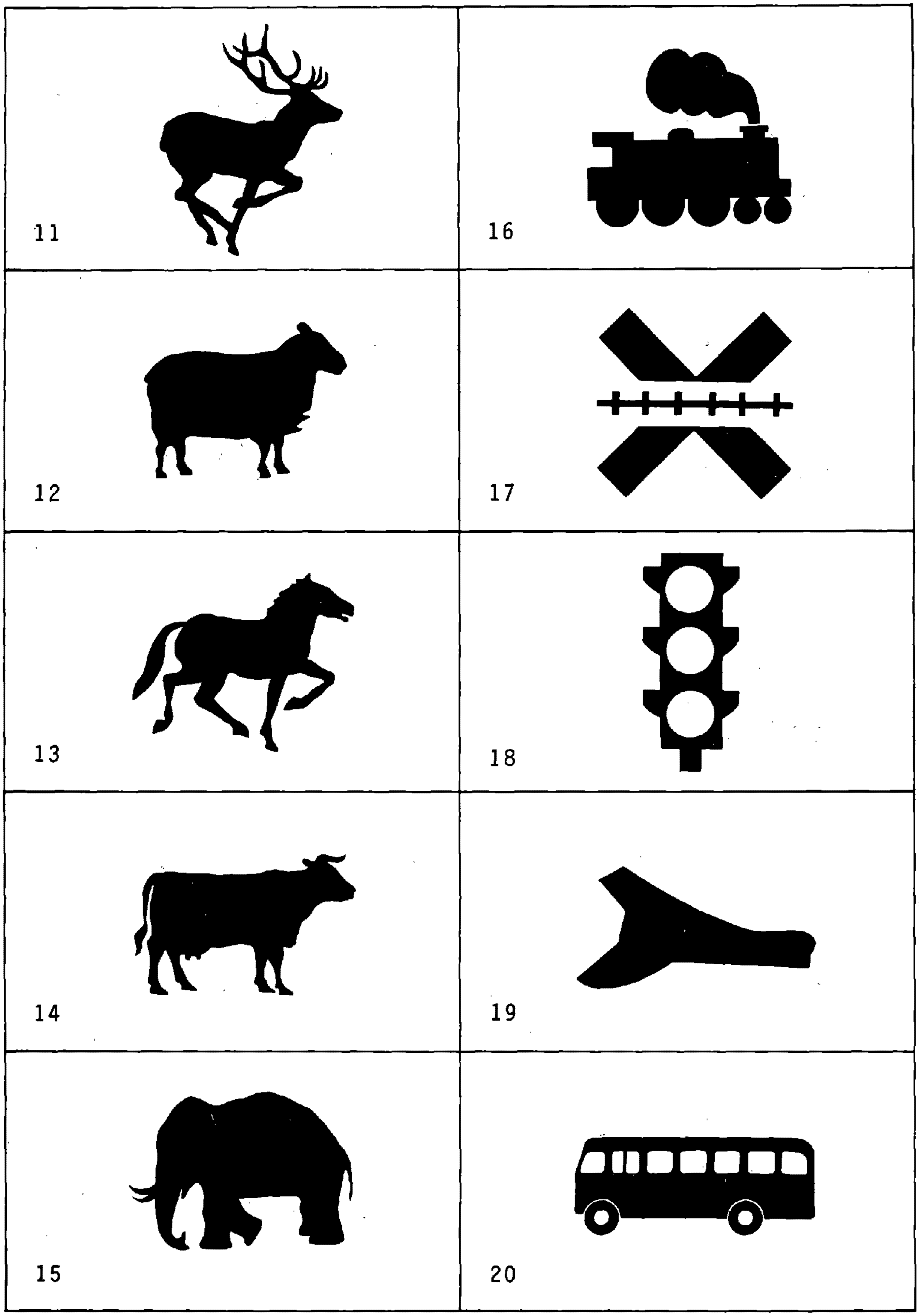


FIG. 3-36b SPECIMEN PICTOGRAPHS (CONTINUED)

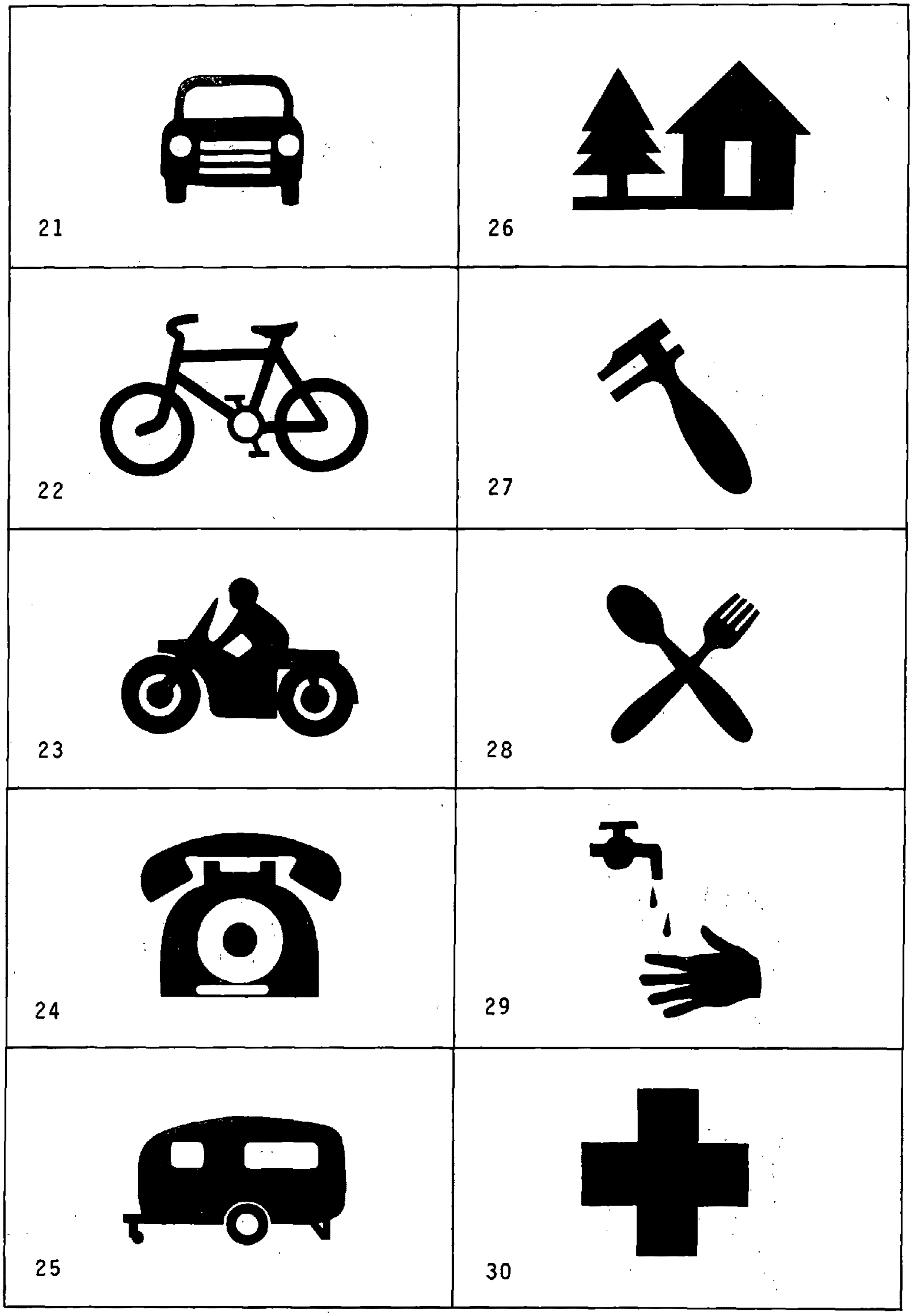


FIG. 3-36c SPECIMEN PICTOGRAPHS (CONTINUED)

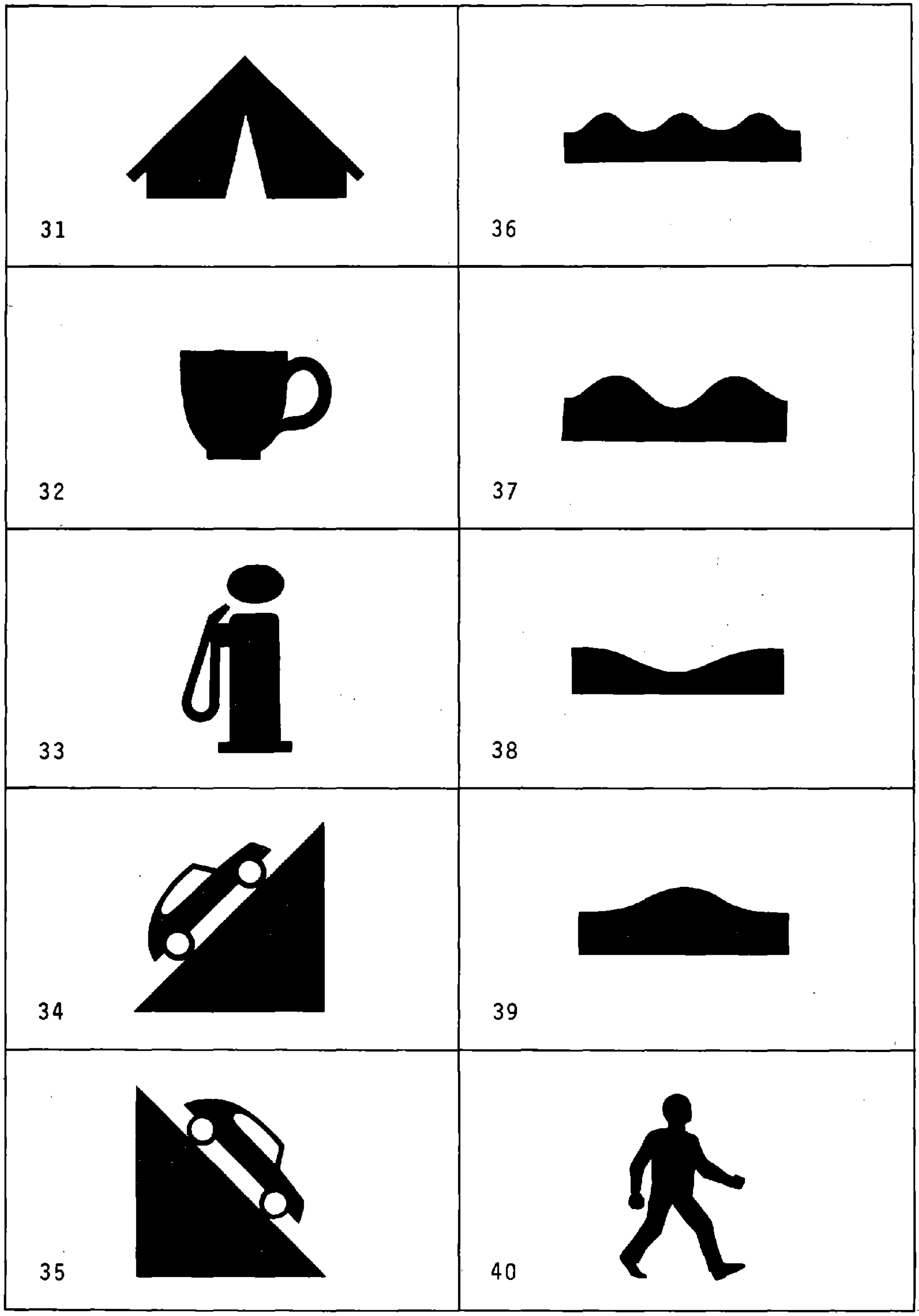


FIG. 3-36d SPECIMEN PICTOGRAPHS (CONTINUED)

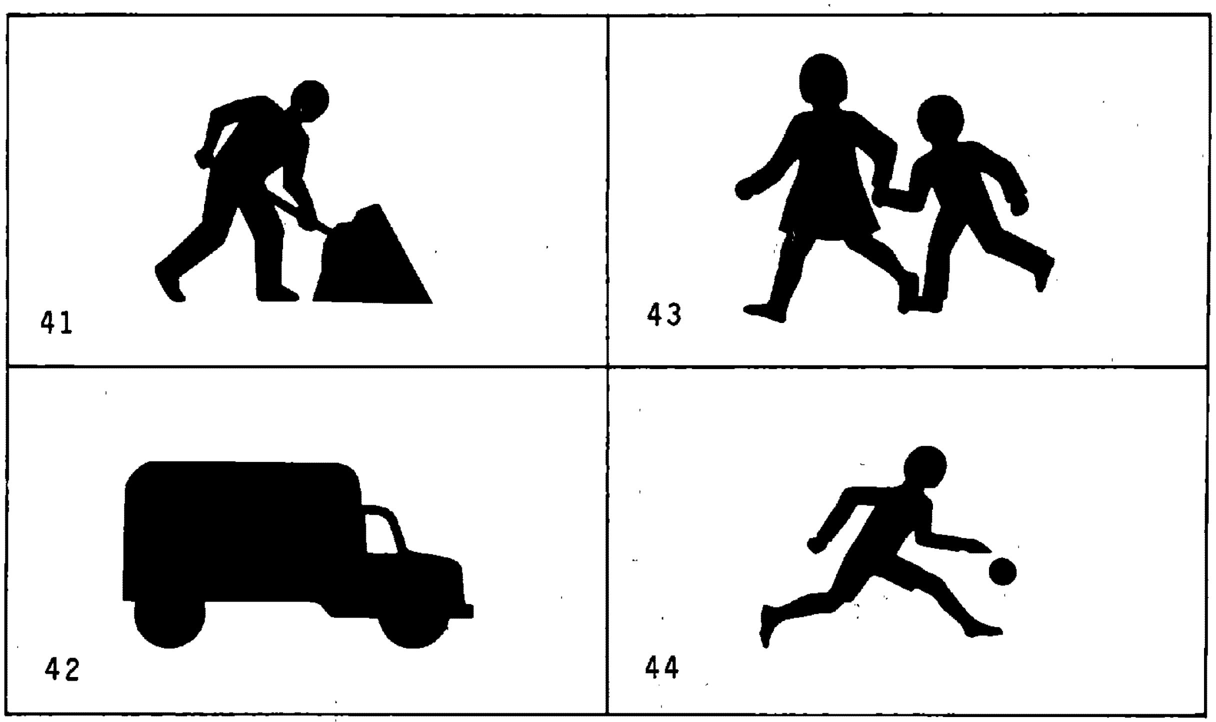


FIG. 3-36e SPECIMENS PICTOGRAPHS (CONTINUED)

TABLE 3-28

Falling rocks	Motorcycle
River bank	Telephone
Swinging bridge	Trailer camp
Sudden side winds	Youth hostel
Electric cables	Mechanic
Hump bridge	Food
Slippery road	Wash room
Low flying aircraft	First aid
No horn blowing	Camping
No passing	Drink
Deer crossing	Gas
Sheep	Up hill
Horse	Down hill
Cattle	Rough road
Elephant	Uneven road
Train	Dip
Railroad	Bump
Signal ahead	Pedestrian crossing
Police	Road Work
Buses	Truck sign
Motor vehicle	Children playing
Bicycle	Children crossing

TABLE 3-29.

Falling Rocks		River Bank		Swing Bridge		Side Winds		Electric Cables		Hump Bridge		Slippery Road		Airplane		Horn		No Passing		Deer	
.020	.001	.049	.009	.033	.007	.000	.000	.000	.000	.028	.007	.032	.000	.022	.000	.000	.000	.030	.006	.029	.000
.052	.009	.062	.013	.063	.013	.000	.000	.025	.004	.049	.009	.063	.005	.028	.018	.018	.000	.083	.009	.045	.012
.140	.011	.084	.025	.125	.020	.029	.000	.050	.007	.092	.015	.090	.008	.053	.021	.026	.001	.106	.015	.084	.025
.284	.012	.284	.035	.173	.022	.652	.005	.102	.013	.224	.025	.250	.013	.308	.022	.077	.007	.220	.036	.229	.057
.526	.235	.487	.194	.531	.231	.374	.377	.452	.376	.370	.267	.282	.230	.511	.217	.309	.340	.403	.226	.476	.132
.680	.440	.706	.230	.640	.316	.657	.481	.714	.392	.509	.501	.468	.345	.741	.364	.684	.490	.561	.474	.517	.389
.800	.600	.798	.537	.846	.790	.693	.619	.844	.679	.666	.560	.742	.738	.786	.658	.825	.523	.750	.726	.810	.679
d' = 1.74		d' = 1.17		d' = 1.10		d' = 0.92		d' = 1.04		d' = 1.11		d' = 1.64		d' = 1.54		d' = 0.98		d' = 0.98		d' = 0.81	

Sheep		Horse		Cow		Elephant		Train		Railroad Crossing		Signal Ahead		Police Hat		Bus		Car		Bicycle	
.027	.000	.044	.012	.033	.000	.048	.008	.036	.000	.044	.000	.065	.004	.034	.000	.046	.012	.058	.014	.051	.013
.048	.005	.065	.015	.045	.000	.070	.012	.067	.003	.068	.000	.073	.007	.057	.013	.064	.018	.082	.015	.096	.020
.053	.013	.092	.022	.078	.003	.105	.019	.100	.013	.081	.000	.142	.015	.067	.020	.087	.021	.122	.020	.119	.028
.124	.017	.251	.039	.087	.009	.207	.037	.218	.018	.097	.004	.291	.024	.076	.026	.113	.049	.244	.037	.227	.046
.283	.231	.350	.218	.304	.285	.386	.231	.374	.360	.214	.469	.356	.258	.293	.205	.206	.257	.342	.229	.357	.224
.530	.367	.603	.341	.348	.487	.536	.380	.545	.483	.351	.628	.380	.355	.459	.486	.495	.274	.452	.369	.539	.390
.804	.603	.796	.603	.685	.657	.741	.591	.818	.576	.730	.722	.720	.592	.686	.678	.700	.650	.713	.758	.683	.657
d' = 0.88		d' = 1.08		d' = 1.02		d' = 0.94		d' = 1.28		d' = 1.33		d' = 1.32		d' = 0.48		d' = 0.41		d' = 1.04		d' = 0.90	

Motorcycle		Telephone		Trailer		Youth Hostel		Wrench		Fork & Spoon		Rest Room		First Aid		Tent		Cup		Gas Pump	
.051	.000	.017	.005	.045	.034	.019	.000	.017	.005	.019	.022	.052	.000	.049	.003	.026	.012	.038	.015	.056	.014
.063	.005	.044	.012	.080	.043	.049	.005	.029	.012	.034	.024	.069	.015	.081	.012	.046	.014	.069	.024	.063	.025
.132	.009	.078	.026	.104	.064	.095	.008	.056	.025	.052	.047	.131	.019	.146	.032	.070	.024	.131	.033	.109	.035
.158	.013	.110	.046	.147	.076	.110	.013	.085	.026	.089	.075	.224	.042	.291	.245	.123	.037	.259	.042	.144	.058
.381	.363	.333	.166	.218	.165	.336	.275	.316	.206	.350	.223	.340	.240	.384	.359	.347	.238	.360	.271	.415	.360
.540	.513	.424	.355	.503	.393	.458	.519	.396	.618	.482	.301	.483	.461	.675	.627	.545	.385	.536	.397	.731	.404
.742	.640	.754	.653	.710	.676	.917	.642	.833	.775	.701	.545	.689	.628	.799	.627	.833	.528	.717	.615	.784	.731
d' = 1.33		d' = 0.41		d' = 0.36		d' = 1.09		d' = 0.54		d' = 0.06		d' = 0.98		d' = 1.08		d' = 0.58		d' = 1.11		d' = 0.47	

Up Grade		Down Grade		3 Bumps		2 Bumps		Dip		1 Bump		Pedestrian Crossing		Men Working		Truck		Children Crossing		Children Playing	
.049	.013	.033	.000	.029	.000	.015	.000	.054	.015	.046	.000	.030	.000	.018	.012	.041	.006	.034	.014	.026	.000
.075	.034	.042	.009	.048	.000	.019	.005	.070	.022	.062	.007	.038	.011	.045	.014	.053	.009	.062	.019	.033	.005
.119	.044	.084	.015	.062	.007	.046	.009	.080	.033	.088	.012	.079	.023	.098	.023	.083	.022	.084	.025	.062	.017
.211	.059	.173	.020	.110	.012	.098	.014	.139	.056	.143	.017	.157	.032	.154	.028	.170	.037	.129	.039	.150	.026
.415	.385	.527	.268	.422	.289	.420	.405	.482	.372	.511	.421	.349	.284	.386	.256	.389	.293	.516	.256	.366	.316
.747	.402	.669	.520	.634	.416	.652	.555	.536	.399	.696	.562	.581	.580	.643	.537	.595	.569	.723	.282	.626	.402
.774	.671	.764	.679	.809	.760	.856	.805	.839	.729	.797	.768	.794	.662	.714	.671	.742	.661	.764	.514	.819	.530
d' = 0.74		d' = 1.10		d' = 1.09		d' = 1.04		d' = 0.47		d' = 0.97		d' = 0.89		d' = 0.84		d' = 0.80		d' = 0.62		d' = 0.84	

TABLE 3-30. Pictographs.

	d'		d'
Falling Rocks	1.74	Rest Room	.98
Slippery Road	1.64	1 Bump	.97
Airplane	1.54	Elephant	.94
Railroad Crossing	1.33	Side Winds	.92
Motorcycle	1.33	Bicycle	.90
Signal Ahead	1.32	Pedestrian Crossing	.89
Train	1.28	Sheep	.88
River Bank	1.17	Men Working	.84
Hump Bridge	1.11	Children Playing	.84
Cup	1.11	Deer	.81
Swing Bridge	1.10	Truck	.80
Down Grade	1.10	Up Grade	.74
3 Bumps	1.09	Children Crossing	.62
Youth Hostel	1.09	Tent	.58
Horse	1.08	Wrench	.54
First Aid	1.08	Police Hat	.48
Electric Cable	1.04	Gas Pump	.47
Car	1.04	Dip	.47
2 Bumps	1.04	Bus	.41
Cow	1.02	Telephone	.41
Horn	.98	Trailer	.36
No Passing	.98	Fork and Spoon	

For purposes of later discussion the pictographs are separated into five categories. The category boundaries chosen are successive intervals of d'=0.40. The distribution of the pictographs among the five categories is shown in Fig. 3-37 below, and for our purposes provides reasonable categorization.

According to this categorization, those pictographs *most easily recognized* are those depicting FALLING ROCKS and SLIPPERY ROAD. Those pictographs which are *easily recognized* include AIRPLANE, RAILROAD CROSSING, MOTORCYCLE, SIGNAL AHEAD, and TRAIN.

On the other hand, those pictographs *poorly recognized* include UP GRADE, CHILDREN CROSSING, TENT, WRENCH, POLICE HAT, GAS PUMP, DIP, BUS, and TELEPHONE. Those pictographs *most poorly recognized* are the TRAILER and FORK AND SPOON. The balance of the forty-four pictographs fall into the central category shown in Fig. 3-37.

Discussion

In evaluating the results of this series of experiments it must be borne in mind that the first experiment has only determined the recognizability of the pictographs from among the set of pictographs displayed. Meaning of the pictographs is considered below and the two sections must be considered together.

With these cautions in mind, let us make a few observations about the data which might not have been obvious at first. One of these is the performance of the animal pictographs. In the presentation set there were five animals represented, all four-legged. Offhand, because of their similarity, one might suppose they would perform quite poorly due to inter-confusions. In fact, however, none were below average. From the operational standpoint

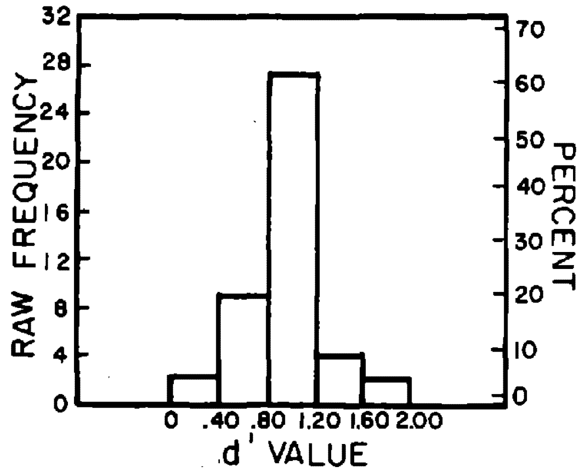


FIG.3-37 PICTOGRAPHS-RECOGNIZABILITY CATEGORIES.

one might question whether making fine distinctions between four-legged animals — slow-moving chicanes — provides additional useful information for the driver. That is, does a driver behave differently if warned a deer crossing area, or a cattle crossing? A point precisely analogous can be made concerning one, two, and three "bumps".

Disappointingly poor were CHILDREN CROSSING, TELEPHONE and FORK AND SPOON, inasmuch as these messages are to be borne by pictographs presently in our system. Uncrossing the utensils (as is being done) undoubtedly is a help removing general confusions with X, a recurrent theme. Another possibility is to use the CUP instead. Alternatives to the pictured telephone — a handpiece and dangling cord, for example — are available, and should be tried. The poor performance of the CHILDREN is disconcerting and it might be well to consider alternatives before finalizing the design.

The best of the pictographs speak for themselves. Interestingly, the SIGNAL tested was extremely good without the complexity and consequent cost of two additional colors as is currently proposed for the 1970 draft *Manual on Uniform Traffic Control Devices* (MUTCD). It is comforting to see the superior performance of the symbols for AIRPLANE and SLIPPERY ROAD, both of which are coming into use. In this context it should be pointed out that the rendition of SLIPPERY ROAD tested is not that of the most recent draft (MUTCD). Rather, it conforms to international usage, and might be profitably substituted. The motorcycle rendition also differs from that proposed, but slightly.

3.10.2 Meaning inferred from pictographs

Method

The same set of pictographs was used in this series of experiments as was used in the previous series. These stimuli are shown in Fig. 3-36 in Sec. 3.10.1.

Because of the nature of the experiments it was desirable to avoid using an overly bright population of observers, clearly unrepresentative of the driving rank and file. The experiment used twelve female assembly workers from a nearby plant. By the choice of the fairer sex, we implied no denigration of the native intelligence of women. Rather, it was hoped that this selection would exclude driving enthusiasts – people with a long-term personal interest and involvement in highway problems.

The twelve observers were run continuously over fifteen daily sessions. Each session lasted two hours, during which time an observer was exposed to one hundred tachistoscopic stimulus presentations, twenty-five at each of four exposure durations. The exposure durations used were 0.015, 0.020, 0.025 and 0.030 seconds. As in previous experiments, and for reasons previously described, each stimulus presentation was both preceded and followed in time by masking fields (visual noise of slightly higher energy).

In contrast to previous experiments, a set of response alternatives was not defined for the observers. Instead, they were asked to tell what they saw on each trial in their own words.

At first blush, the decision to use brief visual presentations of the stimuli in this particular series of experiments might seem to be a strange one. On the basis of the previous series of experiments, however, it was known, in fact, that brief visual exposures were sufficient to select responses from a closed set of alternatives. The experimenters were admittedly curious to discover whether such brief presentations would suffice in this case. Partly because of curiosity, but more importantly because of the basic belief that viewing time on the highway is, in many circumstances, a scarce and valuable commodity, the tachistoscopic presentation method was used. As will be seen, this choice allowed one to discriminate among the pictographs.

Results

Inasmuch as this series of experiments departs from the more usual methods of data collection, the responses of each observer were treated differently than in other experiments. Each response from each observer was evaluated independently. The evaluation consisted of a sorting into four categories which were: *strictly correct, generally correct, irrelevant, and contradictory.*

Table 3-31 gives the percentage of *strictly correct* pictograph interpretations, pooled over observers. Table 3-32 presents the cumulative percent correct responses (*strictly* ang *generally correct*). Both tables are rank-ordered from best to worst.

Figure 3-38 shows the frequency distribution of responses according to percent correct responses. The dashed lines imposed on the frequency distributions give hypothesized distributions and indicate that the apparent bi-modality of the raw distribution

TABLE 3-31. Pictographs - *strictly correct* responses.

43	children crossing	64%
1	falling rocks	56%
15	elephant	56%
12	sheep	52%
9	horn	52%
14	cattle	48%
11	deer	48%
7	slippery road	48%
29	rest room	44%
20	bus	44%
40	pedestrian	43%
42	truck	42%
25	trailer	40%
13	horse	38%
32	cup	38%
18	signal ahead	36%
8	airplane	36%
28	fork & spoon	36%
3	swing bridge	33%
44	children playing	32%
35	downgrade	32%
16	train	32%
24	telephone	31%
27	wrench	30%
39	one bump	28%
17	railroad crossing	25%
34	upgrade	25%
41	men working	24%
22	bicycle	24%
37	two bumps	20%
36	three bumps	20%
23	motorcycle	16%
38	dip	16%
31	tent	12%
33	gas pump	11%
19	police hat	8%
4	sidewinds	4%
5	electric cable	0%
30	first aid	0%
21	car	0%
2	river bank	0%
26	youth hostel	0%
6	hump bridge	0%
10	no passing	0%

TABLE 3-32. Pictographs - *strictly* and *generally correct* responses.

43	children crossing	92%
12	sheep	92%
40	pedestrian	91%
9	horn	84%
14	cattle	84%
1	falling rocks	80%
11	deer	78%
15	elephant	76%
13	horse	76%
18	signal ahead	76%
44	children playing	72%
7	slippery road	67%
29	rest room	60%
25	trailer	60%
8	airplane	60%
32	cup	57%
28	fork & spoon	56%
42	truck	54%
3	swing bridge	54%
24	telephone	54%
41	men working	52%
22	bicycle	52%
20	bus	51%
34	upgrade	50%
17	railroad crossing	46%
23	motorcycle	42%
4	sidewinds	42%
35	downgrade	40%
37	two bumps	40%
38	dip	40%
5	electric cables	40%
16	train	36%
36	three bumps	36%
27	wrench	35%
39	one bump	32%
31	tent	32%
19	police hat	28%
33	gas pump	17%
30	first aid	13%
21	car	12%
2	river bank	9%
26	youth hostel	4%
6	hump bridge	4%
10	no passing	0%

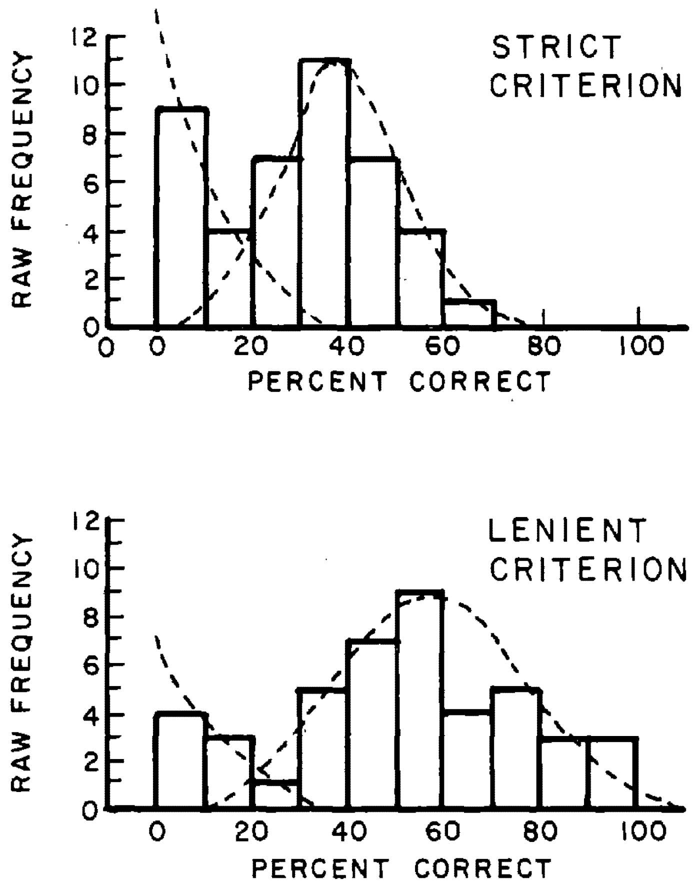


FIG.3-38 PICTOGRAPHS-DISTRIBUTION OF CORRECT RESPONSES FOR THE 44 STIMULI.

may be accounted for by two underlying populations – one of basically uninterpretable pictographs, the other those whose meaning can be inferred to a greater or lesser degree.

Discussion

It seems appropriate to base this discussion upon the more lenient evaluation of correctness. This decision is based upon the fact that the highway environment is not likely to be as demanding as is that of the laboratory. Accordingly then, the first part of this discussion centers around the data of Table 3-32.

Disappointing, and at the same time instructive is the poor performance of the NO PASSING pictograph. It is, of course, the only pictograph incorporating the negating diagonal slash. In addition its message depends upon an abstract spatial representation – abstract in that it must be viewed from "outside," as by a third party. Surprising too, by its poor showing is the FIRST AID symbol. Bear in mind, however, that it was not a "*red* cross" – all pictographs being black silhouettes.

On the positive side, it is refreshing to see many of those pictographic symbols currently proposed, or already in use, relatively high up on the list.

Particularly interesting is the outstanding performance of the pictograph depicting children crossing. This is in contrast to its poor showing strictly in terms of recognition from amongst the set of forty-four (at crucially shorter exposure durations). Such a contrast in performance isolated by the two techniques reinforces the *a priori* feeling that two dissimilar processes are involved. At the same time, such a dichotomy raises the question of how to weight each process.

While one can give no pat answer to the question, the data can help the reader resolve the dilemma according to his own *a priori* weightings. Most useful for this purpose is Fig. 3-39 below. The Figure shows each pictograph, identified by number, located on a grid by two coordinates, one its recognizability, the other its meaning transmissibility. The closer to the upper right-hand corner a pictograph lies, the better. The worst lie closest to the lower left-hand corner. A series of parallel lines of negative slope can be used to separate the pictographs according to quality. The actual slope chosen determines the weighting of meaning relative to recognizability. The steeper the slope, the more heavily meaning is weighted. The shallower the slope, the more heavily recognizability is weighted.

For purposes of this discussion of both experiments on pictographs, we have scribed lines of unit negative slope. Accordingly, the best pictographs are: FALLING ROCKS, SLIPPERY ROAD, SIGNAL AHEAD, AIRPLANE, CATTLE CROSSING, PEDESTRIAN CROSSING, SHEEP, HORN, HORSE, ELEPHANT, and CHILDREN CROSSING.

According to this same classification scheme, the worst of the pictographs are: GAS PUMP, NO PASSING, POLICE HAT, YOUTH HOSTEL, FORK & SPOON, HUMP BRIDGE, TENT, WRENCH, DIP, CAR, RIVER BANK, FIRST AID, BUS, TELEPHONE, and TRAILER.

3.11 Some Selected Signs

This series of experiments with a selected series of signs must be viewed as an investigation of the most preliminary sort

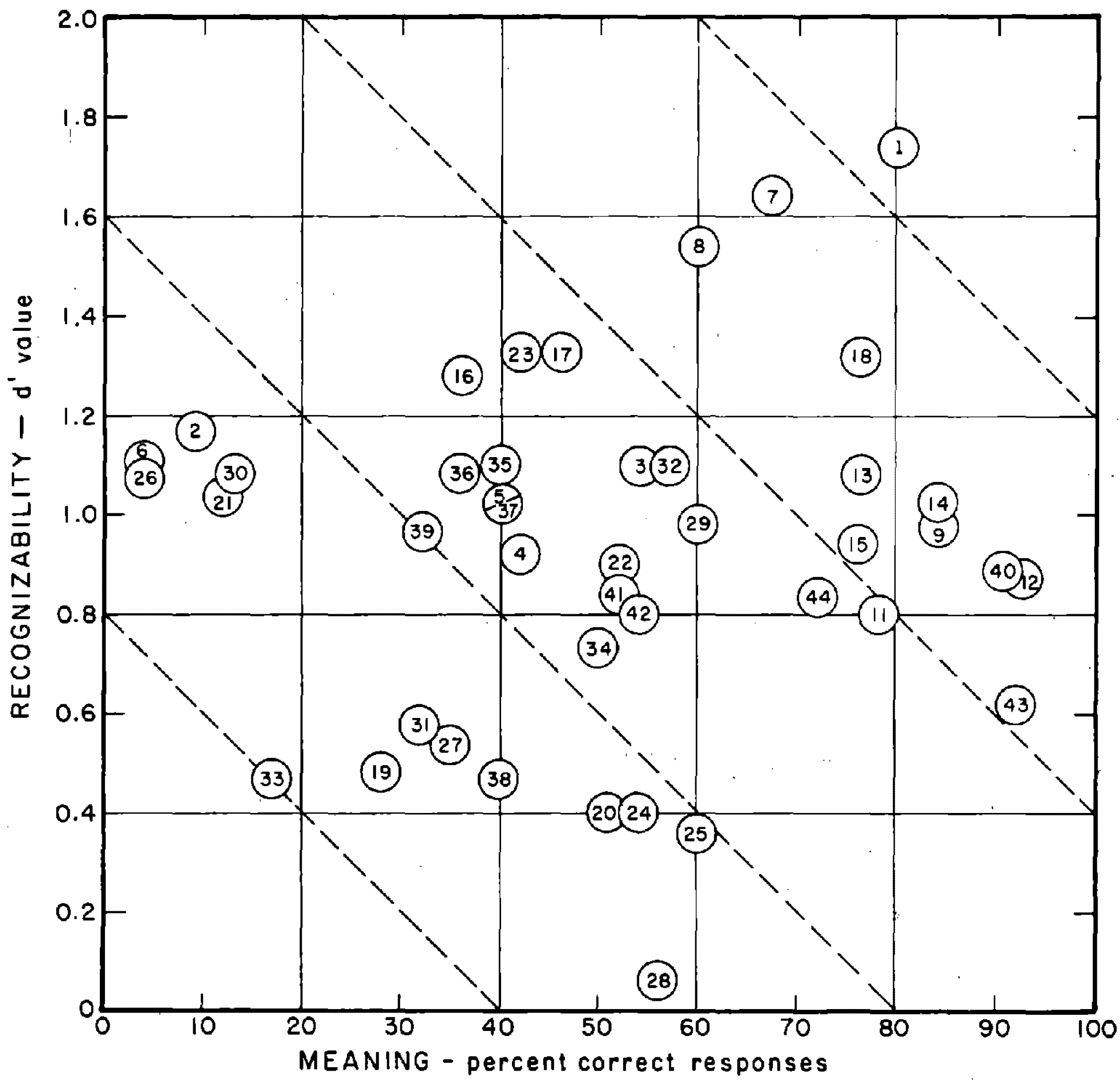


FIG. 3-39 PICTOGRAPHS — AN EXAMPLE OF A COMBINED RATING SCHEME. NUMBERS CORRESPOND TO PICTOGRAPHS SHOWN IN FIG. 3-36 AND LISTED IN TABLE 3-28.

designed with several objectives in mind. The experiments include both experimentation in the laboratory of the sort now familiar to the reader, and more realistic experimentation on the road, described in detail below. Other differences between these and previous experiments are reflected in our choice of stimuli. In keeping with the basic philosophy of intensive examination of basic design elements of traffic control devices, stimuli in previous experiments were deliberately and painstakingly restricted to simple, uncontaminated examples of the elements. The present series of experiments deals with certain signs in their entirety and entails the complex interaction of the basic elements. Using an identical set of stimuli in the laboratory and on the road enables us to isolate whatever basic differences exist between the two situations. In turn, this allows us to qualify conclusions drawn from the laboratory findings. One basic difference encountered between the two situations was the role of color. This was not unexpected; our previous discussion of the results of laboratory experiments pointed up the necessity for caution where brief exposures of colors are involved. As a result, the data analysis comparing the two situations turns out to be complicated. The road testing procedures which we have employed are interesting in their own right, of course, and provide a valuable technique for further explorations.

An initial selection of ten signs was made and these signs are shown in Fig. 3-40. As can be seen from the figure, the group is far from homogeneous. Colors, shapes, legends, pictographs, and abstract symbols are variously intermixed. Moreover, there are two versions of each message. Note that this selection is in violation of the previous warnings about the difficulties

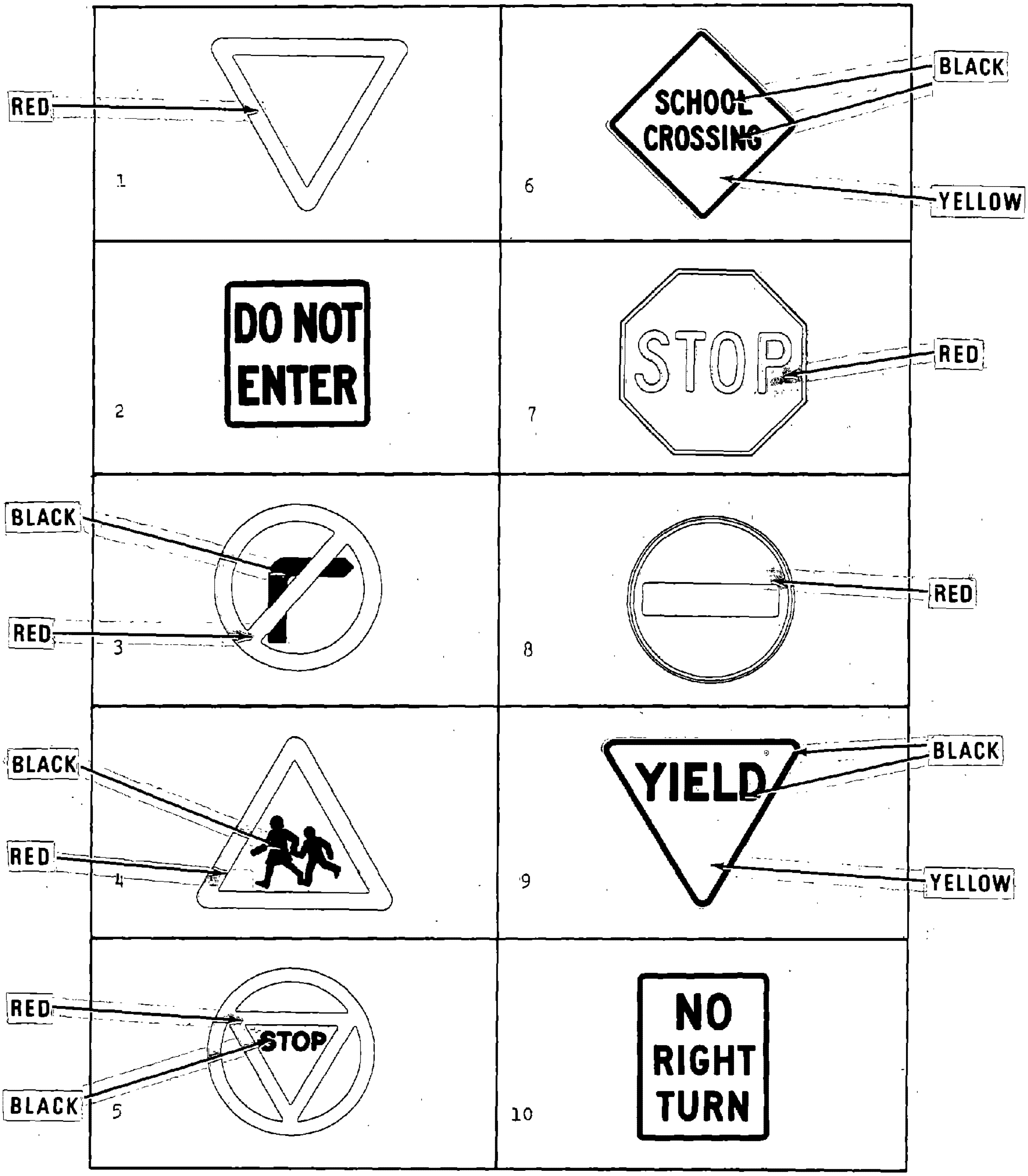


FIG. 3-40 SOME SELECTED SIGNS FOR LABORATORY AND ROAD TEST.

inherent in trying to do evaluations with a mixed system. As will be seen, this leads to complexities in the data analyses. Nonetheless, this avenue of experimentation was considered necessary. Hopefully, the difficulties encountered in this series will not serve to obfuscate the merits of the techniques employed.

3.11.1 Selected signs in the laboratory

Method

Tachistoscopic projection of the stimuli was used with two exposure durations, 0.015 and 0.020 seconds. As in previous experiments stimulus presentation was both preceded with and followed by visual masking fields, visual noise of slightly higher energy. The ten stimuli used are shown in Fig. 3-40.

Seven observers were used, each for ten daily sessions. Each session lasted approximately an hour during which time each observer was presented with eighty stimuli, forty at an exposure duration of 0.020 seconds, and forty at an exposure duration of 0.015 seconds.

Each observer was provided with a copy of Fig. 3-40 and a suitable answer sheet. On each trial the observer was required to indicate by number which of the ten stimuli had most likely been presented. In addition the observers were required to indicate the confidence they attributed to their answers. These confidence ratings were given on the basis of a four-point scale ranging from *very sure to very unsure.*

Results

The basic data were reduced as in all previous experiments (excepting those dealing with the meaning of pictographs) in accordance with the procedure detailed in Sec. 3.3. Because of the complexity of the stimulus set a number of different breakdowns of the data were necessary, some of which, as indicated below involved discounting of certain data.

The basic data, pooled over observers and exposure durations is presented in Table 3-33. In Table 3-34 these data are broken down according to exposure duration. Estimates of d' are included in the Tables.

One breakdown to be made in the stimulus set is between two sets of signs, one of current United States signs, the other a set of alternatives. The former set is comprised of Nos. 2, 6, 7, 9, and 10. The alternatives are Nos. 8, 4, 5, 1, and 3, respectively. One can look at the performance of a sign *within its own set* by separating the data appropriately and ignoring those confusions which arose between signs of one set and those of the other. The relevant data for the United States signs are presented pooled over exposure durations in Table 3-35, and broken down according to exposure durations in Table 3-36. Estimates of d' abstracted from the data are included in the Tables. The relevant data for the alternatives are similarly presented in Tables 3-37 and 3-38.

Another way in which the stimulus set can be broken down is according to color: six red signs, Nos. 1, 7, 8, 3, 4, and 5 (the last three with black); two yellow signs, Nos. 6 and 9; two signs black on white, Nos. 2 and 10. The relevant data are

TABLE 3-33. Some Selected Signs — Laboratory Experiment.

Sign #1		Sign #2		Sign #3		Sign #4		Sign #5	
.283	.002	.300	.000	.156	.000	.163	.000	.213	.000
.312	.005	.417	.000	.253	.000	.250	.000	.303	.000
.538	.011	.630	.000	.366	.000	.333	.005	.516	.002
.640	.018	.727	.011	.590	.010	.571	.020	.533	.015
.898	.590	.790	.667	.817	.700	.916	.615	.718	.770
.971	.860	.930	.889	1.980	.716	1.00	.693	.888	.860
1.00	.898	.997	.920	1.00	.784	1.00	.777	.998	.901
d' = 2.41		d' = 2.93		d' = 2.55		d' = 2.23		d' = 2.12	

Sign #6		Sign #7		Sign #8		Sign #9		Sign #10	
.155	.002	.176	.000	.155	.000	.130	.000	.190	.000
.233	.005	.276	.000	.419	.002	.223	.003	.370	.003
.300	.009	.377	.002	.566	.009	.395	.006	.555	.003
.444	.012	.563	.005	.688	.022	.567	.020	.681	.006
.944	.575	.898	.668	.909	.517	.796	.666	.919	.500
1.00	.763	1.00	.800	1.00	.611	.880	.700	1.00	.710
1.00	.833	1.00	.835	1.00	.670	.995	.718	1.00	.815
d' = 2.17		d' = 2.72		d' = 2.56		d' = 2.23		d' = 2.98	

TABLE 3-34. Some Selected Signs — Laboratory Experiment

20 msec.

Sign #1		Sign #2		Sign #3		Sign #4		Sign #5	
.500	.014	.823	.000	.382	.000	.578	.000	.565	.000
.722	.028	1.00	.000	.588	.000	.789	.000	.739	.000
.944	.049	1.00	.000	.647	.000	.895	.010	.826	.005
.944	.064	1.00	.064	.764	.031	.895	.036	.826	.005
.944	.116	1.00	.090	.882	.094	.895	.102	1.00	.055
.944	.378	1.00	.266	1.00	.245	1.00	.243	1.00	.177
1.00	.526	1.00	.558	1.00	.522	1.00	.533	1.00	.399
d' = 3.10		d' = 4.00		d' = 2.58		d' = 3.03		d' = 3.52	

Sign #6		Sign #7		Sign #8		Sign #9		Sign #10	
.389	.000	.387	.000	.545	.000	.163	.000	.250	.000
.778	.000	.710	.000	.818	.000	.250	.006	.659	.006
.944	.000	.839	.006	.939	.013	.562	.006	.659	.006
.944	.016	.903	.006	.939	.026	.625	.010	.781	.006
.944	.092	1.00	.080	.939	.104	.688	.084	1.00	.061
1.00	.242	1.00	.235	1.00	.246	.750	.221	1.00	.235
1.00	.510	1.00	.511	1.00	.528	.875	.494	1.00	.497
d' = 3.60		d' = 3.80		d' = 3.43		d' = 2.65		d' = 3.28	

TABLE 3-34 (cont'd)

15 msec.

Sign #1		Sign #2		Sign #3		Sign #4		Sign #5	
.010	.000	.012	.000	.000	.000	.000	.000	.000	.000
.029	.006	.167	.000	.053	.000	.083	.000	.074	.000
.071	.012	.333	.000	.083	.013	.090	.066	.222	.000
.286	.050	.417	.071	.167	.042	.333	.019	.222	.043
.792	.779	1.00	.756	.833	.650	1.00	.679	.667	.799
.929	.906	1.00	.884	.917	.884	1.00	.779	.889	.813
1.00	.997	1.00	.997	1.00	.988	1.00	.919	.963	.929
d'	= 1.08	d'	= 1.27	d'	= .80	d'	= 1.61	d'	= .98

Sign #6		Sign #7		Sign #8		Sign #9		Sign #10	
.000	.003	.000	.000	.000	.000	.000	.000	.000	.000
.167	.009	.087	.000	.267	.006	.083	.000	.071	.000
.250	.021	.087	.000	.553	.012	.333	.019	.142	.000
.583	.101	.261	.031	.667	.046	.500	.075	.214	.006
1.00	.794	.957	.765	.917	.822	.833	.820	.929	.772
1.00	.920	1.00	.905	1.00	.923	.917	.910	1.00	.907
1.00	.969	1.00	.997	1.00	.997	1.00	.997	1.00	.967
d'	= 1.48	d'	= 1.24	d'	= 2.08	d'	= 1.40	d'	= 1.69

TABLE 3-35. Some Selected Signs — Laboratory Experiment. Performance of U.S. Signs Within Their Own Set.

Sign #2		Sign #6		Sign #7	
.350	.007	.222	.010	.389	.000
.778	.020	.500	.015	.667	.005
.800	.060	.677	.030	.723	.020
.963	.075	.780	.076	.898	.059
1.00	.196	.961	.216	1.00	.205
1.00	.267	1.00	.511	1.00	.460
1.00	.550	1.00	.700	1.00	.715
d' =	3.15	d' =	2.17	d' =	2.83

Sign #9		Sign #10	
.291	.000	.200	.000
.416	.010	.550	.007
.560	.037	.778	.040
.700	.050	.900	.080
.909	.277	1.00	.187
1.00	.516	1.00	.385
1.00	.725	1.00	.698
d' =	2.16	d' =	2.68

TABLE 3-36. Some Selected Signs — Laboratory Experiment. Performance of U.S. Signs Within Their Own Set.

20 msec.

Sign #2		Sign #6		Sign #7		Sign #9		Sign #10	
.500	.000	.500	.000	.489	.000	.300	.000	.500	.000
.780	.005	.600	.009	.609	.000	.650	.005	.600	.000
.850	.010	.750	.015	.700	.007	.750	.015	.750	.010
.950	.050	.800	.027	.820	.020	.875	.049	.800	.029
1.00	.157	.970	.217	1.00	.202	.980	.195	1.00	.160
1.00	.360	1.00	.383	1.00	.390	1.00	.406	1.00	.384
1.00	.610	1.00	.709	1.00	.626	1.00	.667	1.00	.711
d'	= 3.28	d'	= 2.72	d'	= 2.96	d'	= 2.82	d'	= 2.72

15 msec.

Sign #2		Sign #6		Sign #7		Sign #9		Sign #10	
.260	.009	.222	.020	.200	.000	.190	.000	.180	.000
.477	.010	.300	.045	.350	.005	.217	.025	.275	.012
.563	.078	.500	.050	.400	.026	.336	.029	.300	.039
.780	.087	.760	.090	.500	.043	.440	.057	.580	.060
1.00	.270	.889	.279	1.00	.303	.600	.340	1.00	.300
1.00	.393	1.00	.386	1.00	.416	1.00	.526	1.00	.506
1.00	.786	1.00	.802	1.00	.778	1.00	.790	1.00	.609
d'	= 2.11	d'	= 2.04	d'	= 1.95	d'	= 1.40	d'	= 1.75

TABLE 3-37. Some Selected Signs — Laboratory Experiment. Performance of Alternate Signs Within Their Own Set.

Sign #1		Sign #3		Sign #4	
.367	.007	.490	.000	.330	.000
.497	.011	.609	.000	.556	.000
.605	.029	.715	.020	.633	.009
.811	.053	.800	.029	.700	.015
.956	.182	1.00	.190	.933	.190
.989	.217	1.00	.330	1.00	.320
1.00	.578	1.00	.595	1.00	.511
d' = 2.52		d' = 2.72		d' = 2.58	

Sign #5		Sign #8	
.312	.007	.412	.002
.426	.010	.510	.015
.520	.025	.700	.023
.636	.039	.820	.059
.810	.217	.923	.173
.926	.370	1.00	.303
1.00	.520	1.00	.505
d' = 2.11		d' = 2.46	

TABLE 3-38. Some Selected Signs — Laboratory Experiment. Performance of Alternate Signs Within Their Own Set.

20 msec.

Sign #1		Sign #3		Sign #4		Sign #5		Sign #8	
.511	.000	.500	.000	.500	.000	.375	.005	.510	.000
.626	.007	.625	.000	.750	.000	.500	.010	.725	.000
.702	.010	.750	.007	.795	.000	.690	.029	.797	.020
.898	.026	.800	.013	.820	.013	.750	.033	.898	.035
.990	.150	1.00	.128	.950	.136	.900	.202	1.00	.119
1.00	.300	1.00	.290	1.00	.285	.950	.315	1.00	.356
1.00	.653	1.00	.580	1.00	.517	1.00	.626	1.00	.670
d'	= 3.16	d'	= 3.16	d'	= 3.24	d'	= 2.56	d'	= 3.03

15 msec.

Sign #1		Sign #3		Sign #4		Sign #5		Sign #8	
.200	.010	.318	.000	.117	.000	.126	.005	.217	.007
.350	.022	.496	.000	.256	.000	.375	.025	.400	.027
.400	.033	.512	.020	.393	.015	.420	.036	.510	.033
.500	.040	.603	.040	.513	.023	.550	.036	.660	.050
.725	.211	.756	.311	.650	.390	.798	.200	.789	.297
.900	.363	.920	.397	.825	.526	.910	.397	.853	.412
1.00	.750	1.00	.690	1.00	.700	1.00	.680	1.00	.620
d'	= 1.75	d'	= 2.00	d'	= 2.08	d'	= 1.68	d'	= 2.05

presented in Table 3-39 broken down according to color (disregarding confusions across color) and pooled across exposure durations. These data, broken down further according to exposure durations are presented in Table 3-40. Estimate of d' are included in each of the Tables.

The final breakdown of the stimulus set regards those signs with word legends, and those without. Nos. 2, 5, 6, 7, 9, and 10 incorporate word legends; Nos. 1, 3, 4, and 8 do not incorporate a word legend. Data relevant to this breakdown are presented in Table 3-41.

TABLE 3-39. Some Selected Signs — Laboratory Experiment. Performance of Signs Within Color Sets.

Red Stimuli

Sign #1		Sign #3		Sign #4		Sign #5	
.427	.000	.375	.000	.366	.000	.398	.002
.519	.000	.500	.000	.422	.002	.512	.015
.758	.009	.725	.009	.530	.013	.587	.019
.850	.035	.900	.011	.778	.023	.699	.020
.970	.195	1.00	.207	.923	.200	.780	.195
1.00	.359	1.00	.411	1.00	.365	.921	.370
1.00	.630	1.00	.675	1.00	.690	1.00	.709
d' = 2.79		d' = 3.60		d' = 2.82		d' = 2.58	

Sign #7		Sign #8	
.411	.000	.404	.003
.522	.000	.526	.013
.670	.010	.667	.040
.725	.027	.720	.051
.931	.292	.987	.206
1.00	.350	1.00	.390
1.00	.712	1.00	.673
d' = 2.49		d' = 2.22	

Yellow Stimuli		Black on White Stimuli	
.372	.008	.328	.000
.651	.031	.613	.036
.822	.039	.759	.051
.915	.085	.934	.066
.961	.178	.949	.241
.969	.349	.964	.387
.992	.628	1.00	.672
d' = 2.74		d' = 2.94	

TABLE 3-40. Some Selected Signs — Laboratory Experiment. Performance of Signs Within Color Sets.

Red Stimulus Only

20 msec.

Sign #1		Sign #3		Sign #4		Sign #5	
.447	.000	.495	.000	.500	.000	.404	.000
.590	.000	.755	.000	.725	.000	.626	.000
.868	.007	.923	.003	.810	.004	.778	.007
.955	.025	1.00	.050	.910	.009	.889	.025
1.00	.068	1.00	.110	.919	.075	.910	.150
1.00	.311	1.00	.296	1.00	.296	1.00	.325
1.00	.595	1.00	.505	1.00	.560	1.00	.606
d' = 3.63				d' = 3.69		d' = 3.11	

Sign #7		Sign #8	
.398	.000	.395	.000
.506	.005	.420	.005
.693	.012	.510	.015
.802	.032	.710	.022
.926	.090	.889	.095
1.00	.260	.966	.298
1.00	.583	1.00	.560
d' = 2.72		d' = 2.60	

15 msec.

Sign #1		Sign #3		Sign #4		Sign #5	
.217	.000	.311	.000	.300	.000	.202	.005
.400	.000	.580	.000	.450	.010	.523	.015
.660	.009	.626	.010	.550	.030	.623	.023
.720	.050	.700	.059	.700	.035	.715	.040
.920	.256	.909	.223	.820	.251	.818	.212
1.00	.480	1.00	.502	.900	.395	.956	.390
1.00	.606	1.00	.717	1.00	.616	1.00	.670
d' = 2.22		d' = 2.08		d' = 2.28		d' = 2.33	

Sign #7		Sign #8	
.205	.000	.262	.010
.416	.007	.313	.012
.511	.020	.572	.043
.707	.058	.600	.055
.826	.271	.797	.290
.990	.392	.868	.313
1.00	.708	1.00	.717
d' = 2.10		d' = 1.80	

TABLE 3-40 (cont'd)

Yellow Stimulus Only — Signs #6, #9

20 msec.		15 msec.	
.509	.000	.306	.006
.667	.014	.581	.006
.877	.018	.742	.019
.982	.070	.839	.051
1.00	.155	.919	.121
1.00	.324	.935	.268
1.00	.592	.984	.535
d' = 3.52		d' = 2.63	

Black on White Stimulus Only — Signs #2, #10

20 msec.		15 msec.	
.325	.000	.286	.000
.649	.013	.486	.066
.779	.013	.629	.098
.961	.026	.771	.115
.961	.211	.800	.279
.974	.342	.814	.443
1.00	.671	1.00	.672
d' = 3.63		d' = 1.92	

TABLE 3-41. Some Selected Signs — Laboratory Experiment. Performance of Signs Within Sets: With, Without Legend.

Signs With Legends

Sign #2		Sign #5		Sign #6	
.243	.006	.289	.000	.220	.003
.454	.026	.455	.006	.492	.019
.678	.032	.710	.014	.773	.030
.954	.035	.910	.022	.894	.038
.967	.243	.938	.245	.901	.303
.987	.433	.979	.408	.947	.462
1.00	.679	1.00	.675	.992	.675
d' = 3.39		d' = 3.39		d' = 2.98	

Sign #7		Sign #9		Sign #10	
.289	.003	.182	.003	.202	.000
.523	.006	.530	.016	.519	.011
.752	.014	.750	.016	.682	.027
.926	.034	.917	.030	.946	.046
.926	.276	.917	.275	.946	.252
.960	.454	.955	.471	.961	.458
.993	.698	.985	.665	1.00	.664
d' = 3.35		d' = 3.28		d' = 3.28	

Signs Without Legends

Sign #1		Sign #3		Sign #4		Sign #8	
.278	.000	.292	.003	.295	.003	.357	.000
.451	.000	.507	.014	.518	.006	.579	.005
.691	.009	.694	.014	.770	.008	.722	.013
.950	.023	.958	.017	.950	.015	.937	.024
.950	.246	.958	.253	.957	.275	.937	.270
.969	.452	.979	.492	.986	.489	.952	.516
.981	.754	1.00	.758	.993	.764	.976	.783
d' = 3.69		d' = 3.80		d' = 3.69		d' = 3.60	

3.11.2 Road testing of signs

The experiments previously described in this chapter report the performance of the basic elements of traffic control signs, based on a controlled and systematized laboratory test technique. It is natural to ask whether or how these results relate to a more realistic test situation, that is, testing with actual road traffic.

As explained in Sec. 3.1, results of many "simple" road tests are subject to a number of systematic errors or ambiguities. Road testing, *per ipse*, is not necessarily more valid, although it is usually more expensive. To model the eventual performance of a proposed set of traffic control devices (which could include just one new sign) a road test must (a) replace the old set with the new throughout a sizeable test area, (b) expose the driving population to the individual signs in natural locations (i.e., SLIPPERY ROAD signs where this condition does occur) and (c) observe the long-time end results (for a STOP sign, *obedience;* for SLIPPERY ROAD, *incidence* of skidding accidents). This procedure is more like regional implementation than testing, and is far beyond the scope or resources of the present research.

It is, however, useful to ask whether the results change if the test is shifted from the recognition task as isolated in a laboratory to the recognition task imbedded in an actual driving situation. It was this latter form that was conceived for the road experiments; to reproduce the laboratory recognition experiment while adding as much detail of the actual driving task as possible. The situational differences are many. In the laboratory the only task is recognition. The observer is seated at a fixed distance from and has a continually unobstructed view of the point of stimulus presentation. The stimulus always appears after an audible and visible warning cue.

The laboratory experiment to be replicated on the road was that using the ten selected signs shown in Fig. 3-40. The driving task was not simulated, but used a real car on a real road, and the observer was the driver. By the choice of car and road, and the apparatus to control the amount of visual attention the driver could devote to the task, the experiment attempted to present a driving situation that was both as realistic and as demanding as possible. It was within this driving situation, with its high visual information processing demands, that the sign recognition experiment was conducted. The individual components of this experimental situation, as will be described in the following paragraphs, were carefully chosen.

The Vehicle

The car driven by the observer had been specially purchased for previous research for the Federal Highway Administration. This vehicle had been specified to meet a number of requirements, many quite appropriate to the present experimental use:

(a) The exterior and interior appearance and dimensions were that of an ordinary vehicle, so the car seemed "normal" to the range of observer-drivers.

(b) The driving environment was similar to that experienced by the average American driver. This requirement, which related to seating configuration, level of physical effort required to operate vehicle controls, and vehicle dynamic response to ordinary control inputs, was integrated with requirement (c).

(c) The range of stable and predictable operation (based on population stereotypes) was extended to higher limits of longitudinal accelerations and decelerations and lateral accelerations. Since the experiment involves operation at attention levels that approach the limit of the driver's controlling ability, it was felt that special efforts should be made to extend the safe range of operation of the vehicle and to insure that limit behavior is reasonably predictable from the normal experience.

(d) The vehicles were equipped with optimum available occupant-protective equipment. Although absolute speeds would be low, and no other vehicles would be present, the task was demanding, and error-inducing.

The following illustrates the matching of the vehicle as well as its equipment to the requirements listed above. For item (b) the basic vehicle dimensions (wheelbase, overall length, weight) were matched within 2% to the reported average for full-size, four-door sedans as purchased in the U.S. Such full-size vehicles represented 51.3% of total automobile production in the U.S. for the year reported (1967).

By matching the wheelbase, weight, and length, quite a number of vehicle-behavior parameters that affect the "feel" to the driver are simultaneously matched. For example, quickness of steering is matched since it is related to wheelbase and steering gear ratio at low speeds and in addition, polar moment of inertia at higher speeds. The steering response time, which depends on the center-of-gravity height and suspension damping ratio, and the ride and pitch frequencies (controlled by the vehicle weight, spring rates, and pitch polar moment), are also well matched to the weighed average by matching the three selected parameters as described.

The Road

The road used for the experiment was Bryar Motorsport Park. This track, shown in Fig. 3-41, is typical of many road racing circuits: the outer circuit has a total length of 1.6 miles with 10 turns of varying direction and radii, and numerous elevation changes. The road surface is smooth asphaltic concrete as used in modern highway construction. Many of the turns are superelevated, following the formulae used by the New Hampshire Highway Department, but extrapolated to the smaller radii used on the track layout. All roadway is a minimum of 28 ft wide, and all curves are a minimum of 40 ft wide. This road is considered a good example of the narrow, winding, hilly country road that places considerable demands on a driver. All driving was done in a clockwise direction around the outer circuit, presenting the driver with four left-hand and six right-hand curves.

Equipment for Varying Driver Attention

Control of driver attention is based on a translucent screen which can be periodically lowered over the driver's eyes and through which no road or vehicle detail can be seen. This screen is the pivoting face shield of a protective helmet actuated by a pneumatic cylinder mounted on the helmet. The visor action can be seen in Fig. 3-42.

The pneumatic cylinder is powered from a CO_2 bottle, pressure regulated to 5-7 psi and the gas flow controlled by a solenoid valve. The electrical control to the solenoid valve derives from an interval timer which cycles the visor up or down for

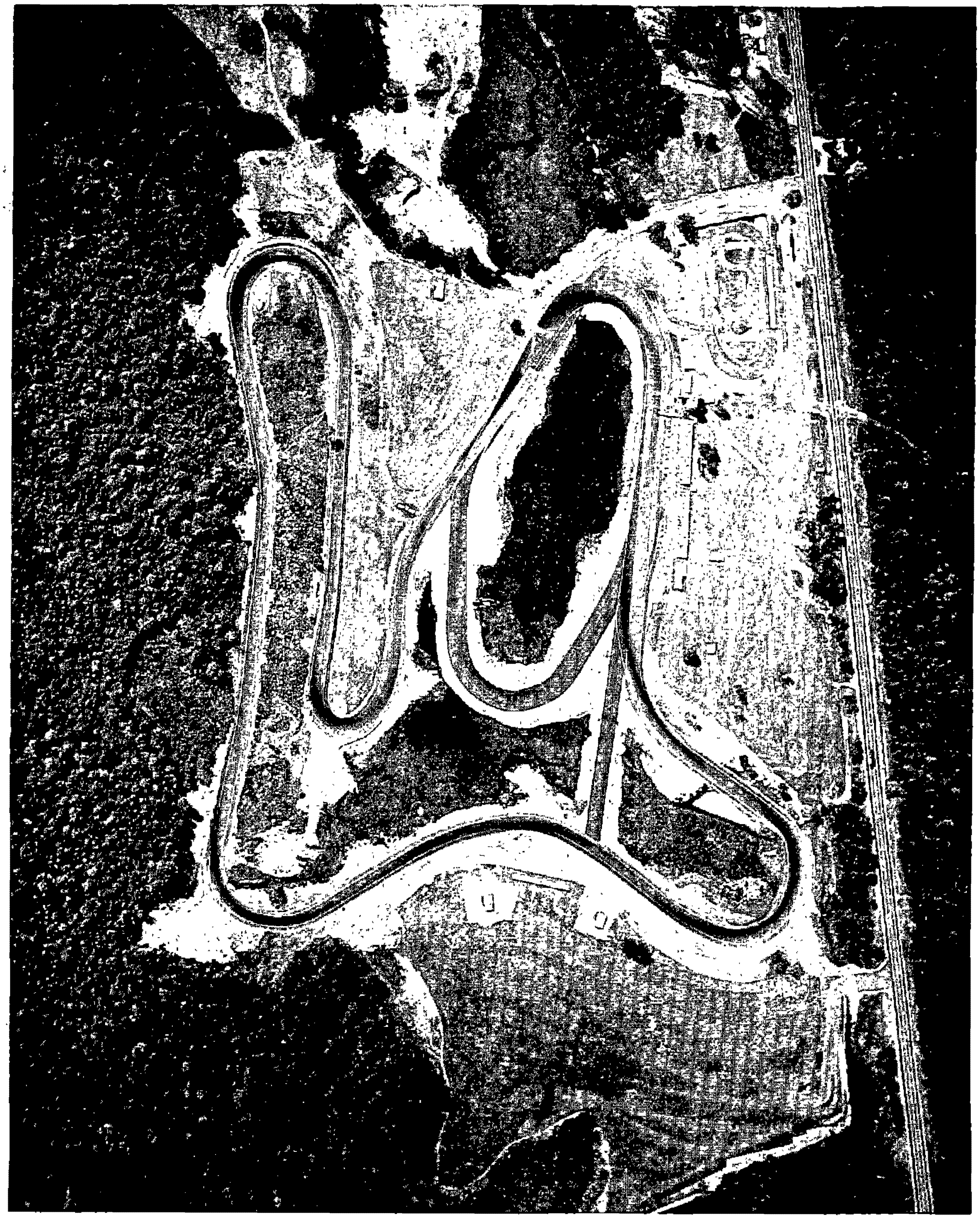


FIG. 3-41 BRYAR MOTORSPORT PARK, LOUDON, NEW HAMPSHIRE.

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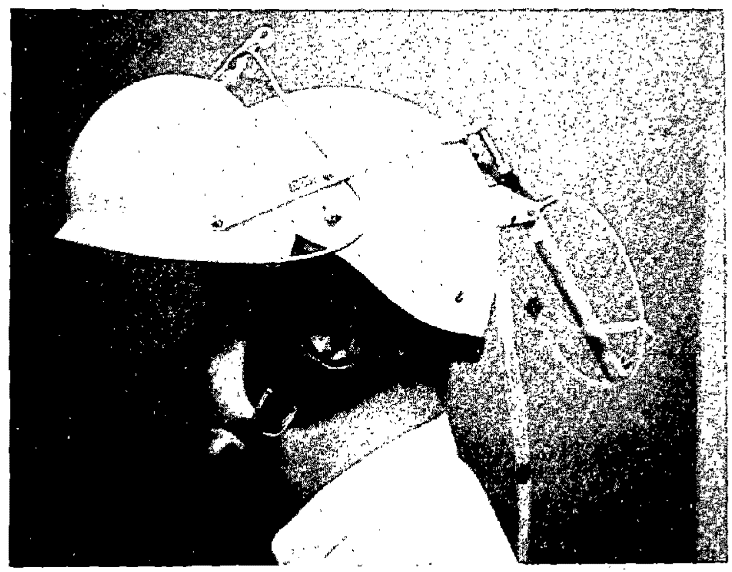
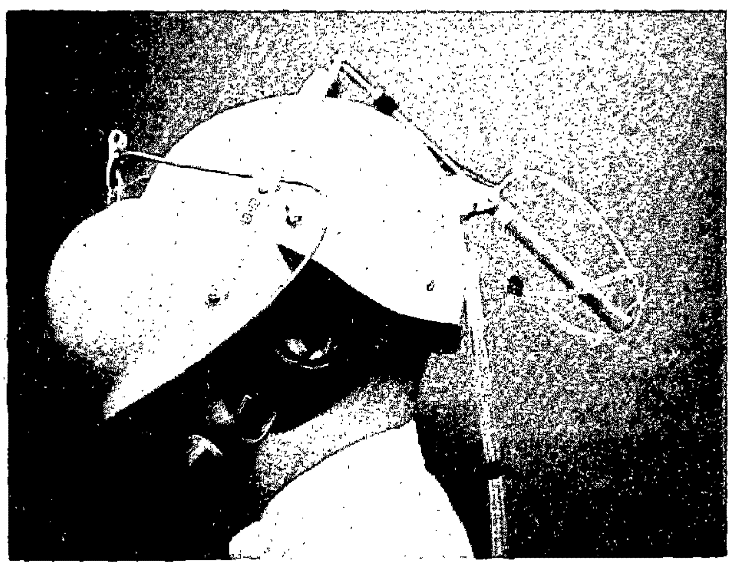


(a)



(b)

FIG. 3-42 VISION INTERRUPTION APPARATUS.

fixed time intervals. The time intervals for up or look time (T_L) and the down time (T_D) could be adjusted from 0.2 to 20 seconds. A "dead man" safety switch for the experimenter held the visor up unless this foot switch was held depressed. Only the timer controls and safety switch were placed in the front passenger space with the experimenter. The remainder of the apparatus (CO_2 supply tank, power inverter, solenoid valve, other control switches, valves, and meters) were mounted together on a platform fitted to a rear footwell of the car.

The motivation for the use of the vision interruption apparatus described is twofold: efficiency and safety. As just described, the test road is rather demanding to drive at "normal" speeds, and the experiment could have asked the driver to drive as fast as possible, without leaving the marked roadway (error-free driving). Under these circumstances drivers who had no inhibition about speed itself would find themselves driving parts of the road at a speed limited by their ability to process visual information, and parts at speeds limited by the capabilities of the vehicle. For those curves and parts of the road where information processing capabilities were taxed, the recognition experiment stimuli could be displayed at random, and the observer/driver's responses recorded. For those easier stretches, the attentional demand of the road would be so low that such an experiment would yield near-perfect scores, useless for comparative recognition tests.

Obviously, such speeds would put excessive stresses on the vehicle, and considerably increase the risk of injury in case of an off-road excursion. The vision interruption apparatus can impose a sampling rate that reduces markedly the amount of visual information the driver can process per unit time. Thus the driver can still drive to the limit, and the visual information processing task will set his maximum speed everywhere on the road. In this way a larger number of stimulus display locations can be used.

The look interval was chosen to give the observer time for a single visual fixation. Visor operating times that yield 7–15% vision (such as T_D=3 sec, T_L=0.4 sec) can limit a driver to speeds for curves and tangent sections that are close to those chosen for a "normal" drive on such a road.

Display of Experimental Stimulus

Eleven possible locations were selected along the roadside for display of the experimental stimulus. At each location, a portable sign holder was assembled. This sign holder, shown in Fig. 3-43, has a set of magnets and a locating pin which hold the changeable display in place. A clear plastic backing prevents wind forces from dislodging the display.

Since the signs in the stimulus set were not all the same shape, they were normalized to a 200 sq in. area. Each sign in the stimulus set was then reproduced in color on poster board. Steel plates (for the magnetic attachment) were glued to the back. An entire stimulus set was stored at each display location; only a few seconds were required to replace one display with another.

Observer/Drivers

The observer/driver selection procedure used more than the minimum requirement: a license to drive. The road experiments

(a) Sign holder, showing magnets for sign attachment.

(b) Sign on holder. Folder at base contains the 9 other signs.

(c) Typical sign position along road.

FIG. 3-43 THE ROAD EXPERIMENT STIMULUS.

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entail considerably more effort and potential risk than the corresponding laboratory tests, and this influenced the choice of observer/drivers. The goal was to achieve good motivation for what was a demanding mental and physical task. Selection standards were chosen that favored rapid stabilization of performance, coupled with an opportunity to get insight into the experiment from the observer viewpoint. The requirements beyond a license were (a) an expressed liking for the normal experience of driving, (b) current or recent experience in driving a car of this type, and (c) daily driving experience and a minimum of 50,000 miles total driving experience. All observers were given between 100 and 200 miles of familiarization with the test vehicle on public highways, and a minimum of ten laps on the test road using the vision interruption apparatus.

To test the influence of this selection procedure, the performances of three "normal" observers and three "selected" observers were compared. The "normal" group drove very slowly at first; often they were unable to avoid driving errors unless a shorter vision interruption interval (T_D) was used, corresponding to an increase in the sampling rate. This group was able to use the same sampling rate as the "selected" group after an extended learning period, although they continued to drive at somewhat lower and more erratic speeds. The recognizability test scores for the individual stimuli were generally lower for the "normal" group. Significantly, the relative performance of the stimuli was not different for the two observer groups. This finding is in complete agreement with the results of laboratory tests (Sec. 3.9.1) comparing "bright" and "average" observers. Most importantly, the results suggest that no biasing of the results would result from the use of the selection procedure.

3.11.3 Some selected signs on the road

Method

The stimuli used in this series of experiments were the same as those used in the preceding laboratory experiment and are shown in Fig. 3-40.

Six observer/drivers were used over a period of 12 days at the test road. In each test session, which lasted approximately two hours, observers were used in pairs. Three such sessions were run in a day.

The experiment was arranged so that the observer/driver was driving the test vehicle along the test road at the limit of his ability to process visual information, as described in the preceding section. In a single lap, each observer drove by the 10 stimuli displayed alongside the road, as seen in Fig. 3-44. At the end of the lap, the observer finishing his run was replaced by the alternate. At the end of the next lap, the display stimuli at each of the 10 positions were replaced with a new set randomly selected from the 10 possibilities at each position. At the end of the succeeding lap, the first observer drove once more, allowing the alternate to rest. Each randomly selected set of stimuli displayed at the 10 locations alongside the road was thus seen by two observers, for a total of 20 observations, before a new set was displayed. In the course of the experiment the six observers made 280 laps, for a total of 2800 trials, the number used at one exposure duration in the laboratory experiment.

Each observer was provided with a copy of Fig. 3-40, and required to memorize the five sign names YIELD, DO NOT ENTER, NO RIGHT

(a) Subject and Experimenter.

(b) The Experimental Stimulus.

FIG. 3-44 THE ROAD EXPERIMENT.

TURN, SCHOOL CROSSING, and STOP. He was also required to memorize two categories: *standard* (stimuli 2,6,7,9,10) and *alternate* (stimuli 1,3,4,5,8). On each trial the observer was required to indicate by calling out the name and category which of the ten stimuli had most likely been presented. In addition the observers were required to indicate the confidence they attributed to their answers. These confidence ratings were given on a four-point scale ranging from *very sure* to *very unsure*. The experimenter, seated in the front right, recorded the answer and confidence rating.

The sampling rate of the vision interruption apparatus worn by the observer/driver was set at 0.3 sec T_L (look time) and 3.0 sec T_D, allowing vision 9% of the time. Each observer was instructed to drive as fast as possible, while making no driving errors. The white lines at the road edge were considered to define the "driving lane" and crossing the white line was to be considered an error, equal to complete loss of control in normal driving. Crossing the white line was cause to reject the trial data at that location. Drivers were given a short rest after each pair of laps as noted above. For the visual sampling rate used, the performance of the subjects was usually driving error free during a session. As the subjects learned the vehicle and road, their driving speeds rose slightly. This increase in speed (from 22 to 28 mph for example) automatically increased the attentional demand rate of the driving task and kept the observer operating at his self-assessed limit of ability to process visual information.

Results

The basic data were reduced as in the previous laboratory experiment in accordance with the procedure detailed in Sec. 3.3. Because this stimulus set involved the simultaneous presence of several graphic design elements a variety of breakdowns of the basic data are possible. Those breakdowns previously reported for the laboratory data will be repeated.

The basic road experiment data, pooled over all observers is presented in Table 3-42, and d' estimates are given.

The first breakdown to be made in the stimulus set is between the set of standard U.S. signs (stimuli 2,6,7,9,10) and the set of their alternatives (stimuli 8,4,5,1,3, respectively). The performance of such signs *within their own set* can be isolated from the basic data by separating out the data for correct identifications and confusions of signs within one set. The appropriate data for U.S. signs are presented in Table 3-43, along with estimates of d' abstracted from this reduced data base. The relevant data for the alternative set is similarly presented in Table 3-44.

A second way the stimulus set can be broken down is according to color: the set of five red signs (stimuli 1,7,8,3,4,5), the two yellow signs (stimuli 6 and 9), and the two black-on-white signs (stimuli 2 and 10). The relevant data are presented in Table 3-45 by color set (disregarding confusions between color sets), and are accompanied by appropriately estimated values of d'.

The third breakdown of the stimulus set is into two sets, one with word legends, and one without. Stimuli 2,5,6,7,9,10 include word legends, stimuli 1,3,4,8 do not. Data and estimates of d' relevant to this breakdown are presented in Table 3-46.

TABLE 3-42. Some Selected Signs — Road Experiment

Sign #1		Sign #2		Sign #3		Sign #4		Sign #5	
.273	.004	.136	.000	.353	.004	.267	.000	.136	.000
.394	.004	.318	.022	.510	.004	.367	.007	.409	.000
.455	.007	.364	.036	.569	.032	.433	.026	.455	.009
.606	.075	.500	.069	.627	.039	.533	.086	.500	.044
.909	.352	.818	.386	.902	.389	.833	.379	.864	.318
.969	.521	.818	.549	.980	.547	.933	.528	.955	.385
1.00	.734	.909	.726	1.00	.756	.967	.732	.955	.755
d' = 1.68		d' = 1.47		d' = 2.08		d' = 1.42		d' = 1.75	

Sign #6		Sign #7		Sign #8		Sign #9		Sign #10	
.226	.004	.296	.003	.196	.004	.435	.000	.038	.000
.419	.007	.407	.009	.413	.016	.609	.007	.115	.004
.516	.011	.481	.022	.456	.040	.652	.011	.154	.004
.548	.026	.519	.041	.478	.063	.739	.055	.231	.014
.839	.373	.815	.334	.739	.413	.957	.369	.574	.382
.903	.537	.963	.627	.935	.540	.957	.544	.692	.544
1.00	.728	1.00	.803	1.00	.718	.957	.745	.962	.721
d' = 2.01		d' = 1.80		d' = 1.50		d' = 2.19		d' = 1.31	

TABLE 3-43. Some Selected Signs — Road Experiment. Performance of U.S. Signs Within Their Own Set.

Sign #2	
.333	.000
.690	.067
.833	.081
.952	.100
.976	.255
1.00	.383
1.00	.658

d' = 2.92

Sign #6	
.346	.007
.577	.022
.750	.050
.769	.101
.904	.223
.962	.309
1.00	.669

d' = 2.02

Sign #7	
.659	.007
.756	.007
.829	.014
.902	.036
.927	.214
.976	.371
1.00	.807

d' = 3.03

Sign #9	
.383	.000
.638	.014
.702	.035
.723	.078
.851	.213
.936	.319
.957	.681

d' = 1.98

Sign #10	
.382	.000
.559	.020
.618	.034
.824	.034
.941	.176
.971	.331
1.00	.649

d' = 2.80

TABLE 3-44. Some Selected Signs — Road Experiment. Performance of Alternate Signs Within Their Own Set.

Sign #1		Sign #3		Sign #4	
.333	.000	.250	.000	.389	.000
.544	.004	.589	.008	.556	.000
.667	.021	.696	.042	.648	.004
.760	.068	.786	.092	.741	.079
.930	.336	.964	.361	.889	.328
1.00	.443	.982	.471	.963	.456
1.00	.685	1.00	.668	1.00	.701
d' = 2.18		d' = 2.14		d' = 2.04	

Sign #5		Sign #8	
.365	.000	.333	.000
.577	.000	.550	.008
.615	.012	.617	.008
.673	.049	.733	.008
.885	.329	.950	.275
.962	.461	1.00	.517
1.00	.695	1.00	.725
d' = 2.08		d' = 2.07	

TABLE 3-45. Some Selected Signs — Road Experiment. Performance of Signs Within Color Sets

Red Stimulus Only

Sign #1		Sign #3		Sign #4		Sign #5	
.317	.000	.241	.000	.368	.000	.358	.000
.517	.003	.569	.006	.526	.000	.566	.003
.633	.017	.672	.039	.614	.007	.604	.010
.750	.074	.776	.084	.702	.070	.660	.046
.933	.293	.966	.342	.860	.295	.887	.289
1.00	.421	.983	.458	.965	.423	.962	.438
1.00	.660	1.00	.658	1.00	.668	1.00	.668
d' = 2.14		d' = 2.17		d' = 2.00		d' = 2.05	

Sign #7		Sign #8	
.429	.000	.303	.000
.492	.003	.500	.034
.540	.020	.561	.038
.587	.047	.667	.038
.762	.315	.894	.306
.857	.451	.970	.454
1.00	.685	1.00	.656
d' = 1.87		d' = 2.19	

Yellow Stimulus Only

Sign #6		Sign #9	
.367	.024	.367	.000
.612	.048	.612	.043
.796	.095	.786	.106
.816	.190	.810	.191
.898	.214	.905	.213
.959	.286	.952	.362
1.00	.571	.976	.617
d' = 1.80		d' = 1.76	

Black on White Stimulus Only

Sign #2		Sign #10	
.318	.000	.333	.000
.659	.256	.487	.068
.795	.282	.538	.091
.909	.282	.718	.091
.909	.462	.744	.204
.932	.513	.744	.341
1.00	.667	1.00	.682
d' = 1.92		d' = 1.92	

TABLE 3-46. Some Selected Signs — Road Experiment. Performance of Signs Within Sets: With, Without Legend.

Signs With Legends

Sign #2		Sign #5		Sign #6	
.298	.000	.432	.000	.346	.005
.617	.043	.682	.004	.577	.014
.745	.060	.727	.022	.750	.032
.851	.112	.795	.044	.769	.065
.894	.246	.932	.204	.904	.226
.936	.323	1.00	.342	.962	.336
1.00	.534	1.00	.591	1.00	.576
d' = 2.27		d' = 2.59		d' = 2.21	

Sign #7		Sign #9		Sign #10	
.587	.004	.367	.000	.277	.000
.674	.004	.612	.009	.404	.013
.739	.009	.673	.023	.447	.030
.804	.027	.694	.051	.596	.030
.848	.210	.837	.217	.745	.185
.934	.353	.939	.336	.787	.323
1.00	.629	.959	.581	1.00	.534
d' = 2.72		d' = 2.14		d' = 2.14	

Signs Without Legends

Sign #1		Sign #3		Sign #4		Sign #8	
.352	.000	.286	.000	.447	.000	.345	.000
.574	.007	.673	.000	.638	.000	.569	.000
.704	.020	.796	.044	.745	.000	.638	.000
.833	.073	.898	.101	.851	.050	.759	.000
.944	.258	.980	.296	.936	.248	.948	.207
1.00	.364	.980	.409	1.00	.391	1.00	.367
1.00	.636	1.00	.623	1.00	.671	1.00	.640
d' = 2.42		d' = 2.56		d' = 2.68			

Discussion

The results from this series of road experiments are, as mentioned, of interest in comparison with the results obtained from the same stimulus set in the laboratory, but not particularly of interest or moment themselves. Indeed, the least valid use for these results would be as an evaluation of the practical performance of the particular 10 signs used as experimental stimuli. This is true for a number of reasons; certainly because no stretch of the imagination could suggest that this set represented a complete or a meaningful part of a *system* of traffic control signs. If a sign one might like to evaluate *does* appear in the set, the signs it should be evaluated with *do not* appear in the set. Thus, as pointed out in the beginning of this chapter, it is only too possible for the considerable effort to get statistically significant answers to be expended on a question with no practical significance.

The appropriate comparisons between the road experiment results and the laboratory experiment results reported in Sec. 3.11.1 can be made from the paired data breakdowns.

The basic data from the laboratory are shown in Tables 3-33 and 3-34; the comparable data from the road tests are in Table 3-42. A comparison of d', the measure of recognizability, shows the road test values are generally lower than the laboratory values derived from the pooled data (Table 3-33) but lie between the data for 15 msec and 20 msec exposure times (Table 3-34). This suggests that the effective visual information processing time for the road experiment was not the entire 0.3 sec (or 300 msec) look time (T_L), but rather only a fraction of that. Moreover, this fraction could be as low as 5–6% if we assume the laboratory and road observer groups had equal recognition abilities. This is strong evidence that the attentional demand of the driving task, as desired, left little visual processing reserve for a sign recognition task.

The relative recognizability of individual signs in the set shows differences between the laboratory tests and the road tests. By marking three equal intervals of d' between the lowest and highest values reported for each experiment, the signs can be grouped into arbitrary categories of recognizability. This arrangement is shown in Table 3-47.

TABLE 3-47. Some Selected Signs — Comparison of Tests.

Recognizability Category	Road Tests	Laboratory Tests
upper	Sign #3,6,9	Sign #2,7,10
middle	1,5,7	1,3,8
lower	2,4,8,10	4,5,6,9

The greatest difference in performance is seen for DO NOT ENTER (#2), SCHOOL CROSSING (#6), YIELD (#9), and NO RIGHT TURN (#10). DO NOT ENTER and NO RIGHT TURN have superior performance in the laboratory. These signs are both rectangular, and in the laboratory both the 35mm slide aperture and the projection screen provide a comparison rectangular format that is not present on the road. Both YIELD and SCHOOL CROSSING are yellow. The "disappearance" behavior of yellow shapes at short visual exposure times reported in Sec. 3.8.1 is borne out by the poor performance observed in the laboratory for these two signs.

The performance of U.S. signs within their own set is reported in Tables 3-35 and 3-43 for the laboratory and road respectively.

The relative performance within the set was quite consistent across the test procedures; and it should be noted that here the average d' values were nearly equal. Tables 3-37 and 3-44 show that the alternative signs, evaluated within their set matched almost as well, and again showed average d' values between test procedures that were nearly equal. The relative performance of these two sets did not change with test procedure.

It has been noted that the base data for the 10-sign set shows a wider gap between average d' values for the two test techniques than is observed for either the U.S. or alternate signs within their own set. This finding can be interpreted simply as the presence of more confusion *between sets* in the road test observations than in the laboratory test observations.

Examination of the data broken down by color sets (Tables 3-41 and 3-46) is revealing. The road test d' values always are lower than the laboratory values pooled for exposure times. The difference is greatest in the yellow signs and the black-on-white signs. In the road tests, the members of both these sets were less distinguishable (within the set) than members of the red set. In the laboratory, the opposite was nearly true; the red set performed as well as the yellow and poorer than the black-on-white set. The first comparison just reports the relative difficulty of the recognition task for the two test procedures and observer groups. The second comparison suggests that the red signs have cues that are better utilized than those of yellow or black-on-white signs when the testing is done on the road.

Finally, the breakdown with regard to the presence or absence of word legends, as seen in Tables 3-41 and 3-46 show little surprises. The average d' values are again lower for the road test results. The order of recognizability within sets is quite close, and the relative performance of the sets with and without legend does not change with test procedure.

In summary, the detailed comparison of the road and laboratory test results is reassuring. The transfer of the recognition task into a real driving environment did not upset the laboratory findings. The reader should recall that the test stimuli were an unorthodox mixture of complete signs and combined cues of shape, color and content (pictograph, symbol or legend). Whenever this selection of signs was broken down into meaningful sets, the relative recognizability of the signs in the sets was stable across test techniques. Only when the entire stimulus set was analyzed together did several major differences appear, and these seem related to the laboratory test procedures. One of these differences had been observed earlier for brief exposures of color.

These comparisons point out that, with due consideration of artifacts of the laboratory results, the researcher on traffic control devices can use laboratory recognition tests as an efficient research technique to supplement road recognition tests. In this way, it is possible to achieve considerable economies and experimental flexibility.

4. CONCLUSIONS

4.1 Warning and Regulatory Signs

Comments about warning and regulatory signs will be grouped together because they have in common the property that the messages they convey form a reasonably limited set of alternatives - as opposed, for example, to guide signs. That is, the well-educated motorist, driving down a road, seeing a sign which he can classify as to warning, or regulatory, can make a reasonably good guess as to just what its message is. The important advantage of this should be obvious. Let us spell out on which factors the advantage depends.

First, the sign must be able to be quickly and easily categorized at a distance. Currently a distinct shape and distinct color(s) (ignoring the YIELD sign) serve to define the warning sign. Warning signs are diamond-shaped, and yellow (with orange and differently shaped purple proposed), and, as the experiments have indicated, both the shape code and the color code are recognizable. (An unfortunate exception is retention of the circular RAILROAD CROSSING sign.) For regulatory signs, several shapes - rectangle, octagon, triangular and circular (as proposed) - are used, as are several distinct colors - white and red; again, this study and others have demonstrated the recognizability of these. Note that in the case of regulatory signs as newly proposed, a "red" subcategory of messages is being defined, and in the case of warning signs, two new subcategories, "orange" and "purple" are being defined. In all, then, there will be five distinct and recognizable subcategories under the general heading of regulatory and warning signs, and a few others comprising guide signing.

Psychologists have, in other areas, shown that the number of categories conveniently kept in mind is in the neighborhood of seven, so one can assume that a well-educated motorist can make the initial classification by category. How good a guess the motorist can now make about the precise message of a sign depends on (1) the number of alternatives in the category, and (2) how many additional cues are given by such things as road geometrics, the behavior of preceding vehicles, and the like.

In the "purple" subcategory there will be two alternatives; in the "red" subcategory there will be three; and a substantially greater number in the "yellow," "orange," and "white" subcategories. The question is how can we limit the number of alternatives further in the broader regulatory and warning categories. One way is to make even further subdivisions; the U.N. convention to code speed limits with a circular border is an example.

Another avenue is to strive for greater uniformity in regulations — perhaps agreeing that speeds need only be limited to the nearest ten miles per hour, rather than the customary five-mile-per-hour increments. Agreement on a few basic time periods during the day for qualification on signs regulating parking, left turns, etc., is another instance. A relatively few such basic time periods, properly coded, would eliminate the motorist's burden of reading part of the message and checking real time to the nearest half-hour.

As regards general warning signs, any attempt to further delimit the set of alternatives or to divide them into subcategories must await the proper development of a model of driver behavior — specifically, the interaction of driving behavior and warning signs. This report has occasionally remarked on the fact that the number of options open to a driver/vehicle is far smaller than the number of messages directed at that driver/vehicle. A proper model of driver behavior (and, of course, vehicle dynamics – a far easier problem) would allow us to define the options more precisely. It should be clear that it is the driver/vehicle combination, with its two-fold limitations that must be considered. Once these options were defined we could then suggest appropriate subclassifications of warning signs. Certain other distinctions are, of course, reasonably intuitive – for example, contrast the probabilities inherent in a "deer crossing" warning with a curve warning.

In other research, the authors have begun exploration of the operational use of roadway information by drivers. The basis of the technique is the use of the special visual interruption apparatus, which enables the experimenter to control the rate of information presented to the driver or, alternatively, to measure the rate at which he demands information. While this has made a start toward an information-processing model of driver behavior (described elsewhere), a substantial amount of work is still necessary. Here we wish only to argue the priority of such work, encourage investigators toward that end, and point up the relation of that work, seemingly abstract on the face of it, to the very real problems of the design and operation of more effective signs, signals, and markings.

4.1.1 Design of warning signs

From a graphic designer's point of view, the warning signs of the U.S. system, in general, have much to commend them. The use of black on yellow is effective and distinctive. The diamond shape is distinctive, and, for symbolic content or very brief verbal content, very efficient. The advantages of the U.S. format were recognized by the U.N. Group of Experts in their studies and subsequent recommendations.

The diamond is not an efficient shape for complex verbal messages; this, however, would become less of a problem if there were a transition to pictographic images.

Content is something of a problem in warning signs. What hazards should be defined? How specific should that definition be? How can hazards best be communicated? What do we expect from the driver in response to a given sign, or to hazard signs in general?

"The more warning signs there are on the highway, the less significant they become" is a statement often repeated and as often misconstrued. The statement is really an inadequate phrasing of the following problem.

One can think of a motorist's viewing of a warning sign as a stimulus presentation about which a decision must be made — namely, should he believe and heed the warning, or, alternatively, what is the likelihood that the specified danger is actually present? As the motorist passes the sign he sees if in fact the danger was present — that is, he gets "feedback" about his decision. Now, as explained before, one of the factors which affects each decision is the *a priori* likelihood of the danger which the motorist attributes to the message. Influencing this *a priori* evaluation is the past history of feedback in similar circumstances. If, in the motorist's recent prior experience, 90% of such signs have been "false alarms" — feedback showed no danger — then the *a priori* probability of danger estimated by the motorist will be low. If, on the other hand, a similarly high percentage of the time the danger had actually materialized, the motorist would hold a high *a priori* probability of the presence of a danger given a warning sign.

Thus, the significance of warning signs is *not* dependent of the number of warning signs. It depends on the percentage of such warning signs actually followed by feedback indicating a true hazard.

The prescription for more effective warning signs is not to arbitrarily remove so-and-so many of them. One way would be to remove only the signs least often indicating a real hazard. But now we are caught on the horns of a dilemma. It is often those cases where a hazard materializes rarely, but drastically, that the motorist most needs warning. Fortunately, these rarer, but exceptionally important cases, may also contribute to the "significance" or credibility of warning signs. A second component in the motorist's decision can be shown to be the "utility" or importance of the outcome of the decision.

It is unlikely that anyone would argue the importance of warning drivers of impending curves and intersections, or of acute hazards in the roadway. If a car runs into a deer at a given point on the highway, however, is it necessary or meaningful to place a "deer crossing" sign at that point? Do drivers react to such signs? In some areas there are "squirrel crossing" signs; should we also have "raccoon crossing" or, even more important, "skunk crossing" signs? If we were to do so, we might end up with solid walls of hazard signs (not of equal importance) along the highways. What is the optimum? When do we have "enough" and not "too many?" While there

is no pat answer at the moment, the problem is solvable. It is solvable along the lines indicated above - quantifying the probabilities involved, estimating the utilities, and how feedback on the highway changes a motorist's *a priori* evaluations. In short, we are again urging that recent advances in statistical decision theory be applied.

There are questions of another type to be investigated, too. If animal warnings are critical, is it important to define the specific animal? What's the difference in desired driver reaction between a deer crossing warning and a cow crossing warning? Do we need to differentiate between school children crossing, playing children crossing, and other pedestrians crossing?

If pictographs and symbols are used, what should they illustrate? In existing systems, some pictographs illustrate the hazard (falling rocks, for example) while others illustrate the result (such as a skidding car for a slippery road situation).

All of these questions and many others that evolve from them should be answered in an effort to re-evaluate the operational aspects of the warning sign system.

Once an initial list of specific signs has been completed, and an approach to them developed, pictographic symbols, based on the best in the existing systems, but modified to be consistent with each other and the rest of the system, and to be as clear and as effective as possible, should be developed and tested.

4.1.2 Design of regulatory signs

The basic problems of U.S. regulatory signs are the result of the system's use of verbal rather than visual messages.

As we have indicated elsewhere, much has been learned about effective lettering since the current U.S. standards were first instituted, but little of this research has been applied to these standards. If they were to be evaluated against today's understanding of typographic communication, they would fare poorly. As will be discussed in detail in the guide sign section of this report, new lettering standards should be developed.

Even if the alphabets were greatly improved, however, basic layout problems in warning and regulatory signs would not be solved. Current U.S. regulatory signs reflect a layout which seems to imply that the sign maker should do whatever possible to fill the entire sign with the message, using whichever alphabet or alphabets can most efficiently fit on the field. Since sign face sizes are varied by six-inch increments, the actual process seems to be that of attempting a marriage of the most convenient sign face size with the most promising alphabet sizes to produce a finished sign. Although this is a deliberate misinterpretation of a practice which was intended to emphasize, by size, the important word(s) of the message, it is disturbing to note that this misinterpretation appears totally consistent to the outside observer.

The result, of course, is that there are many inconsistancies in size and layout of U.S. regulatory signs. Messages are broken into different sizes and configurations, and are often cramped and obscured by the layout. As we have indicated, this is primarily the result of the need to handle the variety of different verbal message lengths.

The use of a consistent pictographic system, however, would change the situation completely. Such a system would still require careful planning in order to have the internal consistencies which are necessary for maximum effectiveness in communication. By streamlining the number of alternative regulatory messages — eliminating inconsequential differences — the effectiveness of symbolic presentation would be assured.

It is unlikely that any pictographic system could be completely word-free. And, during any transition to a pictographic system, it is likely that verbal confirmations or explanations would be required until the new signs were firmly implanted in drivers' minds. So although a conversion to a pictographic system would change the problems considerably, it would not eliminate them.

Thus, work will still be needed with American standard alphabets and with the layouts of verbal messages within the regulatory section of the U.S. system. This work should be undertaken in connection with any transition to visual messages.

A consistent, logical system is most easily learned and understood. It is therefore important that the rationale behind regulatory signs is consistent throughout, and that this rationale be based not only on visual considerations but also on a consistent philosophy of expression.

Every regulatory sign is the result of a prohibition. Unless there is something that the driver is not allowed to do, then there is no need for a regulatory sign. For example, a RIGHT TURN ONLY sign is needed only when drivers are prohibited from making a left turn or from continuing straight ahead. Although the underlying intent is always to prohibit, it sometimes seems more efficient and emphatic to tell the driver what he must or can do, instead of what he must not do.

Not all systems agree on which instructions are best expressed as permission and which are best handled as prohibition. When pictographic images are used, these questions are still not resolved.

In the Canadian system, for example, most regulatory turn signs are visually permissive: arrows are used to indicate the turns which may be taken and a green ring is used around the image to reinforce the permissiveness. But the NO U TURN sign is an exception and is expressed as a prohibition.

An even greater inconsistency in the current Canadian system involved the use of supplemental plates for the transition period from verbal to symbolic signs. Many of the signs which are visually permissive have plates which are verbal prohibitions.

A consistent and optimal arrangement of prohibitory and mandatory (permissive) regulatory signs has not been worked out. It is a subject which should be studied so that a responsible determination can be made. This determination should then be translated into a system of regulatory signs which could be immediately understood and followed. This task is particularly critical in the urban environment, as we have pointed out in another Chapter, if signs are to help alleviate the congestion of urban traffic.

In developing such a system, careful attention should be paid to the relationship of all signs in the system to each other, and to visual cues in the environment.

For example, in many regulatory sign situations (particularly lane use and turn control signs in the urban environment) the message carried by a sign is often reinforced by other signs or visual cues in the situation. If a driver is at a simple four-way intersection and is faced with a RIGHT TURN ONLY sign, he is also likely to be within viewing range of DO NOT ENTER and/or ONE WAY signs at each of the other corners. He is also likely to be faced with a strong visual cue to the situation as he sees all lanes of the street to his left and front occupied by cars heading into the intersection. Even if there were no signs at all, this flow of traffic might convince him that a right turn was the only move he could make.

We are not suggesting the elimination of regulatory, or in fact, warning signs. Rather we are pointing at the potential use of visual cues - well planned and obvious geometrics - and of other signs in a given traffic situation which may be used to reduce the total number of signs required to keep traffic moving safely and efficiently. We are also calling attention to the fact that each of these signs is an element of a comprehensive system and not a single unrelated piece of visual communication.

As this country moves toward pictographic regulatory signs, it should do so logically and with care. Signs used in other systems should be patiently questioned before they are recommended for incorporation. Designs should be considered in relation to the total U.S. system; not only to the current system but to that of the future as well. The evolution must be planned in advance.

For example, the use of circles of color - red or green - around pictographs on Canadian regulatory signs (some of which are now being recommended for use in this country) does create some semblance of shape similarity between these signs and the circular counterparts now in use elsewhere in the world.

Whether the retention of this circular image is of importance is questionable — regulatory signs tell their story with their specific messages and not by their general shape (excepting the STOP and YIELD sign perhaps). Thus the propagation of the circle may not be so significant.

From a design point of view, it would be much more visually efficient to use the full field of the sign. If a border is helpful, it should follow the configuration of the edge of the sign — i.e., it should be rectangular not circular. If color is critical, perhaps the entire background should be in the significant color, or perhaps the pictograph itself should be colored on a white field. These questions should be answered before the United States embarks on any full-scale transfer to pictographic regulatory signs.

4.2 Guide Signs

With the exception of the British, none of the major sign systems manuals of the world deal extensively with guide sign problems.

The *United States Manual on Uniform Traffic Control Devices* (MUTCD) deals extensively with route markers and arrows. It dwells on placement and on general descriptions of signs. It appears that guide signs have not evolved as a system but rather as a continuing series of additions or revisions to a base established in the very early efforts to produce a coordinate sign system in this country.

Fifty years ago guidance problems were much simpler than they are today. The response which was necessary and appropriate at the time was the development of a very simple set of highway markers so that the driver would know what road he was on, and, if possible, where he was headed.

These are still the primary functions of guide signs. Today, however, there are a great many more roads than there were a half century ago, and there are very many more cars traveling at much higher rates of speed on these roads. The type of information need may have remained a constant, but the type of solution required has changed considerably.

The British recognize this in their new guide signs. They comprise a true system and not a collection of elements. To an extent this has been done in the U.S. Interstate system. All other U.S. guide signs should also be systematically organized, so that they do their jobs in the best possible way, while effectively relating to all other elements of a total sign and communication system.

4.2.1 Route signing

It is appropriate to begin with route number signs.

In most cases, route numbers are enclosed in one type of shield or another. The shield may have been an interesting heraldic device a half century ago, but we must question whether it is appropriate or in any way necessary today. It can be a somewhat awkward shape which restricts the size of the message which is contained within it. If the route number is the message to be communicated we should communicate it as efficiently as possible, and should not decorate it with unnecessary graphic devices.

We should, however, also question the basic premise of the system of route designations. Is the current definition of routes — Interstate, U.S., state, county — at all useful for orienting drivers? Are these designations meaningful to drivers?

Perhaps we should have another system which would differentiate among primary (limited access) highways, secondary highways, and local roads. Perhaps color-coding or other visual means could be used to differentiate among these highways. These same colors could be used on maps as well as being used consistently throughout the sign system. An example is given in Fig. 4-1.

Again we feel it is important to consider signs as an element of a larger communications system. There must be a comprehensive approach to guide sign design problems as there must be to other sign design problems. This approach must include the systematic presentation of information in such a way that the driver will be able to relate sign material and visual cues in the environment as well as those provided by other orientation and guidance materials, such as maps.

In the years to come, we would expect also that the electrical and electronic techniques (such as the Bureau of Public Roads ERGS) will become a significant part of our highway guidance system. For the immediate future, however, we must assume that two-dimensional signs will provide the essential guidance information.

4.2.2 Sign layout

There are no map-type signs specified in the U.S. MUTCD, whereas the British system and other systems make extensive use of this type of advance direction sign where it can be used to advantage.

The British Road Research Laboratory has conducted experiments to evaluate the effectiveness of the U.S. stack-type sign as compared to the map-type sign. Subjects were exposed to various signs. After each exposure they were asked to indicate the direction of

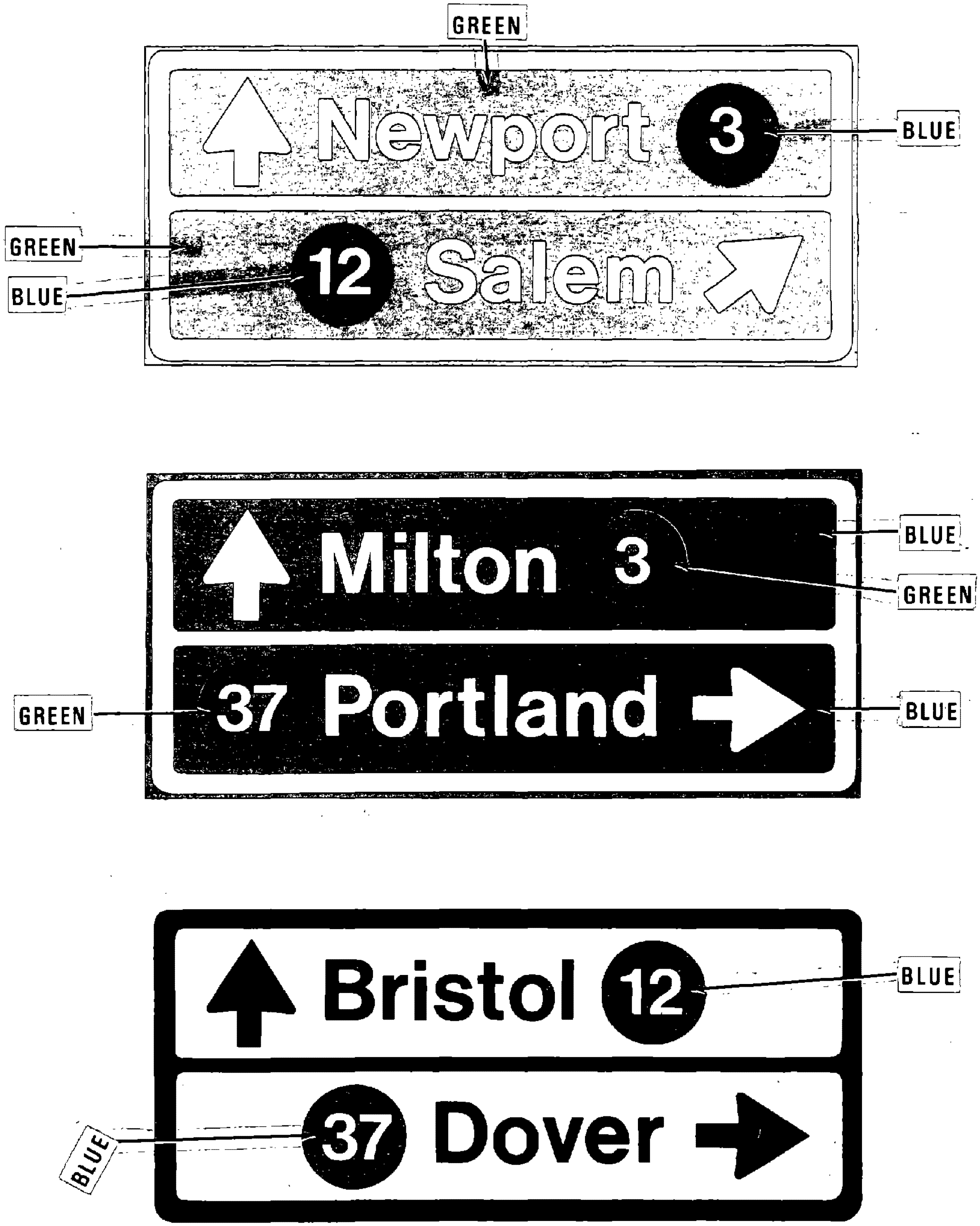


FIG. 4-1 ROUTE NUMBERS — COLOR CODING EXAMPLES.

a particular destination. The signs included varying complexities of intersections.

The fact that larger letter sizes are possible on stack-type signs meant that destination names could be read at greater distances than was possible with the map-types. For simple junctions the stack-type sign proved more effective. However, at five-way junctions, considerably more errors were made with the U.S. sign than with the map-type equivalent.

Experiments conducted by the Medical Research Council's Industrial Psychology Unit (also of England) also led to similar conclusions. These experiments also indicated that drivers were capable of dealing with a mixed system of signs which included both map and stack-type layouts.

The map-type sign provides two thresholds of recognition. The map layout itself provides the first threshold. It is a visually strong image with a high target value and makes it possible for the driver to comprehend visually what lies ahead.

The second threshold of recognition is of the destination names, making it possible for the driver to relate names to the visual image he has of the highway ahead. In a complex situation this provides a much better method of orientation than does a stack-type sign in which placement and layout have little relationship to the actual environment.

Map-type signs should be explored as part of the guide-sign system, particularly for complex junctions, such as five-way intersections or even four-way intersections with unusual features (Fig. 4-2).

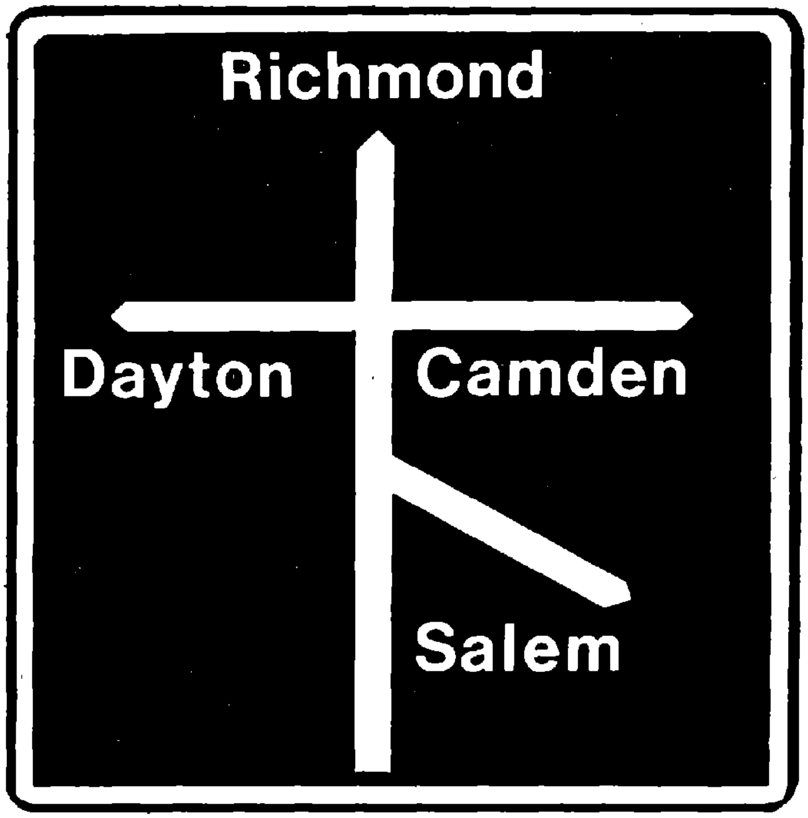


FIG. 4-2 EXAMPLES OF MAP-TYPE SIGNS.

4.2.3 Other layout considerations

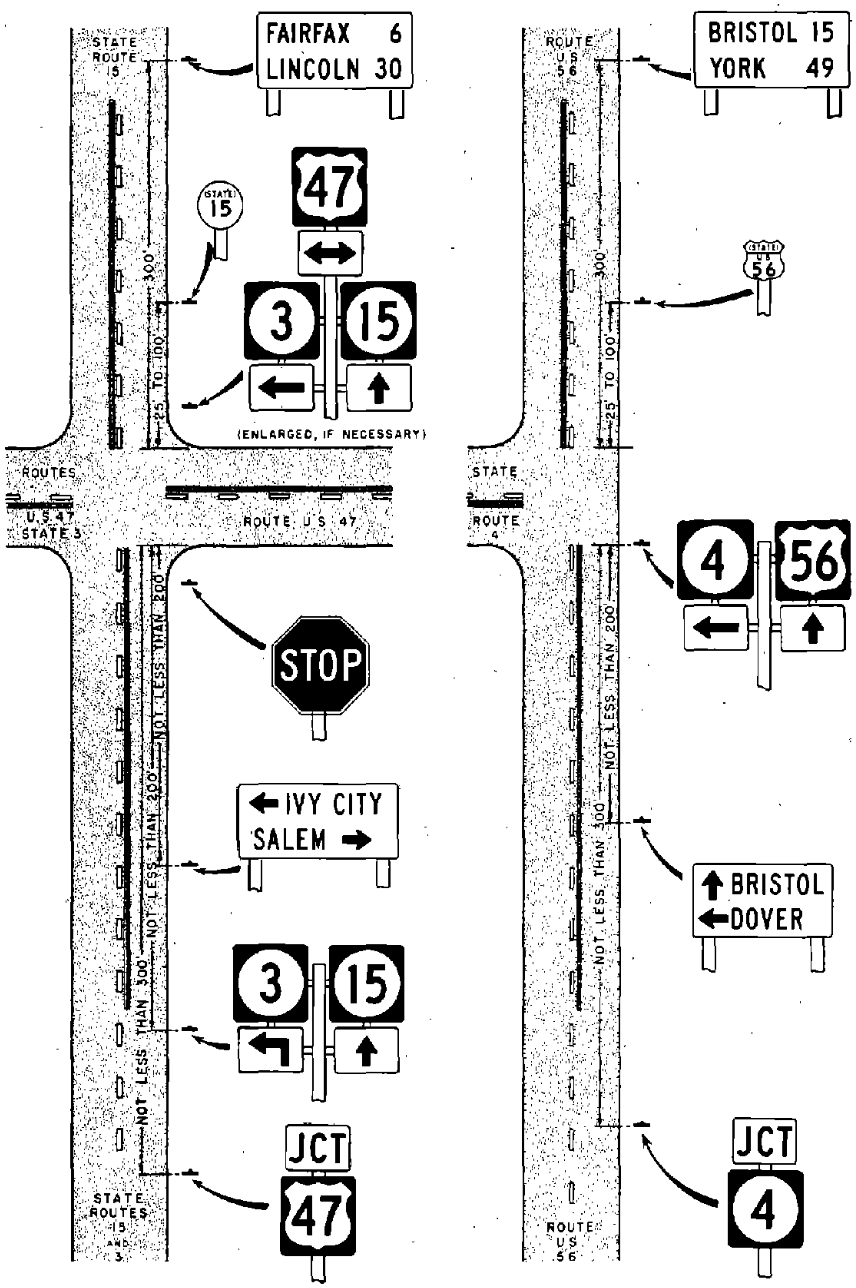
The U.S. MUTCD provides for this use of underlining in guide signs to provide a graphic separation. It does not, however, provide any example of such a layout. It has been demonstrated that such underlining is useful in reducing the possibility of destination name being associated with a wrong directional arrow. The technique should, therefore, be incorporated into the Manual with specific examples and illustrations of its use.

Except for Interstate highways, route numbers are not normally combined with destination and direction signs (Fig. 4-3). They should be combined wherever possible, and, once a proper system is developed, should utilize color as an indicator of the type of route. The combination of such signs will not only improve communications effectiveness, but will also help to reduce the number of signs on the highway (Fig. 4-4).

In dealing with layout problems the totality of the sign must be carefully considered along with its relationship to the entire sign system. Layout should provide the best possible arrangement of essential elements on the sign surface. It should also provide the definition of hierarchal values for these elements. And it should help improve aesthetic quality at the same time.

4.2.4 Lettering

Guide signs must communicate verbally for the most part. Although pictographic symbols may be used for outstanding landmarks and service facilities, almost all distance and destination signs must be verbal. As a result, the lettering on the signs is most critical.



Typical route markings at intersections (for one direction of travel only).

FIG. 4-3 EXAMPLE OF CURRENT PRACTICE.
(FROM U.S. *MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES*, 1961 EDITION)

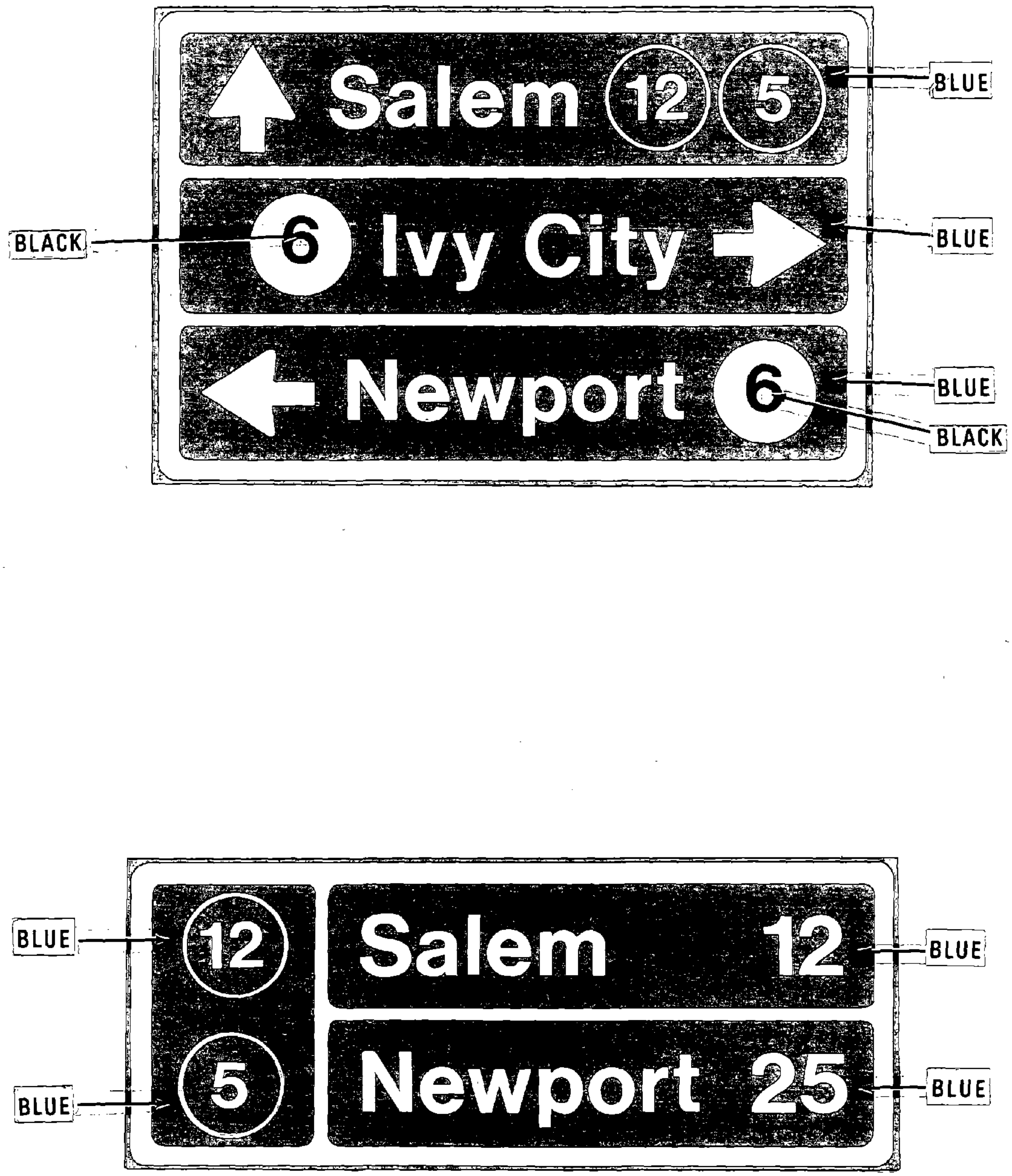


FIG. 4-4 COMBINATION SIGN EXAMPLES DISCUSSED IN SEC. 4.2.3.

The lettering standards provided in the U.S. system have several shortcomings in design and specification.

A great deal of research has been done on legibility of lettering. Many factors are known to affect it. Letter width, stroke width, spacing between letters, proximity of borders and other lettering, contrast between color and brightness between lettering and background, and general level of brightness all affect legibility. These factors interact with each other to affect legibility in different ways than each does individually. As a result, the conclusions reached in the study of individual elements has varied with those reached when factors were studied in combination.

For example, Berger found that the optimum relationship for stroke width to letter height was 1:8 for black letters on a white background and 1:13 for white letters on a black background. Lauer found ratios of as low as 1:4 for black letters on the white background.

Narrower strokes are recommended by Soar for white lettering on black backgrounds because of the visual phenomenon known as "irradiation" or "halation." That is, the visual image of the bright area appears to spread into the dark background so that the light area appears larger than it actually is. The same phenomenon has been found to reduce the legibility of white signs on dark backgrounds as the lettering seems to become surrounded by a light halo.

In the alphabets specified as U.S. standards the stroke width varied in conjunction with the letter width (the ratio of the U.S. series E is 1:6, which is the same as the ratio used by the

Ministry of Transport in England). No accommodation is made for variations if the lettering is to be used in the negative, however.

It has been found that the legibility of signs can be increased by increasing the spacing between letters, as the 1961 MUTCD indicates Solomon found, for example, that in certain American signs, maximum legibility was obtained when the length of a place name was 40% larger than it would be with normal letter spacing. However, given the same amount of space, increasing the letter size results in a significantly greater increase in legibility; so although letter spacing is important, letter size remains the overriding factor.

The legibility of lettering of a given size can also be improved by increasing the space between the message and the edge of the sign. Again, however, this is less than the increase obtained when the letter size is increased and the border width reduced. Bridgeman and Wade found that the border width need be no wider than the stroke width for black letters on a white ground. The British Ministry of Transport has found that optimum legibility results from the use of space equal to about two stroke widths between names and between the message and the border of the sign.

The question of whether to use upper and/or lower case letters is another one involving legibility.

It has been claimed that lower case lettering (with an initial capital) is better than all capitals in direction signing because the ascenders and descenders of such lower case letters (such as B and Y) give a characteristic shape to a name, which in turn facilitates recognition. In an experiment carried out in this country (Forbes, *et al.*), recognition was improved by about 10% when lower case letters were used rather than upper case letters in signs of equal area.

This experiment is suspect, however, for several reasons. Only single-name signs were used. The marginal spaces were too large for maximum legibility and more space was left empty on the capital letter signs than on those which contained the lower case letters. So although the results are interesting from a laboratory point of view, they may not relate well to the realities of road signing.

Christie and Rutley at the British Road Research Laboratory have carried out a number of experiments involving upper and lower case comparisons and have found that the differences between good examples of upper and lower case lettering are negligible. In these experiments signs of equal area were used with the x-height of the lower case letters being approximately 3/4 of the height of the upper case letters. We feel that these experiments were realistic and that their conclusions are valid.

Legibility may also be related to the details of the lettering design. These same authors have suggested, for example, that serifed letters might be more legible than the sans-serif letters normally used for traffic signs.

This has been tested by them and the results indicate that any advantage in using serifed letters is small.

It may be possible to increase this advantage by emphasizing the distinguishing features of the letters, for example, by exaggerating the horizontal bar on the G to distinguish it from a C. However, it is doubtful that this could be done in any way that would be aesthetically acceptable.

4.2.5 The U.S. alphabets

The U.S. standardized alphabets have, according to the 1961 MUTCD, been "standardized by many years" (Fig. 4-5). Research over the years has had no effect on the letters themselves and little effect on the specifications for their use. For example, the MUTCD states that better legibility can be obtained by using relatively wide spacing between letters, than by using wider or taller letters with cramped spacing. As we have explained above, this is not always true.

The specifications for spacing given for standard alphabets are quite complex and unnecessarily confusing. A better system would be to determine spacing by the use of a body or block on which each letter is mounted.

This is the method by which spacing is determined in the *British Traffic Signs Manual* (Ministry of Transport) and provides a much-simplified means of setting up words correctly.

The relationship of the lower case alphabets to the upper case alphabets in the U.S. system is also poor. Specific lower case alphabets should be designed for each upper case alphabet. Type face design is a precise technology and the advances made in this technology in recent years should be incorporated into the U.S. system of lettering.

Also, more specific standards should be included in the manual on word spacing, interlinear spacing, and the use of upper and lower case alphabets.

U.S. SERIES B	A	B	C	D	E	F
C	A	B	C	D	E	F
D	A	B	C	D	E	F
E	A	B	C	D	E	F
F	A	B	C	D	E	F
	a	b	c	d	e	f

U.K. TRANSPORT (dark on light)	A	B	C	D	E	F
	a	b	c	d	e	f
U.K. TRANSPORT (light on dark)	A	B	C	D	E	F
	a	b	c	d	e	f

FIG. 4-5 STANDARDIZED ALPHABETS.

In short, work should be carried out both to improve the U.S. alphabets and to provide better specifications for their use.

4.3 The Role of Color

The Subcommittee on Color, of The National Joint Committee on Uniform Traffic Control Devices (NJCUTCD), has provided the Committee with a great deal of background on the subject of color and has made recommendations which are consistent with the findings of others who have conducted research on color perception.

For example, Conover, Kraft and other researchers have found that there are a relatively limited number of different colors which we can easily discriminate. In the NJC Color Subcommittee's report, this number is defined as nine or ten.

Accordingly, the Subcommittee assigned each of nine colors to various sign categories. Some, such as yellow for warning signs, have long been used. Others, such as brown for recreational and cultural locations, have been used only on a limited basis, if at all.

If we are to maximize the potential impact of any visual element in a sign system, such as color or shape, it must be used very carefully. If we are to maximize the effectiveness of our total sign system, we must use each of these elements with careful regard to the needs of the system as a whole. We must begin with driver information needs and proceed through the structuring of a complete system to respond to those needs, as they relate to each other and to the total problem.

Whether the current recommendations for the 1970 MUTCD on the use of color reflect such an approach is questionable. The use of brown for places of recreational, scenic and cultural interest, for example, does not seem appropriate in the system concept. If, as the report states, there are only nine colors which can be used, is it wise to use two of them – blue and brown – to classify guide-sign information not "directly essential to the driving task?".

Color can be used to indicate meaning, or as a coding device. In the U.S. system, it is primarily used for coding purposes – to separate one class of sign from another. Although there are exceptions, such as in the use of red or green in signal lights and perhaps the use of red on the STOP sign, color seldom is used to convey a specific message to the driver. Yellow may indicate a hazard, for example, but the driver must rely on the text or image contained on the sign for the specific nature of the hazard. And, since there are so many hazard warnings of varying significance (and since color education is poor) there is no motivation to associate the specific color with a specific response.

Obviously, we cannot have a separate color for each sign in a system, as we cannot have the same number of separate shapes. So color will always be used primarily to code, rather than for meaning. The question arises, however, as to what the most effective coding system might be. We need a rationale for color coding that is consistent with drivers' overall information needs, the driving task, and the entire sign system.

Within this system, we may want to use a very few colors to make highly critical signs unique. Thus, we have the stop sign in red (and perhaps the yield and no entry signs). In all three cases, the message is critical to safety, and the driving response is to stop, or at least pause. There may be other critical signs, such as an extremely dangerous and otherwise unapparent hazard.

Beyond this, we should try to code our signs so as to maximize their communications effectiveness while minimizing the strain created by extraneous visual noise on the driver.

It may be that this coding should follow the type of message rather than the class of sign. Instead of using green, blue, and brown to guide drivers, perhaps we should consider the differences in information needs among different types of drivers. The tourist, for example, is likely to be interested in service facilities on or off the highway as well as in the cultural or recreational amenities of the area. The local driver is likely to have far different information needs than the through driver.

In other words, it may be quite useful to study trip purposes and information needs by driver classification and then use color to channel information for these purposes. A driver who knows that blue signs mean local information while green signs contain through information could be saved the task of wasting his time on local signs and would instead selectively seek through information signs.

Hazard signs, on the other hand, are most likely to contain messages applicable to all drivers and should therefore be of a single color. (Since the black on yellow format is quite successful from a legibility and visibility point of view, its use for hazard signs would seem appropriate.)

The use of red and green on regulatory signs is questionable, except in the stop or go situation. In parking signs, for example, the meaning of the letter color is lost on the predominantly white background, and the driver seeks out very specific information which would probably better be presented in black and white. A sign may say "no parking" but it still must be thoroughly read to determine the applicable hours or days of the exclusion.

The proposed use of the color orange for construction signs is also questionable. Its variance from the yellow might be reinforced by the use of a shape other than the diamond to really set it off. There is also the question of whether construction hazards are more critical than the normal hazards on the highway. In most situations, the obvious disarrangement of the highway, the uses of flares, lights, barricades and oversize signs may emphasize the general fact that construction is taking place.

The segregation of school signs from other signs relating to pedestrians, young and old, can be questioned. The use of purple and the pentagonal shape seems unnecessary. School crossings are safety problems to be sure, but so too are many other hazards. And although there are many arguments about the intrinsic meaning of color, there would seem to be some support for the use of strong vibrant colors for hazards (such as red, yellow and orange) rather than purple, which is pacific.

In short, it does not appear that the proposed uses of color in the American system are the optimal utilization of color, and we feel more careful attention should be given to the use of color, along with shape, throughout the system. More care should be given to the consistent use of color. The use of red and blue in the interstate shield is an example of an inconsistency which, although minor, nevertheless diminishes the overall effectiveness of color in the system. In any case, if color is to convey any meaning or classification, much more should be done to educate the driving public to its significance in the system.

4.4 The Role of Shape

Shape is a major factor in our ability to make visual discriminations. This study tested the recognizability of various shapes in the laboratory and has found that certain shapes, such as the triangle, are more easily recognized and more surely identifiable than are other shapes, such as the hexagon.

Over the years a number of others have studied the comparison of the relative discriminability of various geometric shapes employing various testing methods. Their conclusions seem to vary somewhat depending on the nature of the test and the variety of forms used.

In tests by Munn and Giel aimed at determining the relative recognition thresholds or shapes commonly used as backgrounds in traffic signs (circle, triangle, square, diamond, and hexagon) the triangle scored consistently highest, followed by the diamond, the square, the circle and the hexagon. Elliptical shapes were not so easily recognized. This leads to the assumption that simple forms containing intersecting angles (not more than four) are more easily recognizable than the elliptical or circular forms (including the hexagon).

We can contrast this, however, with experiments by Sleight which examined forms insofar as they could be efficiently sorted and selected when presented to test subjects.

Twenty-four forms were used. The most complex, the swastika, proved to be the most discriminable. Of the six "best" forms, only two could be called "simple" in the sense that this term is used by the gestalt psychologist. In these experiments, complexity proved to be a virtue. A more general rule as we have found might be the absence or infrequency of obtuse angles.

Thus, as Sleight reported, when he had sorted previous literature into "disagreements among comparable data and agreements among unrelated data one reached the conclusion that there can be no efficient ranking of geometric forms as an uniquivocal abstract in itself."

Tests carried out by Ferguson and Cook for the state of Virginia on the recall of sign shapes, for example, resulted in a descending order of octagon, triangle, and circle, with diamond ranking a close fourth.

The interesting fact here is that the three "best" shapes — octagon, triangle, and circle — are used exclusively for single sign functions. Each plays a unique role within the total sign system.

Evaluation must be applied to any given form or group of forms depending upon the total situation being considered and the purpose to be served.

In dealing with sign design and sign effectiveness, shape cannot be considered in isolation. It must be considered in relation to the other design elements available, and it must be related to the hierarchy of functions we wish a sign to perform.

Shape in itself is an abstraction as it relates to sign function. There is nothing inherent in the diamond shape that signifies danger. It must be a learned association. Once learned we may assume that a driver will react to a blank diamond shape on a sign pole as he would if he perceived a sign saying "danger." Because the shape is simpler in configuration than the total of all the letters used in the word "danger" we can assume that he will perceive the symbolic shape earlier than he would perceive a written legend of the same size.

Modern signs are not blank shapes however. In each sign there is a hierarchy of elements which range from concrete to abstract. We can expect that the pictograph or legend in the sign is its most concrete element. Color on a sign is somewhat more abstract. The use of red as a symbol of danger has been almost universal however; red has a meaning in much of our experience and therefore we may expect that the association is relatively strong. We may expect it to be even stronger if we consider it in the context of the highway situation where the red light or red flag or red ball has long meant "stop." We may possibly trace the same associative values with the color green. The "green-go" relationship is well-established in the minds of most drivers. So although color is an abstraction, it may have some associative meaning in certain situations.

There is likely to be a much less learned association with shape, however, and in the sign hierarchy shape may be the least meaningful of the design elements insofar as communications content is concerned. Education then is the key.

What are the purposes to be served by shape in a highway sign system? There are four possible criteria for selecting shape: first is to denote the class of sign, secondly to achieve the highest target value for the basic sign, third, to accommodate most efficiently the elements which appear on each sign, and fourth, to separate a critical or important sign by using a unique shape.

The significance of shape as an indicator of sign type in the U.S. system is not taught consistently in driver education programs and in fact is often omitted. Most drivers do not know that the diamond indicates a warning sign and that the rectangle is used for almost all regulatory signs (Ferguson and Cook). Among the reasons for this ignorance is the lack of specific education about the meaning of shape. It is also possible, at least in the U.S. situation, that the type of sign – regulatory, warning or guide – may be of relatively little significance to the driver. In the U.S. system, with its high dependency on specific verbal communication, there is little reason for the driver to seek other cues as to the meaning of a sign.

Our hypothesis is concerned with situations in which a single shape is used for many different messages. It does not deny the significance of shape as a factor in visibility or even discrimination. In other words, we do not deny that the diamond is an easily distinguishable form; but if the driver may expect to find any one of 30 or 40 different messages written on that form, he will seek and respond to those messages.

If, however, he knows that one shape can have only one meaning, the situation is somewhat different. Thus the highly distinctive shape of the railroad cross buck communicates quickly and efficiently. The same may be true of the octagonal STOP sign.

In the case of the STOP sign's uniqueness, however, other factors must be considered. The octagon, from the graphic designer's view, is close to the circle in its visual characteristics. If there were a number of circular signs in the U.S. system, the octagonal shape of the STOP sign would not be nearly as unique as it now is and it would not be as effective as it may now be. The almost exclusive use of red and the unique legend of the U.S. STOP sign also contribute greatly to its high communication value.

The importance of shape lies in its careful use for the isolation of a very few highly critical signs in the system. Its importance as a means of defining types of signs is less significant.

One could further question the need for any visual indication of sign groupings such as regulatory or warning. We have seen in the comparison of various systems that there are variances in warning and regulatory signs and definitions from system to system, and in some cases the same sign may appear as a warning or regulatory sign in the same system.

At the moment it seems that it is the message which is more important and the driver reaction which that message should evoke.

Both the diamond and the rectangle have much to recommend them as useful shapes. If identifiability and discriminability are of significance both shapes seem to qualify quite well.

Just as important, however, may be the fact that both shapes are very efficient fields for visual forms. The diamond is a highly efficient shape for symbolic images and brief typographic messages. The square or rectangle is very efficient for both symbolic images and verbal messages.

The European triangle is a very inefficient shape for both pictographs and verbal legends. The circle is somewhat more efficient, particularly for pictographs. From the point of view of shape efficiency, we see no reason to adopt European shapes for U.S. signs. One possible exception might be considered in the interest of international compatibility. Since the octagon is close to the circle in its visual dynamics and since most other systems use the circle for "stop," some consideration might be given to adopting the circular shape for the U.S. STOP sign. This would make it compatible with the European sign without altering its visual characteristics significantly. (If this were done we would suggest that the RAILROAD CROSSING sign be changed from a circle to a diamond shape. There seems to be little justification for the uniqueness of the RAILROAD CROSSING sign shape.)

The effectiveness of shape as a communications element diminishes as the number of different shapes in a system increases. Since shape is an abstract visual element, its meaning is not learned easily unless its connotation is critical to the driving task.

4.5 The Use of Legend and/or Symbol

The U.S. system differs from most others in one significant respect: its use of verbal legends rather than pictographs. The obvious trend, however, has been toward the use of more pictographs. The extension of this trend would serve several purposes.

First, it would help make the U.S. system more compatible with others and more international in its attitude. The pictographic or symbolic sign crosses language barriers.

Second, available evidence suggests that the symbol or pictograph may be visible at a greater distance than a word legend on a sign of equal area, and so the extended use of pictographs might help to make the U.S. system more effective.

Third, the length of various messages makes it necessary to use different sign shapes and sizes, and varying letter heights for different messages within those shapes and sizes, to accommodate the messages. This has led to a lack of uniformity, particularly in regulatory signing, and to a variance in the relative visibility of word legends. The pictograph, on the other hand, allows for consistently shaped and sized signs, with consistently sized images on them (Fig. 4-6).

Fourth, there are aesthetic considerations. A pictographic system can be more attractive than a series of cluttered verbal legends.

Although it may potentially have many advantages, a comprehensive and truly effective pictographic system has not yet been developed.

Relatively little methodical work in design and research has been devoted to this problem so far, although many people have worked on pictographic systems. One of the first such efforts (Krampen) led to an auxiliary picture language called "isotype" ("International System of Typographic Picture Education").

The first isotypes were prepared in Vienna, Austria, from 1925 to 1934 under sponsorship of a governmental public museums program. The work has been continued by the International Foundation for the Promotion of Visual Education by Isotype at the Hague and in London. More recently, such organizations and individuals as the International Committee for Breaking the Language Barrier, the International Union of Railways, the International Transport Association, International Council of Graphic Design Associations, Rudolf Modley, Charles Bliss, and others have devoted extensive energy and effort to international symbolic languages.

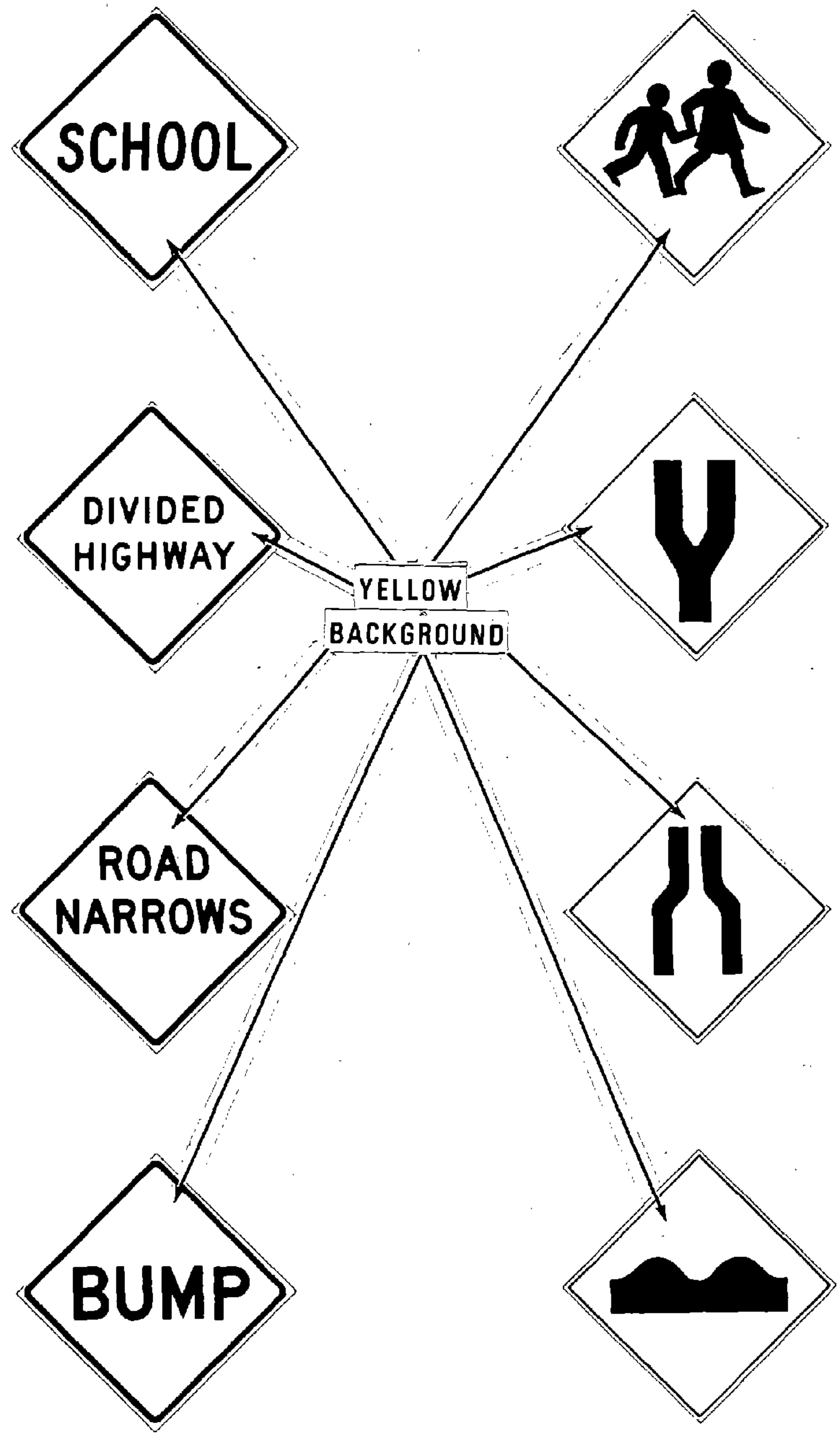


FIG. 4-6 EXAMPLES SHOWING VARIATIONS IN LEGEND SIZE, AND CONSISTENCY IN PICTOGRAPH SIZE.

Most of these efforts have proceeded from certain basic assumptions which can be related to the development of a proper system of symbols for traffic signs.

1. Each symbol should give all the important facts in the statement it is picturing, and should provide a hierarchy of recognition so that if seen only for an instant, it will communicate its most important message.

2. A symbol should not contain unnecessary details which do not play a role in its message (such as a hat on a man's head, or a bow on a woman's dress). "Only a certain amount of knowledge will be kept in mind. A simple picture, kept in the memory, is better than any number of complex ones which have gone out of it."

3. Variety and variations are not intrinsically desirable in a picture symbol. Commonality should be incorporated wherever possible, to provide visual continuity and to facilitate recognition and comprehension. The elements of the message which are unique must be very uniquely expressed, however, so that the total symbol can communicate simply and effectively.

Increasing the number of pictographic images in the U.S. sign system is not as complex as developing a new and totally comprehensive symbolic system, of course. There are a number of pictographs used in various sign systems and many of these could be adapted for U.S. use. The choice is not so simple, however, and much work needs to be done before an optimal pictographic sign system should be introduced on any large scale.

As this report, among many others, has said, an effective sign system must be comprehensive and consistent. So, if pictographs are to be used effectively, they must be treated systematically, and not as a collection of isolated visual images. This must proceed from an understanding of the essential elements of pictographic communication, some of which are mentioned above, of how people perceive and learn to comprehend visual symbols, and of how all of this relates to highway sign problems.

In dealing with pictographs for highway signs, one must begin with the limitations of pictographs in general, and with their inadequacies in other sign systems in particular. For example, pictographs do not adequately cover all message situations, and certain messages such as "keep right except to pass" or "slow down" require rather obscure images.

The quality of a drawing affects the efficiency of the system. In examining the pictographs now used in the various systems throughout the world, one finds many symbols that might be improved if redrawn to sharpen their visual clarity.

There are many ways to render the same subject (Fig. 4-7). One cannot casually determine which of the various renderings of the same subject is the most effective. All prospective pictographs should be tested and compared to each other to determine which is most effective. We must recognize, however, that it is difficult to design reliable tests to determine which variation of the same subject is the most effective in terms of communication, but feel the techniques used in this research may provide a start.

Content is as much a problem in a visual system as in a verbal one, and the problems of content determination do not disappear when pictographs are used.

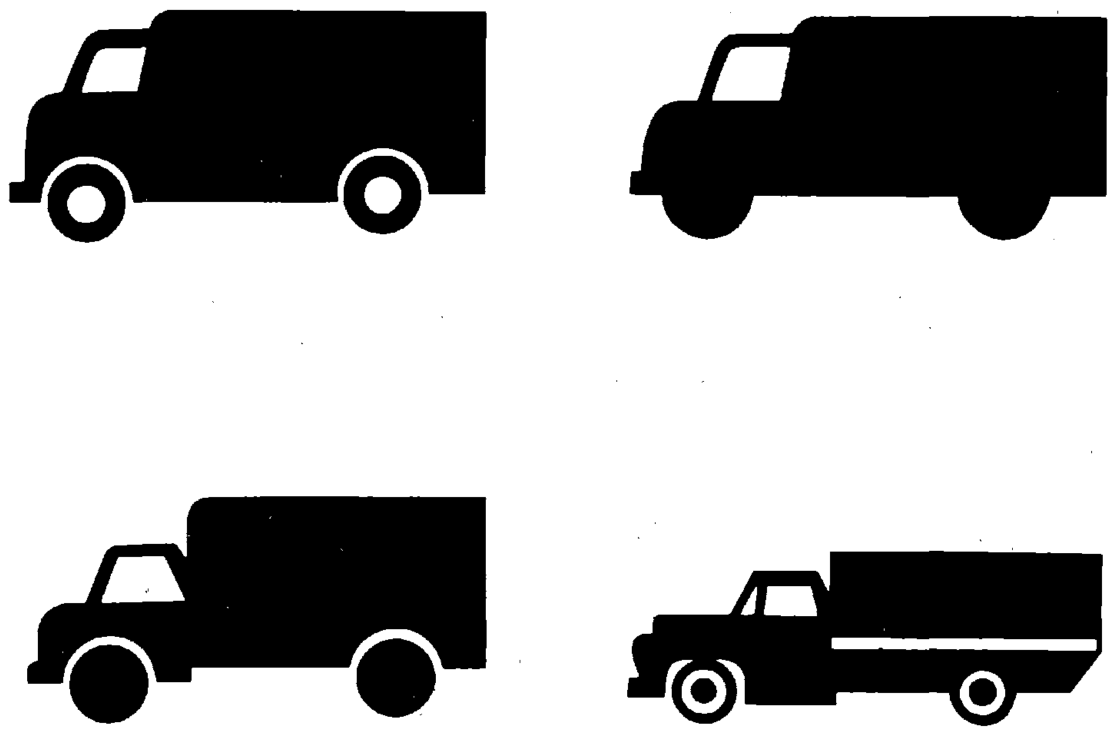


FIG. 4-7 VARIOUS RENDERINGS OF THE SAME PICTOGRAPH SUBJECT.

First there are contradictory philosophies reflected in the visual content of certain current pictographs. For example, in some cases, pictographs reflect the nature of a hazard, such as a bump in the road, while in other cases, the image reflects the result of the hazard, as in a pictograph of a skidding car for a slippery road.

Even more significant is the problem of positive versus negative instruction. Although this problem permeates all sign system philosophy, it is most apparent when dealing with pictographs because of the need for visual consistency. Should a sign tell the driver what he must not do, or should it tell him what he may do? Should we say "no turns" or should we say "straight ahead only?". Which is more convenient? Which is more effective?

As an example of current practice, we could consider certain Canadian regulatory signs. "No left turn" provides a symbol which indicates permission to proceed straight ahead or right. The symbol is surrounded by a green circle to reinforce the positive message. The verbal plate used with the sign, however, provides a negative instruction: "No left turn."

The point is that there should be a consistent philosophy of instruction, and that this consistency is essential to a properly ordered pictographic system.

Animal warnings provide another example of pictographic problems. There are a number of different specific animal warnings contained among currently used pictographic symbols. Is it necessary to differentiate between a deer and a cow? Should the driver react differently to each prospect? For street crossing situations do we really need an image of children in a school zone and adults (sometimes with a child) elsewhere? Could we simply visually say, "people crossing" and use a consistent human image for every crossing situation?

In these hazard warnings, of course, we must be constantly aware of the action we wish the driver to take and the state of readiness he should assume in response to the message. One may say, therefore, that the driver should be aware that the potential pedestrian may be a child since a child is more likely to make an irrational dash across the street, and that therefore the driver should be more alert than if he were faced with the prospect of a more mature and (theoretically) more rational pedestrian. The findings of pedestrian accident studies which suggest that the victims may be the young, the old and the intoxicated are relevant, too. These are some of the questions that should be answered in the development of a comprehensive pictographic system. At the same time, some consideration might be given to abstract signs.

Purely abstract signs (Fig. 4-8) are a visual step beyond pictographic images. A totally abstract visual symbol can have high visual impact and therefore a great potential for rapid communication. Some purely abstract images might be highly effective if judiciously used for important sign functions, in concert with proper education.

Although simple abstract symbols have high visual impact, it would be impossible to design an effective sign system using only abstract images. Such a system would quickly become complex, cumbersome and also almost impossible to learn. A very few of these images, which could not be confused with each other, might be very useful however.

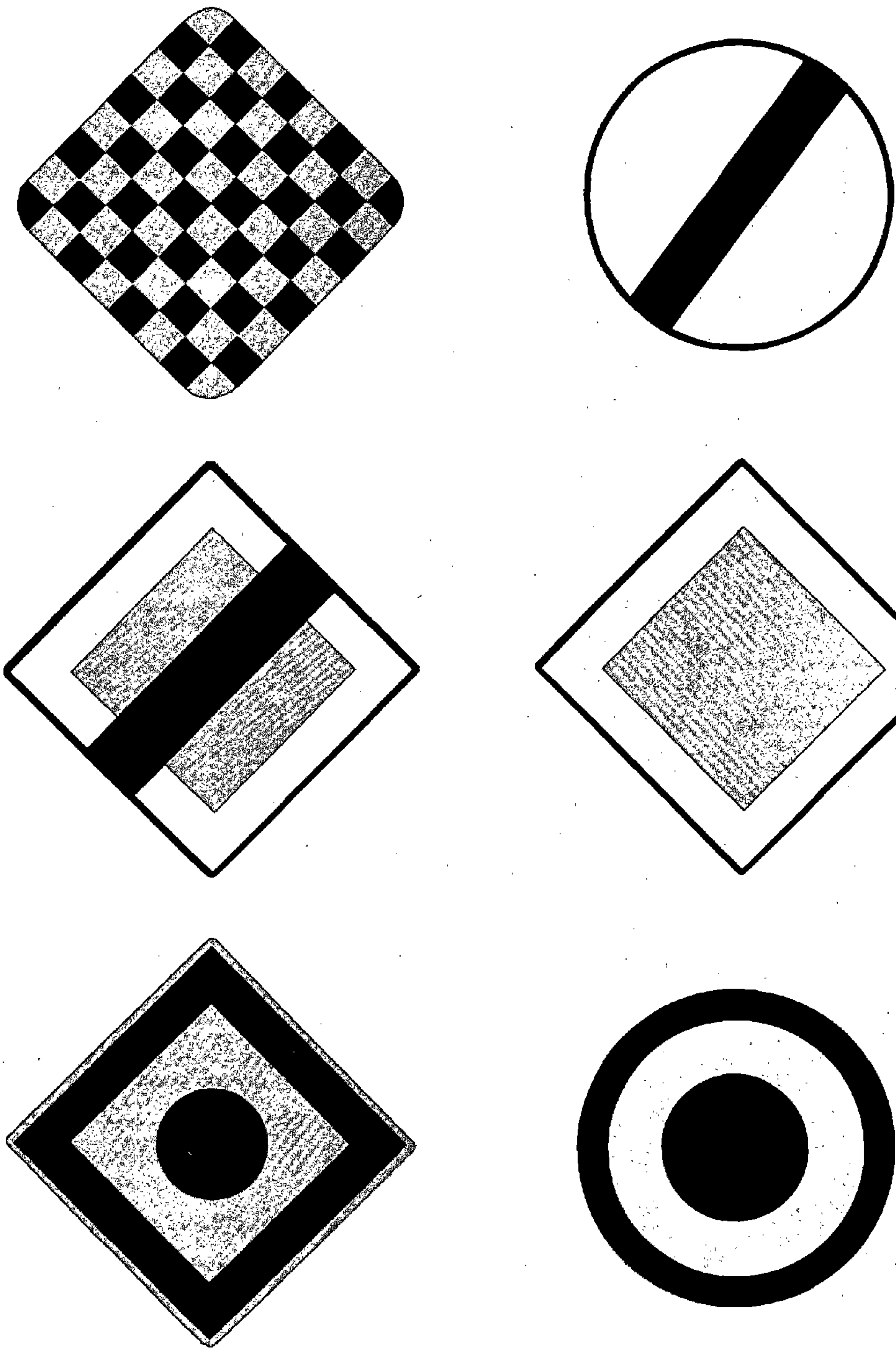


FIG. 4-8 EXAMPLES OF ABSTRACT SIGNS WITH HIGH VISUAL IMPACT. COLOR AND PATTERN WOULD CODE THE MESSAGE.

Signs which are not critical to the driving task are learned very slowly. The verbal SPEED ZONE AHEAD, for example, is unlikely to create a meaningful response in most drivers. These same drivers will slow down when faced with a sign indicating a sharp drop in the speed limit. And, they learn to recognize a STOP sign quite quickly.

The STOP sign, in fact, is often perceived as an abstract image. The driver does not read the sign; he instead reacts to it: to the image of shape, color, and the white band of lettering across its center. In one experiment, reported by Robinson, for example, the large majority of drivers did not notice anything unusual about an octagonal red sign with "TOPS" in white letters across its face.

There is little doubt that a small number of abstract signs for critical messages cuuld be easily learned. The abstract NO ENTRY sign, for example, has been used in many systems and is now being used in this country on an experimental basis. It is a good example of a powerful and simple abstract image. One would also expect that at least part of its success in this country is based on its visual relationship to our STOP signs. The red circle is close to the octagon, and the white band across the center is close to the white band of lettering. When faced with either, the driver must stop.

Traffic signals are very basic and universal images, which are quite critical for the driving task and which are therefore taught and quickly learned. We have no doubt that other critical images could also be quickly learned, if properly taught.

5. CONTINUING PROBLEMS AND RECOMMENDATIONS

5.1 Design Review

As should be clear from the bulk and the content of this report, and from the work of other investigators in the area, the problems of traffic control device design are many and complex. Nor do they all admit of solution at the present time.

What is clear at the present time is that there is the need for uniform design review procedures. These should be performance-oriented, and include not only proposed new designs but continuing re-evaluation of existing designs. Ideally, the procedures would be simple, inexpensive, and implementable at a relatively local level, using State Universities and local consultants for example. In all likelihood, this would not be feasible for some time, and does not in itself provide the national uniformity necessary. An alternative is to provide centralized, or centrally controlled and managed, facilities for continuing performance review of proposed designs. Such a function would be appropriate for the National Traffic Safety Research Center. Interested parties would then be encouraged to submit problems and propose solutions for evaluation. This policy would ensure that evaluations were rendered within the framework of the then-current system of uniform traffic control devices. Implementation of new signs for national use through the FHWA should then occur more easily. As we have emphasized, this total systems viewpoint is necessary in order to avoid proliferating designs which, while independently effective for regional problems, conflict with the current overall system.

Such a central facility would also effect coordination of proposed local testing. By providing consultation in experimental design and data evaluation, the results of such testing would have maximum applicability to other jurisdictions. Moreover, such a facility might gracefully impose upon cooperating local jurisdictions when in vivo testing is found desirable.

Ultimately, any steps taken toward broad-based, performance-oriented testing will have as their consequence the opportunity for culling and advertising a variety of design fundamentals in the area of transportation graphics. Moreover, only when such coordination is established can the costs and values of any *major* revisions to our system of uniform traffic control devices be intelligently evaluated.

We should emphasize that there is nothing intrinsic to our urging coordinated performance testing which comes into conflict with the role of functioning rule-making bodies, such as the National Joint Committee on Uniform Traffic Control Devices (NJCUTCD). The intent is, in fact, to provide better liaison among testing groups, rule-making bodies, and traffic operations personnel in the field.

5.2 Content

The greater part of this effort has been concerned with design-elements of a transportation graphics system rather than with the contents of such a system. Yet, one can hardly embark on such a study without coming repeatedly up against questions of content. In some cases, our ideas have influenced the choice of experiments, as in the work on directional signing.

For the directional signing experiments, we chose to ask two different kinds of questions of the observers because we felt that motorists on the highway might themselves ask these two kinds of questions. These two types of questions, one about particular destinations, the other about the orientation of the choice point, led to rather different content requirements.

In the former case, the demand may be for quite a few, popular destination names – names of frequent destinations, perhaps not well-enough known to orient a complete stranger. While the list may be too long to be remembered, that is not the intent; rather, the purpose of the long list is to preclude, insofar as possible, a motorist searching for an unlisted destination.

In the latter case, the list must be short enough to be remembered, and consist of destinations major enough to provide orientation for the motorist. This case is the one which current signing practice seems to handle best. In part, this is probably accidental and due in large measure to the fact that the signing is decided upon by those who are likely to view the choice point in "plan view" – those who are familiar with the design of the road net – rather than by "users."

Another aspect of content of which the authors have become increasingly aware comes under the heading of "confirmation." When a motorist has processed the information on a sign and has decided upon or initiated a course of action, he should be given confirmation. Needless to say, the more congruent the confirming sign is to the sign upon which the initial decision was based, the better able the motorist is to abstract that confirmation, or note its absence. Subtle changes in color, layout, typography, shape, order of destination, and spelling or abbreviations, can serve to dislocate the motorist. Additional information, or the deletion of information in confirming signs, is to be discouraged.

These comments are meant to apply to signing in advance of the choice point, at the choice point, and after the choice is made. Naturally, in this last case, only information pertaining to that choice should be carried. As a consequence, the necessary degree of congruence can be achieved only if the information on preceding signs has been properly grouped.

There is one possibly acceptable alternative if an operational need is adequately defined — the use of two levels of destination signing, for example. A properly designed, executed, and explained uniform code might be developed for what a driver can expect to be confirmed — perhaps only a color and/or a shape, a code name, or a code number.

Advance signing often also informs the motorist about the distance to the choice point or hazard. This message is usually borne by legend, perhaps on a separate plate. An alternative is to make uniform the number of advance signs in a series, three, for example. A simple code would then tell the motorist which of the series a particular sign was; a proposed international solution is the number of diagonally striped, supplemented bars attached to the sign support. One nice thing about such a scheme is that it is dimensionless. Kilometers, miles, or feet are not spelled out. Instead, the burden rests on known, uniform placement. As a result, placement could be adjusted, dependent on average traffic speed, to always present advance warnings so-and-so many driving seconds before each other and before the hazard or choice point.

Another practice deserving of comment is the use of advisory speeds for complex curves, such as are found at interchanges. Such advance warning only is given as if for a single curve, rather than giving an indication of the points of transition from straight to curving and back again.

More generally, we suspect some of the abuses in signing are in the area of content, in the sense that the contents of a number of signs are totally inappropriate in the highway context. All too often messages are posted for the motorists which have no implication for his driving. Telling the driver how much a stretch of pavement costs, or what the population of a town is are unlikely to affect his driving – except adversely, by drawing his attention from something more important. (If we feel that in certain instances a driver must be distracted by an irrelevant message in order to keep him alert, then these should be carefully conceived to be distinct from the proper message set.)

5.3 Placement and Warrants

One side of the problem of placement has recently been brought to public attention in dramatic fashion. Hearings before a congressional subcommittee have underscored potential hazards of the physical sign or signal structures. This valuable public service will undoubtedly lead to more careful attention to future placements, and, hopefully, to corrective measures for existing installations. A word of caution is in order, however, to ensure that safe placement does not compromise effective placement. For example, one alternative to the roadside-hazards problem is to set signs and signals farther back from the side of the highway.

Note, however, that moving signs back increases the angle of view away from the road, and slightly increases the distance at which the sign must be viewed. To keep the *angle of view* away from the road constant, at the same time as the sign is set farther from the road, the view distance is markedly increased. To have the signs work at these increased distances, they must, of course, be increased in size. Moreover, setting signs further from the road edge makes more difficult the task of judging at what point *on* the road the signs applies — end of passing zone indications, for example.

In general, sign placement must be determined so as to allow sufficient processing time and time for action prior to obstacle or choice point. Inasmuch as time is the crucial parameter, sign size, sight distance, and prior placement must be figured on the basis of expected traffic speeds. Moreover, these factors must be responsive to traffic speeds which have been steadily rising in the majority of cases.

Needless to say, signs should be placed so as to be visible to the drivers of vehicles to which they apply. It is only recently, however, that "no passing" signs, for example, are suggested for left-hand placement. There are undoubtedly other areas in which so seemingly obvious a rule should be applied.

With respect to warrants, we wish only to echo the oft-repeated notion that many signs (for which well-defined warrants do not exist) currently on our roadways are not in any sense warranted.

Construction and other temporary signs persist in some jurisdictions long after they are relevant. KEEP OFF THE MEDIAN signs are found in profusion where often the greatest single hazard in the median is the sign itself. Inadequate signs are often left in place after more and better signs are installed. These and numerous other examples of such practice are to be condemned. Excess signs serve the motorist neither wisely nor well. Rather, they are a distraction, a hazard, and reduce the credibility of the entire system of uniform traffic control devices.

In common to many of the messages borne by signs, signals and markings is the notion of a *change in conditions*. For example, a speed limiting message of, say 50 mph, may signify a change, downward or upward, from the posted limits encountered previously; on the other hand, an identical sign may merely appear at intervals to serve as a reminder, connoting no change. Similarly, for CONSTRUCTION, or MEN WORKING signs, and again for parking regulations. Road markings may change from dashed to solid, or the reverse, with no difference in line width, color or spacing as compared with the steady state. Advance warning only is given of a curve, rather than an indication of the points of transition from straight to curving and back again.

Presently, such changes are handled in a variety of ways: special signs telling the motorist he is leaving a construction zone, SPEED ZONE and END OF SPEED ZONE signing, and NO PASSING ZONE signs. Sometimes the changes are not signified at all. We feel that consideration should be given to developing a common symbolic representation for so common a message. Careful attention should be paid to whether changes in one direction should be treated similarly or distinctively from changes in the reverse direction.

5.4 Driver Education

As has been mentioned, there is a wide variety of public disaffection with the operation of our current system of uniform traffic control devices. The bulk of this study has been the investigation of basic elements of traffic control devices to enable more effective design. The authors have, however, tried to get at the sources of dissatisfaction of the public, and speak to these points where appropriate. There is no doubt that a part of the difficulty with signs and signals is traceable to the driver's ignorance about the operation of today's uniform system.

Now, there are a very large number of messages which might profitably be communicated to a passing motorist by a road sign, but there are a relatively few dimensions, such as color, shape, and legend or pictograph, along which the information can be encoded. In order for a sign to convey its message most efficiently, the population of drivers needs to be aware of the specific roles played by color, shape, and legend or pictograph. Let us see how these dimensions are typically used, and then observe how novice drivers are made aware of the role of each dimension by the various states.

Our first concern is with regulatory and warning signs which, by the information they portray, dictate the actions of all motorists as opposed, say, to destination or guide signs. As an example, consider the familiar STOP sign. To describe a STOP sign as a red, octagonal sign bearing the legend "STOP" is to tell only a part of the story. The STOP sign is the *only* red sign; the *only* octagonal sign; the *only* sign simply bearing the legend "STOP." Thus, any two of the dimensions are totally redundant, by which we mean that a STOP sign is completely defined by any one of its attributes. (Note that this will no longer be precisely the case when and if the red DO NOT ENTER and YIELD signs are adopted. The illustration is useful and familiar, however.)

The purpose of redundancy is, of course, to ensure that a message can be understood even when some parts of it are missing. Notice that the STOP sign is the only sign where the dimensions are used with such complete redundancy. In contrast, the YIELD sign which uses exclusively the triangular shape (vertex downward) and the legend "YIELD" shares its yellow color with round and diamond shaped signs of other meanings. (Again, note the proposal to change the color of the YIELD sign.)

One can guess that a high degree of redundancy is used when the consequences of inappropriate action are particularly costly as in the STOP sign example. Yet, it must be apparent that such redundancy can be effective only where a driver knows the meaning of the individual attributes. That is, a novice driver must be told and shown graphically the role played by each dimension alone. Such knowledge must be made prerequisite to the privilege of driving.

This project analyzed the operator's licensing manuals of the fifty states to ascertain how such information is presented, and, one presumes, tested.

The role of legend in the examples cited is self-explanatory to one who is familiar with the language. The roles of color and shape, on the other hand, need to be explained, and it was found that three basic methods have been used for explanatory purposes —

a textual description, a picture of the sign bearing its legend, and a picture of the sign without its legend. This last method, providing a picture uncontaminated, as it were, by legend is the method which explains the *independent* roles of color and/or shape.

For the purposes of analyses, we considered that each of the three methods – text, picture with legend, and picture without legend – could be used singly, or in combination with one or both of the others. Consequently, a presentation by a state could fall in one of eight categories as shown in Table 5-1. Presentation of the roles of color and shape were analyzed separately and Table 5-1 also contains the findings given as the percentage of states whose presentations fall in each of the eight categories.

As can be seen from the table, two categories, IV and VII, are completely empty, as none of the states' presentations for either color or shape fit this category. While the actual numbering of our categories is not to be taken as an indication of quality, the poorest presentation would be in Category I, and Category VIII represents the most complete definition. Examples of the six non-vacuous categories are given in Figs. 5-1 through 5-6, which are exerpted from various current state driver's manuals.

Because of the importance attached to the role of each dimension, it is felt that the presentation should be as in Category VIII. Naturally, one must appreciate the cost factor involved in the color illustrations necessary for a Category VIII presentation of the role of color. One alternative is a separate uniform flyer or insert which could be made available to drivers on a national basis. Moreover, a complete and concise exposition of the role of signals and markings should be included. Finally,

TABLE 5-1. Description of signs in State Driver's Licensing Manuals. The categories I through VIII are defined by the methods of description used. Y indicates that a method was used, N indicates that a method was not used.

Methods of Description			Category	Percentage of States Using Method to Explain the Role of:	
Picture Bearing Legend	Picture Without Legend	Textual Description	Number	COLOR	SHAPE
N	N	N	I	16%	0%
N	N	Y	II	14	0
N	Y	N	III	0	2
N	Y	Y	IV	0	0
Y	N	N	V	34	22
Y	N	Y	VI	32	36
Y	Y	N	VII	0	0
Y	Y	Y	VIII	4	40

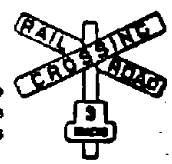
Each traffic sign is placed so as to serve some definite purpose. In addition to its words, the shape of a traffic sign has a meaning. Much thought has been given to their location. They are for your protection. You are a skillful driver when you use them.

Public officials are constantly working toward greater uniformity in traffic signs throughout the nation. Uniform standards provide six basic sign shapes so motorists can tell instantly the type of sign by its shape.

This diamond shape always carries warning of some hazard or unusual condition on the road ahead and calls for caution and reduced speed.

Only one message is ever carried in this round shape: Caution-highway-rail intersection ahead.

The crossbuck is devoted solely to marking highway-rail crossings. It means reduce speed, look and listen for trains before crossing the tracks.



This octagon is used only for the stop sign, which means stop and make sure the way is clear before proceeding.

FIG. 5-1 THE ROLE OF COLOR IS NOT EXPLAINED AT ALL HERE, EITHER IN TEXT OR BY COLOR ILLUSTRATION. THIS PRESENTATION OF THE ROLE OF COLOR IS AN EXAMPLE OF CATEGORY I, AND IS DRAWN FROM A CURRENT STATE DRIVER'S MANUAL.

ROAD SIGNS

TRAFFIC SIGNS AND WHAT THEY MEAN
4 BASIC SHAPES EVERY DRIVER MUST KNOW . . .

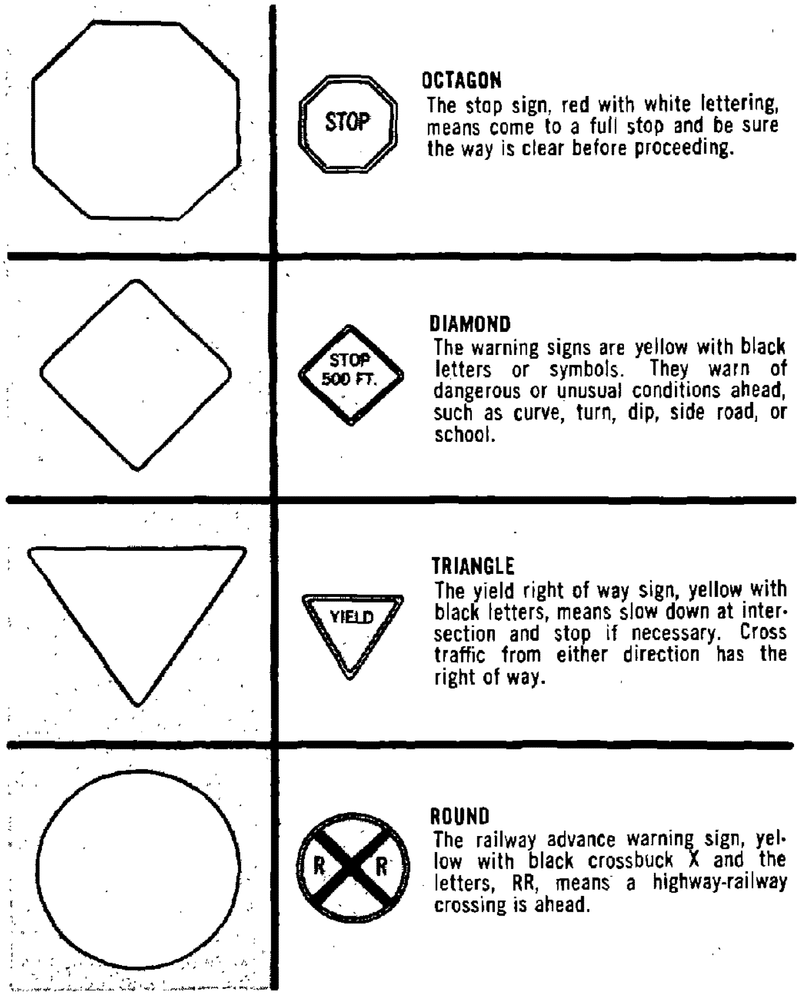


FIG. 5-2 THE ROLE OF COLOR IS GIVEN IN THE TEXT ONLY. THIS PRESENTATION OF THE ROLE OF COLOR IS AN EXAMPLE OF CATEGORY II, AND IS DRAWN FROM A CURRENT STATE DRIVER'S MANUAL.

TRAFFIC SIGNS AND SIGNALS

The signals and signs along the road and the markings on them are a great help in safe driving. They point out to you things you may not have seen. They tell you of danger ahead and ask you to do something about it.

There are many kinds of signs. Some just show you where to go or what route you are on. Others warn you of curves, hills, workmen in the road, cross streets, narrow bridges and other things before you see for yourself what is there. Some of these warning signs just let you know what is ahead, while others advise you by their shape to slow down. The most important signs are the ones which tell you what you must or must not do. You are breaking the law if you do not heed them. "STOP" signs are the most common of these, but there are also others showing one way streets, no parking, speed limits and other rules.

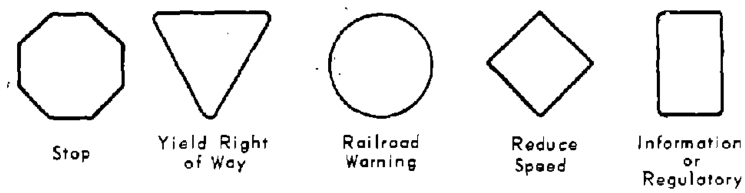


FIG. 5-3 THE ROLE OF SHAPE IS EXPLAINED ONLY GRAPHICALLY, UNCONTAMINATED BY LEGEND. THIS PRESENTATION OF THE ROLE OF SHAPE IS AN EXAMPLE OF CATEGORY III, AND IS DRAWN FROM A CURRENT STATE DRIVER'S MANUAL.

STOP SIGN — White on red

1 Make a complete stop even with sign or stop line. Stop in back of crosswalk.

2 Look in both side directions for traffic and pedestrians. Yield right of way.

YIELD SIGN — Black on yellow

1 Slow down as required when approaching this sign.

2 Look both left and right and yield to traffic and pedestrians.

3 You must stop when necessary to avoid pedestrian or traffic on protected street.

WARNING SIGN — Black on yellow

1 Warning signs warn of actual or potential danger ahead.

2 A specific message is given by words or diagrams.

3 Extra caution should be observed at all warning signs.

4 Most warning signs indicate a decrease in speed.

5 Read and obey the specific message on warning signs.

NO PASSING SIGN — Black on yellow

1 This sign is on the left side of the highway and faces the driver.

2 Marks the beginning of a NO PASSING ZONE.

3 Passing must be completed **before** reaching this sign.

FIG. 5-4 THE ROLE OF SHAPE IS GIVEN HERE ONLY BY A PICTURE WITH LEGEND. THIS PRESENTATION OF THE ROLE OF SHAPE IS AN EXAMPLE OF CATEGORY V, AND IS DRAWN FROM A CURRENT STATE DRIVER'S MANUAL.

Traffic Signs

Eight-Sided Sign .... STOP

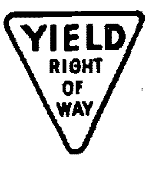
(White on Red, or Black on Yellow)

A stop sign always means STOP—a dead stop—not just a rolling stop.

Even if you stop behind other vehicles that have stopped, you must make another dead stop when you get up to the stop sign.

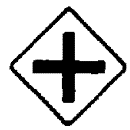
A stop sign is the only sign of this shape.

Triangular Sign .... YIELD



This sign means that you must grant the right of way to other traffic and that you must slow down to a reasonable speed. In the event of an accident such accident shall be deemed . . . evidence of such driver's failure to yield the right of way.

Diamond-Shape Sign .... WARNING



This sign warns you of special hazards just ahead—winding road, hill, underpass, soft shoulders, narrowing pavement, slippery when wet, hospital, school zone, etc.

Rectangular Sign .... INFORMATION

This sign informs you of traffic regulations and provides other helpful information, i.e.—Speed Limits, Do Not Pass, Rotary, One Way, etc.

Round Sign .... RAILROAD CROSSING

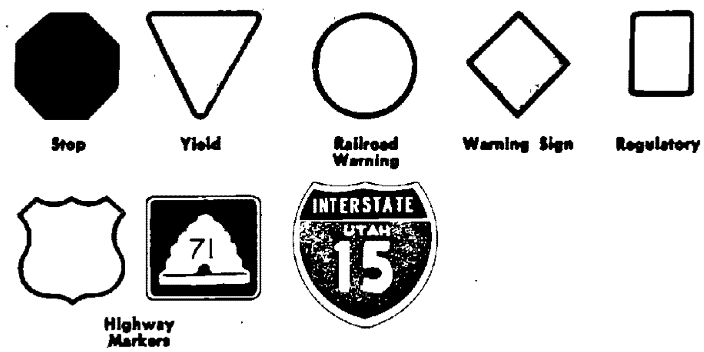
This sign always means that you are within a few hunderd feet of a railroad crossing. Slow down and look carefully before crossing the railroad tracks.

Vehicles carrying explosives or inflammable liquids such as gasoline and oil are obliged by law to stop at all railroad crossings, even if there are no trains approaching or warning signals given, and so are school buses and public service vehicles. Be prepared to stop behind them.

FIG. 5-5 THE ROLE OF COLOR IS EXPLAINED BY A COLOR ILLUSTRATION OF SIGN WITH LEGEND, AND BY TEXT AS WELL. THIS PRESENTATION OF THE ROLE OF COLOR IS AN EXAMPLE OF CATEGORY VI, AND IS DRAWN FROM A CURRENT STATE DRIVER'S MANUAL.

KNOW THESE SIGNS BY THEIR SHAPES.

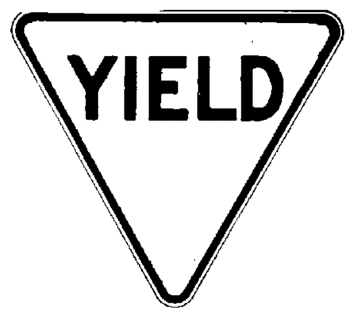
Signs, and their Shapes



Regulatory signs

Regulatory signs regulate the movement of traffic. They are black and white with the exception of the Stop sign, Yield Right of Way sign and the Railroad sign.

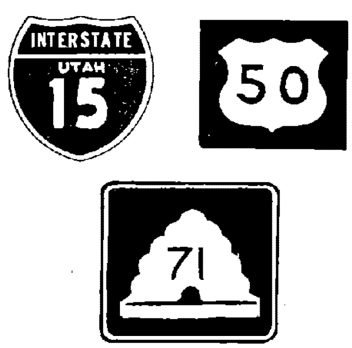
The STOP sign is the only 8-sided traffic sign. It means that you must come to a complete stop before entering the intersection ahead and yield to traffic close enough to be an immediate hazard. If there is a crosswalk, stop before entering the crosswalk.



YIELD — THE YIELD sign is the only triangular traffic sign. It is yellow with black letters. It means slow down so you can yield to vehicles on the roadway being entered.

Guide

These informational traffic signs signify that you are driving on a portion of the national system of Interstate and Defense Highways, or on a U. S. or State Route.



The MERGING TRAFFIC sign informs you that you will be merging with other traffic traveling in the same direction. Rules governing the "changing of lanes" apply here with the driver on the main route having the right of way. Those entering must make use of speed-change lanes to merge with the main traffic flow smoothly and safely.

FIG. 5-6 THE ROLE OF SHAPE IS EXPLAINED BY ILLUSTRATION WITH AND WITHOUT LEGEND AND BY TEXT AS WELL. THIS IS AN EXAMPLE OF CATEGORY VIII, THE MOST COMPLETE DEFINITION, AND IS DRAWN FROM A CURRENT STATE DRIVER'S MANUAL.

special treatment should be given to guide signs explaining the classes of information they convey, and illustrating both the uses and limitations of this information. This issue could be the subject of a National Highway Safety Standard calling for the inclusion of such information into state manuals, and furnishing model sections.

The ideal time for such a document is perhaps now, inasmuch as a new edition of the *Manual on Uniform Traffic Control Devices* is due shortly and will contain several revisions that will in themselves necessitate widespread exposition. Besides, a good explication could be expected to serve not only an educational function, but a public relations function as well. It can serve to dramatize officialdom's concern with the motorists' needs, and to underscore the step being taken to service these needs.

The time for such a document is ideal, too, in light of the proposed periodic retesting and relicensing of drivers. The availability of a good treatment of traffic control devices might thus imbue the retesting with an upgrading of driver knowledge.

Periodic relicensing also provides a distribution outlet for such information. Other good sources are available as well. Permission and encouragement for reproducing or distributing the material might be given to industrial interests as well — oil companies who provide road maps and trip routing services; automobile manufacturers who produce instruction manuals for their vehicles; car rental agencies; automobile clubs, and the like. Appropriate foreign language versions at ports of entry are also worth considering.

It is also interesting to speculate on the effect of enlightening the 100 million odd potential critics and inspectors of our sign system, thereby making them "better" critics.

5.5 Maps and Ancillary Devices

Unquestionably those who make road maps available have performed a needed public service. Such maps serve an informational function both in trip planning and in extrication from difficulty *en route*. The authors of this report do not feel entirely competent in commenting on the research and development which underlie map construction. However, it is necessary to consider briefly the relationship of road maps to the roadway complex, in particular to the signs thereon.

Admittedly, map reading is a difficult skill. Depending as it does upon a facility in spatial relations, it may be that many may never be capable in this area. Making maps conform more closely to the information available on the road, and perhaps the reverse, may be of some help. On limited-access highways, established signing practice precludes providing too much detailed information, which could not be used effectively by the driver. Yet maps specifically designed for the through traveler are not often or readily available.

On many roads, their intersections with political or geographic boundaries are indicated by signs. Often, however, such intersections do not clearly appear on road maps.

Many states currently opt for uniquely shaped state route markers. Yet, these shapes are not provided on many maps. Color codes such as that of interstate route markers are lost, or worse, changed.

On the highway, separate, correctly reading signs are provided for opposing directions of travel. Yet, map readers encountering spatial relations difficulties, who would prefer to rotate the map, are then forced to read "upside-down."

Many classes of highways will shortly be provided with detailed mile markers. It might be helpful if choice points on maps provided related information.

On the other hand, maps are keyed, usually by color and stroke width, to the class of highway. Yet on the highway related information is not always explicitly provided, nor keyed to maps.

Finally, because of their wide distribution, road maps could be used to present useful, updated information of several sorts to the motorist. To date, this avenue has been inadequately explored, certainly with respect to uniform traffic control devices, as well as those non-uniform peculiarities of state practice which may persist. When, as an example, an oil company providing maps changes its emblem, or logo, it is understandably quick in using its maps as one medium for educating the public. As traffic signs, symbols, and markings are changed, or newly introduced, might not maps convey such information?

Likewise, automotive manufacturers both on their product and in the associated manuals might provide a similar service. Again, company logos and brand names are displayed with understandable gusto. In some countries, windshield decals are available with certain information about uniform traffic control devices, but the practice is regrettably absent here. This opportunity for service is also available to car-rental agencies, important inasmuch as their vehicles are quite often used in an environment unfamiliar to the driver.

Information centers, where provided, might also strive to conform more closely to highway symbology than many presently do. Of course, one can envisage a computerized routing system which provides to the questioner not only directions but accurate representations of crucial signing at and preceding crucial choice points. This need not entail storing a representation of every sign, of course. When and if true uniformity is achieved, including a set of logical rules for deciding what information to display on a highway sign, a much smaller data base need be stored. The representations could then be synthesized. While such a system might be regarded as off in the distant future, if ever, it could probably be implemented more easily and quickly than proposals for an Electronic Route Guidance System (ERGS), for example.

Notwithstanding the difficulties in implementing this and others' suggestions for maps and ancillary devices, the efforts should be made because of the gap in what should be the continuing education of every driver.

6. THE URBAN SITUATION

Traffic problems in our cities are acute — causing a progressive arterial strangulation in urban areas. Over the years, some techniques established to alleviate the problems often add to the confusion. New arteries, in the form of expressways, are cut across the urban landscape. Traffic patterns are then revised; regulations increased. Signs, as well as vehicles, clutter the urban area, and the problems grow only more intense.

Obviously, such massive problems require many different levels of action aimed at many different causes. But the development of a comprehensive urban sign system could be one of the more significant attempts to solve some of these problems.

Current sign systems as described in the various manuals pay little attention to the urban problem. There are certain signs which are obviously only used in an urban situation and each of the various manuals will, on rare occasion, acknowledge the fact that the urban environment creates special sign problems. However, there has been no attempt to treat the urban sign problem as a totality or to devise signs that may truly help to alleviate the pressures on urban traffic and to reduce the blight that flourishes on the proliferation of urban traffic signs.

In approaching the problem, it is essential that the emphasis be placed on information needs, with traffic signing serving as a subsystem within a larger system of public orientation and communication within the city.

At the same time, other major traffic generators and orientation points in the city must be identified and their role defined.

These points include natural elements, such as a major and obviously identifiable river, which provides orientation for all but the most foreign to the city. But, more often, they are man-made, ranging from a universally recognizable structure or landmark to the private signs that identify stores, buildings and other features of the city.

All of these elements provide visual communications of varying specificity, and must be complemented and supplemented by the public sign system, which, in fact, provides the great bulk of communications. And this should be done without adding unnecessary chaos to the city's visual environment.

6.1 Information Needs

As we have indicated, the first step in the development of a sign system should be the determination of information needs.

Information needs are not the same for all people. They vary considerably, depending on the individual's familiarity with the city as a whole or the neighborhood in which he is traveling, as well as by his purpose in the city.

Obviously a sign system need not be designed for those who are intimately familiar with the area being signed. On the other hand, it may be very difficult to design a sign system for those who know absolutely nothing about the area. We must encourage these people to acquaint themselves with at least the broad characteristics of the area (by providing maps, for example) and then design the system to supplement that very basic understanding.

We may then assume that a sign system should be designed for those with only the barest knowledge of the environment in question. If we assume this as a constant we are left with another variable: different people require different types of information.

A truck driver may need to know the best truck routes to the mercantile district. He may need to know how to get to a shipping point in the heart of the downtown. He may need to know how to get through the city on those routes which encourage commercial traffic.

A tourist may be looking for totally different sets of information: the location of historical landmarks, of other places of interest, of cultural institutions or of colorful or historic districts within the city.

The occasional downtown shopper is another type of sign user. She may need to know which parking lot is most convenient to the downtown shopping area or which is the best route from the suburbs to downtown.

As a first step in the definition of information needs, we may be able to categorize user groups, such as the truck driver, the tourist or the shopper. Once we have established user categories, we should be able to define the type of destination and en-route guide information that these users will need in order to complete a typical trip. We will need to know how each of these user groups orients itself in the city. Are route numbers of significance? Are neighborhood names meaningful? Are major street names important to emphasize? Are there landmarks which can be used as orientation points?

Although no two cities are alike and the specific answers to some of these questions may vary from city to city, we feel that there are likely to be many common characteristics and types of information needs which may be defined. A tourist in Boston may seek Beacon Hill, whereas his counterpart in San Francisco may seek Nob Hill. But these are superficial differences.

There has been a certain amount of work on how people orient themselves within the city. Kevin Lynch in *The Image of the City*, for example, defines certain elements by which he feels people orient themselves – such as paths, edges, landmarks, nodes, and districts. But Lynch, and others, have also found that many people do not know how to orient themselves within cities even *with* such guidepoints.

The determination of user groups, the definition of trip purposes, and the development of a comprehensive system for defining information needs would not be an easy task. It would not be an impossible assignment, however, and it could lead to basic standards for information content that would not only vastly improve guide and information signs in the urban environment but would also be of significance to guide sign policy for the rural and interurban area.

Even before this is completed, however, there are many changes that should be investigated with respect to the *U.S. Manual on Uniform Traffic Control Devices'* current standards on urban signs.

Generally, the MUTCD's lack of specificity, in defining and illustrating guide sign standards in particular, has not allowed its use to combat the proliferation of unnecessary and redundant signs and signs of divergent content and design from state to state and even from city to city.

6.2 Guide and Information Signs

The concept of the interrelationship of user groups, modes of travel and trip purposes to determine content would have its most significant application in the area of guide and information signs.

The present MUTCD ignores the problem of urban guide and information signs by not setting standards, but, rather, allowing sign jurisdictions to vary at whim within loosely framed verbal specifications. The MUTCD provides no useful illustrations, and so those responsible for urban signs have had to develop their own specifications and to do whatever has seemed appropriate, based on other signs in the MUTCD and on the experiences of other cities.

The problems relating to guide and information signs in an urban environment are not dissimilar from those of the same type of signs in a non-urban situation. The basic and very significant difference, however, is that the compression of space within the urban environment and the multiplicity of decision points, potential destinations and streets all combine to create many very special problems in a very congested environment.

Although the present MUTCD concerns itself only with highway signing as it guides or controls vehicle and pedestrian traffic, in order to be effective, the ideal urban sign system should serve the total scope of travel within the urban area. It must recognize that the urban trip is often divided among several different modes of transportation. The individual may come into the city by car, by bus, by trolley, by train, by subway, or even by helicopter or boat. He may then transfer to a second mode of transportation and then perhaps even to a third before arriving at his destination.

For example, a shopper from the suburbs may come into the city by train, transfer to a subway, and then even to a bus or taxicab, and, finally, may walk the last block or more to his destination. If the urban sign system is to provide the necessary guidance and information for these users, it must provide the necessary content and its elements must be placed in a consistent and predictable fashion — not only in the streets but at major transfer points. It must relate to the subway system and other modes of transportation within the city.

Signs alone cannot meet urban information needs. For example, if maps and other visual materials were created within the city and distributed outside the city, and if these maps were drawn to a consistent and comprehensive system of orientation, signs could then be created to accompany the maps.

Much of the early pressure to post specific route numbers on highways was generated by the need to coordinate these highways with maps. In today's city maps, there are many varying standards. All city maps have street names; some define street numbers; some contain route designations; most define townships one way or another; some define districts within the city. In all of these cases, however, the specific information presented and the method of presentation vary considerably.

In most cities, public transportation maps are available in stations, on buses and subway cars, and for general distribution. Some of these maps, such as those on subway cars and buses, make little attempt to orient the passenger to the city above or around him — rather, these maps are intended only to enumerate the stops on a given line. Transportation system maps which do relate transit lines to the city seem to be notorious for their complexity.

A truly comprehensive urban sign system must consider all modes of transportation within the city and all other means of communicating with travelers and pedestrians in the city. We may, therefore, be wise to consider maps as part of the sign problem and, in fact, to create standard formats which may be used to orient pedestrians within the city. It would be certainly useful to have these maps, and the sign system itself, coordinated with the efforts of other agencies responsible for the orientation and transportation of people within the city.

Creating a matrix that includes user groups, modes of travel and information needs may allow development of a total urban communication system.

User Groups

Within the system, information would need to be channeled to particular user groups; for example, to isolate the information needs of truck drivers and provide a channel of communication — in the form of a special subsystem of signs — for them, as discussed below.

Trucks are excluded from a number of major urban arteries for one reason or another. Other routes are used primarily by trucks during certain hours of the day, although automobile traffic is allowed on them as well. As congestion in the city increases, the need to route truck traffic expeditiously will increase. There will also be increased demand for the reduction of noise and pollution caused by trucks in residential areas of the city. There will be more routes prescribed for trucks only and/or more which exclude trucks completely or limit the hours in which they may pass through a given area. Increased regulation of commercial traffic will increase the need for signs to regulate and particularly to guide this traffic.

A special set of "truck" signs (Figs. 6-1 through 6-5) would provide a compact and consistent channel for communication with truck traffic. These signs might utilize shape, symbol, and perhaps color, to provide vivid identification. They would be so distinctive that the automobile driver (after an introductory period, of course) would instinctively avoid paying attention to them, while the truck driver, however, would be highly conscious of them and, we would expect, would react to their messages quickly and expeditiously.

Another channel of communication could aid pedestrians.

There are several characteristics which should be built into any purely pedestrian sign system. It must work effectively with other signs and must not distract motorists; that is, there should not be situations in which a motorist may detect the presence of such a sign and, not knowing its function, snarl traffic while he stops to read it.

Remember that the ultimate objective of any sign system is to minimize confusion and to expedite all traffic. Great care must be taken to insure that special channels of communication, such as those to pedestrians or truck drivers, sufficiently separate themselves by placement, color coding and design.

Much of the urban regulatory sign problem involves curbside parking signs and so most of our discussion deals with them. We should not lose sight of the other urban regulatory signs that are

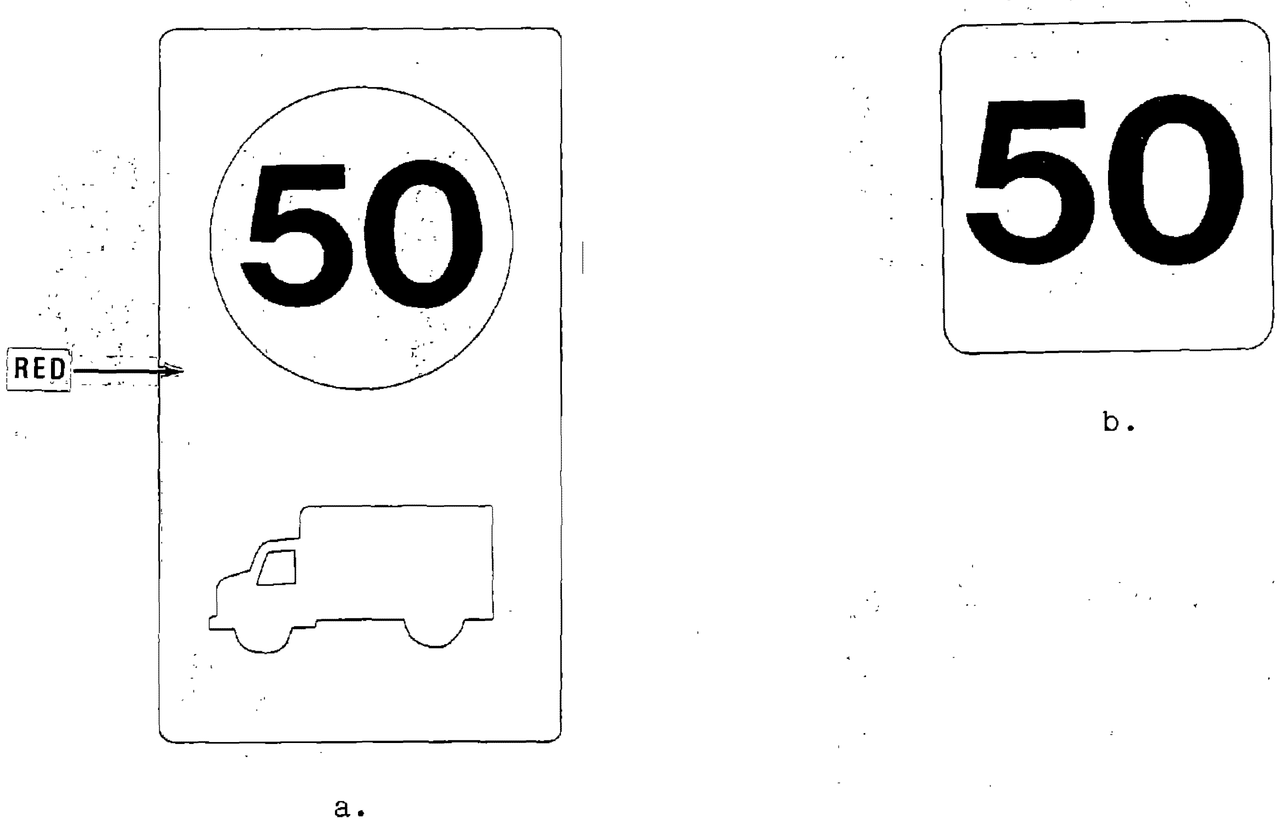
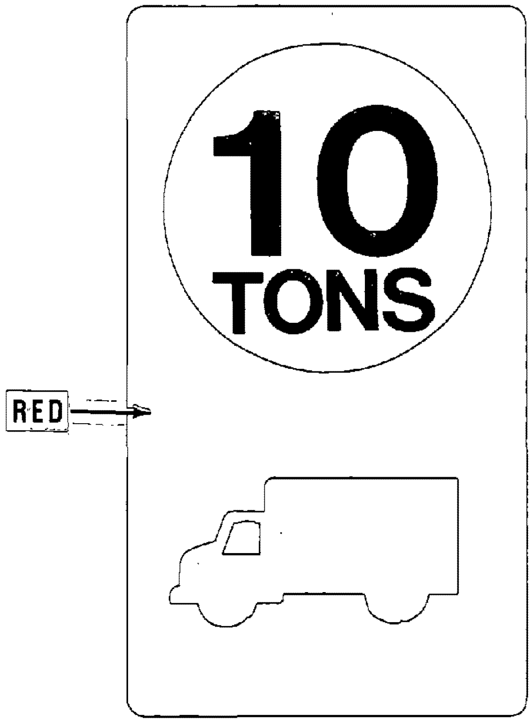
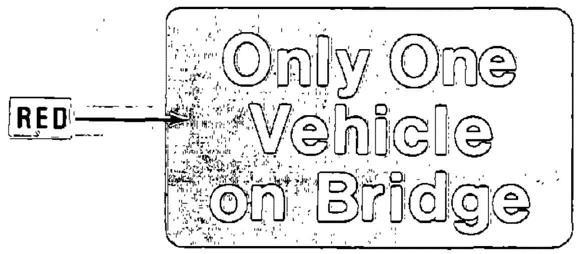


FIG. 6-1 EXAMPLES OF SIGNS FOR TRUCKS.

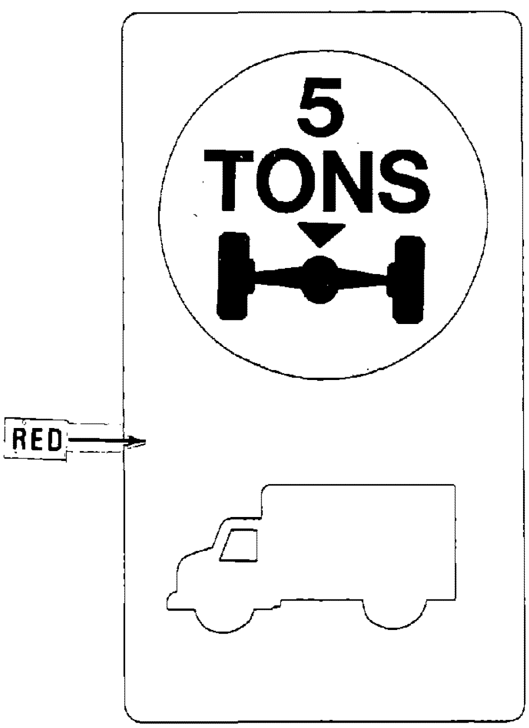


a.

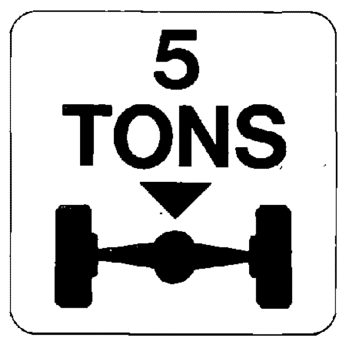
b.



c.



d.



e.

FIG. 6-2 EXAMPLES OF SIGNS FOR TRUCKS.

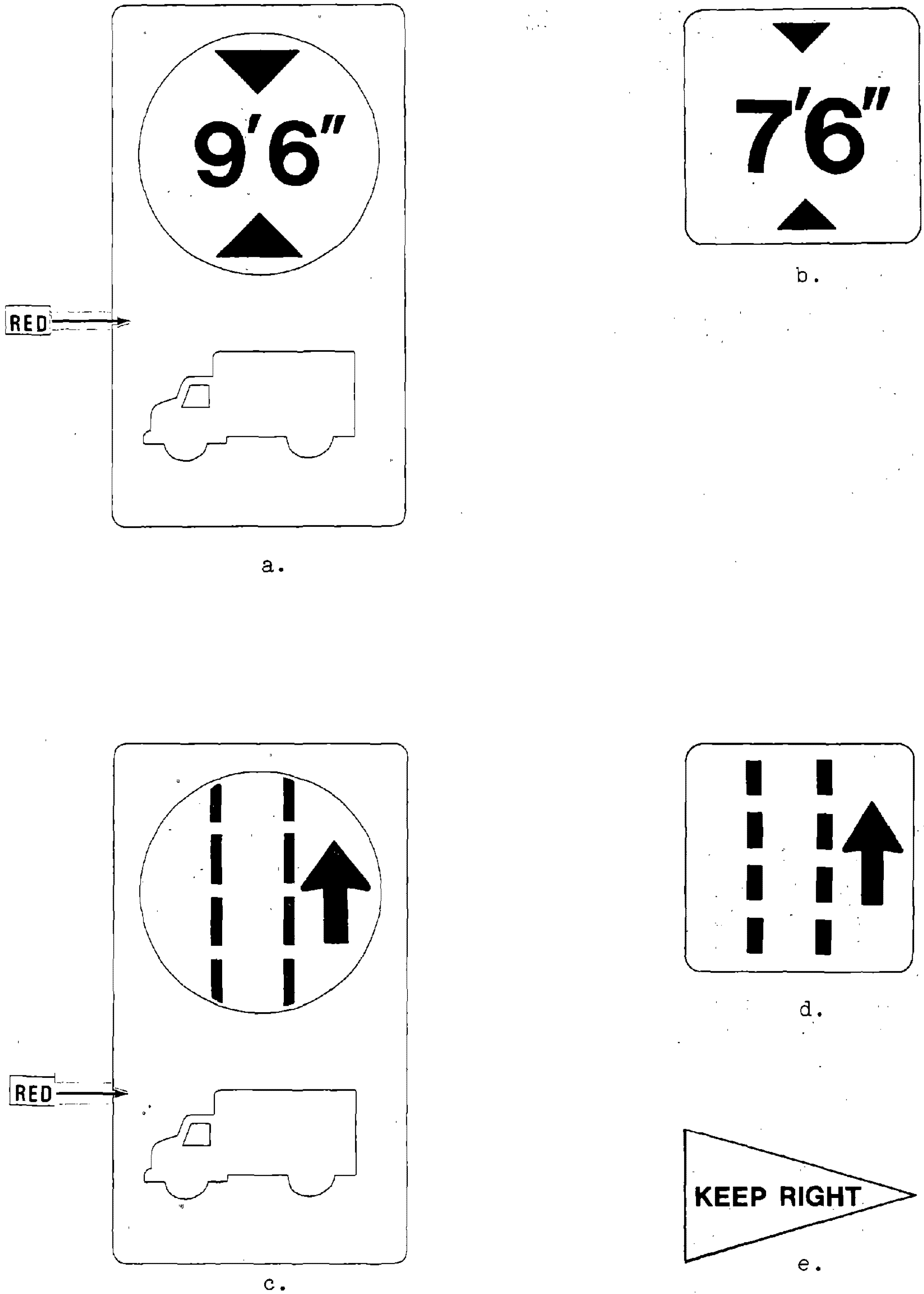
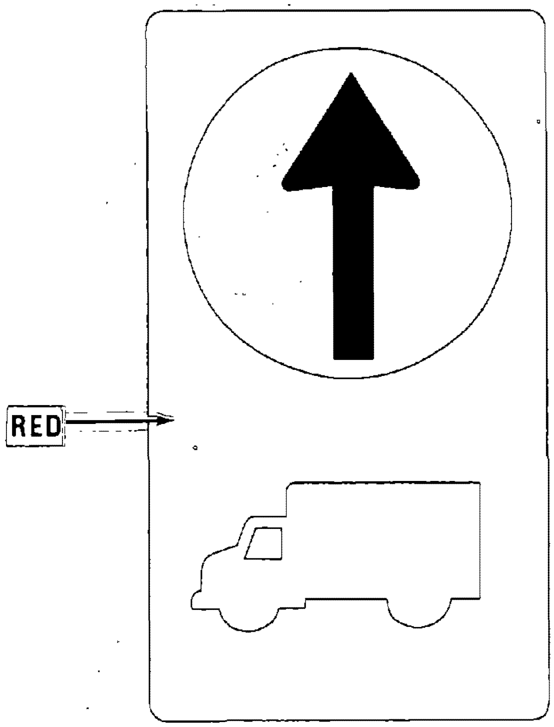
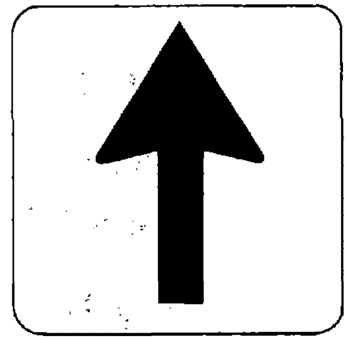


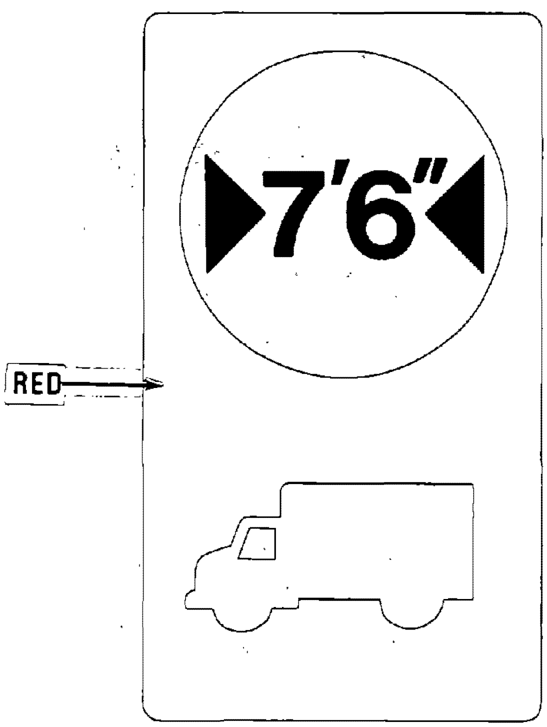
FIG. 6-3 EXAMPLES OF SIGNS FOR TRUCKS.



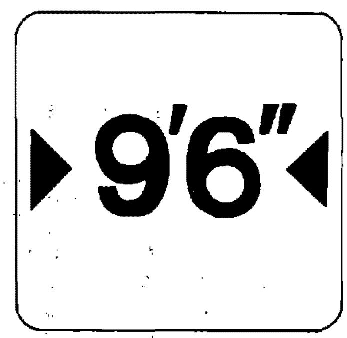
a.



b.



c.



d.

FIG. 6-4 EXAMPLES OF SIGNS FOR TRUCKS.

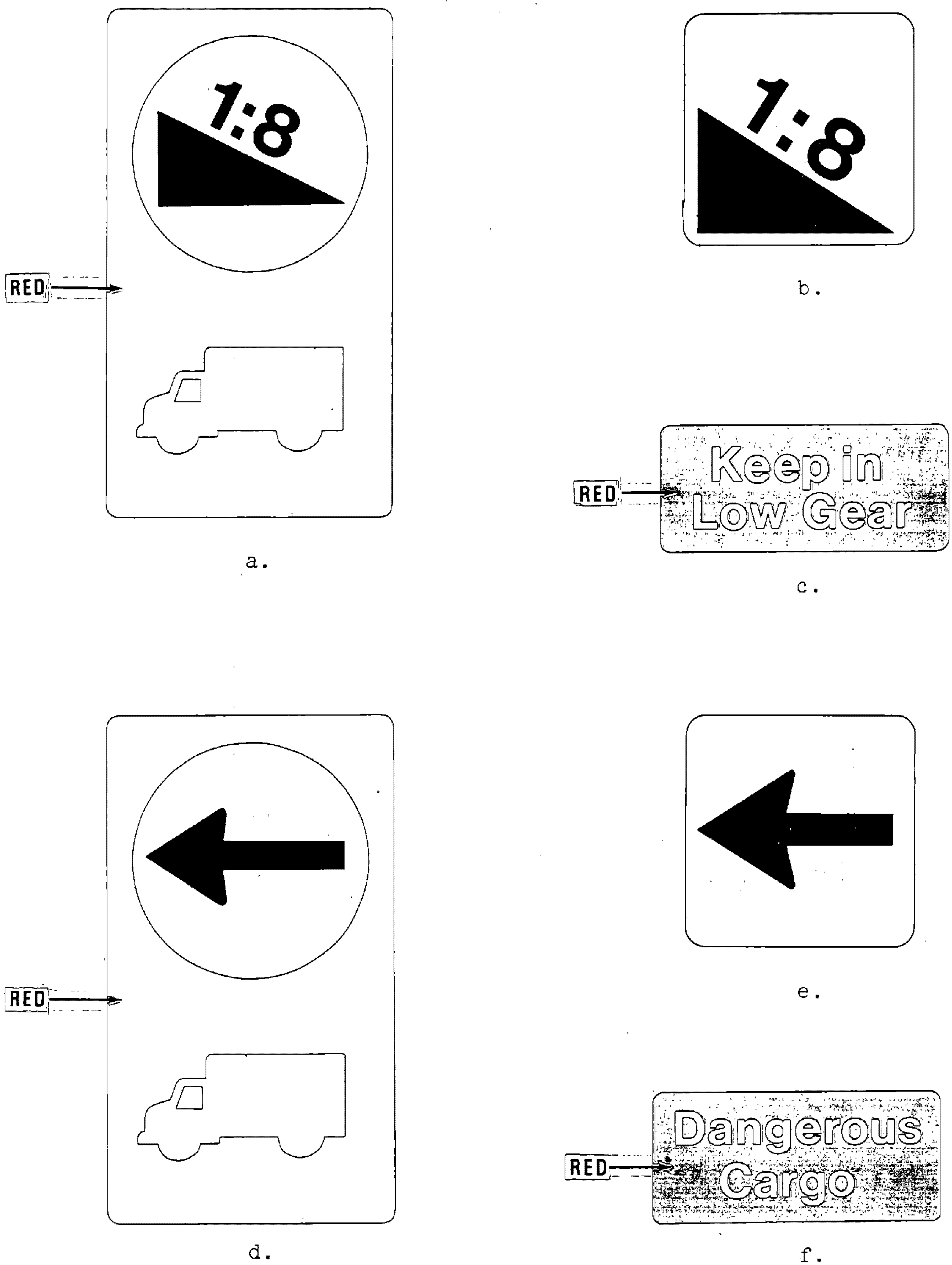


FIG. 6-5 EXAMPLES OF SIGNS FOR TRUCKS.

also a part of the urban scene, and that these signs also have weaknesses. We have already discussed signs for lane use control and traffic flow in the chapter on regulatory signs. That discussion applies to these signs in the urban situation as well.

6.3 Urban Regulatory Signs (Figure 6-6)

Regulations themselves cause many of the problems of urban regulatory signs. Traffic ordinances within a city are often patchworks built up over many years in response to specific pressures at various intervals. Thus, there is rarely a consistent pattern of regulation and, as a result, specific signs are required to pinpoint these regulations. Even more important, however, are questions of basic communication which should be answered in the design of any sign system, and which certainly should be answered in connection with urban regulatory signing.

"What does the driver really need to know?" is a question which again must be asked when designing curbside parking signs. There also seems to be little consideration for other visual cues which can communicate along with sign messages. The potential of supplemental pavement markings, for example, has not been fully explored in the urban context. Nor do we fully utilize the communication potential of other visual elements of the curbside, such as parking meters and light standards.

From an aesthetic point of view, there are a number of shortcomings in most urban signs, and particularly in urban-regulatory signs. The frail sign standard cluttered with a hodgepodge of different parking signs is an obvious example.

The complexity of many messages often creates a serious confusion of graphic elements within the sign. Closely related to this is

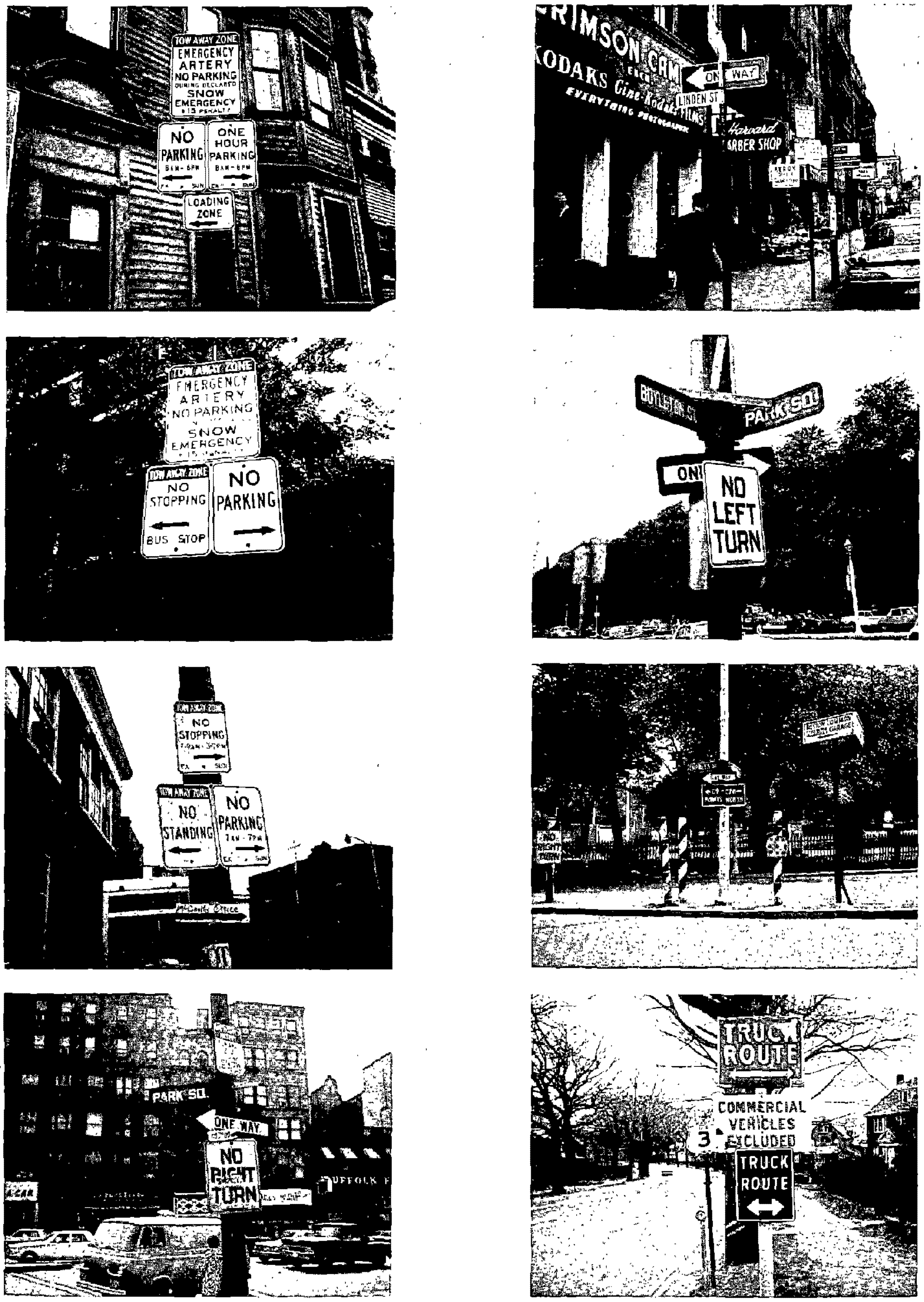


FIG. 6-6 EXAMPLES OF CURRENT URBAN REGULATORY SIGNING.

the fact that the visual emphasis is often on the wrong elements. For example, the fact that a location may be a taxi stand is not as significant to the driver as the fact that he cannot park.

The use of color as a method of delineation on current urban signs is half-hearted and, as a result, color coding is ineffective. Color should be treated so that its meaning is clearly expressed.

Another factor in the visual inadequacies of current urban signs is their purpose. We must expect that the average driver will use a series of visual cues other than signs to bring him to a prospective parking place. A row of cars along the curb with occasional gaps is such a cue. A row of parking meters along the curb is another such cue. These cues guide the driver to the area of the prospective parking place; then the specific sign takes over. So the sign should be sized to be seen from a relatively short distance away.

More attention should be paid to combination signs that would greatly reduce the number of sign assemblies. For example, if, at a given point, parking is prohibited to the left of a sign for a bus stop, and to the right at certain hours for traffic control, a combination sign would have (1) a "no parking" heading or symbol and (2) clear and simple messages on the sign itself. Currently, we would have two separate signs attached to the same pole, unnecessarily repeating information.

It is also possible to combine different types of urban signs: regulatory signs or signals with information signs, for example, as we have illustrated elsewhere.

In addition to the simplification of overall sign structures and organization, much could be done to simplify individual signs.

Along with restructure, there would be an effort to aid communities in untangling the web of regulations that contribute to the confusion of sign standards and also aid in many traffic strangulations. Terminology should be questioned. Is it necessary (or workable) to differentiate between standing, stopping and parking? The necessity of certain messages, such as tow-away zone, snow emergency route, etc., should be questioned. We must primarily consider only the information that the driver needs to respond appropriately to the instructions conveyed by the sign.

We realize the practicality of providing the driver with an indication of the seriousness of the offense, should he choose to violate a parking law; we know that drivers are often willing to hazard a $1 fine or a $2 fine where they would not be nearly as likely to take a chance on a $15 or $25 fine. We feel, however, that this may be done in a more efficient and effective manner. Symbols, or perhaps even color bands, could be used to communicate these messages, if they are really necessary.

Most curbside regulatory signs in this country today have a confused lettering that detracts from the effectiveness. This is partially because of the multiplicity of messages and message units which are often compacted on a single sign. In conjunction with the simplification of message or content, it would also be very useful to provide new, well-designed specifications on lettering style, and on the sizes for these regulatory signs.

Although the federal government must respect the prerogatives of local communities in (a) establishing parking systems appropriate to each community, and (b) providing the signs which are necessary for the proper administration of those regulations, we nevertheless feel that the national Manual should provide more specific guidance. We also feel that the national Manual could provide more specific illustrations for local officials.

6.4 Design Exploration

6.4.1 Parking signs

On the following pages we have illustrated a series of exploratory exercises involving possible design directions for parking signs. These are indicative of general directions only and require intensive additional exploration.

In this exercise we have used color to differentiate between prohibitory messages and permissive messages.

Figure 6-7 (a and b). Color coding the entire background of parking signs provides a very strong visual cue as to the type of message the sign contains. This strength is, however, a weakness. Too much emphasis on the basic message distracts from the distinctiveness of the specific information included on the sign. In addition, the use of a solid red background creates an immediate confusion with the stop sign. Possibly the use of solid color in this way would lead to some confusion and would provide a disturbing element in the urban environment.

Figure 6-7 (c and d). Present standards call for the use of colored lettering to indicate the basic sign message. We feel that there are serious questions as to whether the general diffusion of color on the whole sign face causes a reduction in its meaningfulness for

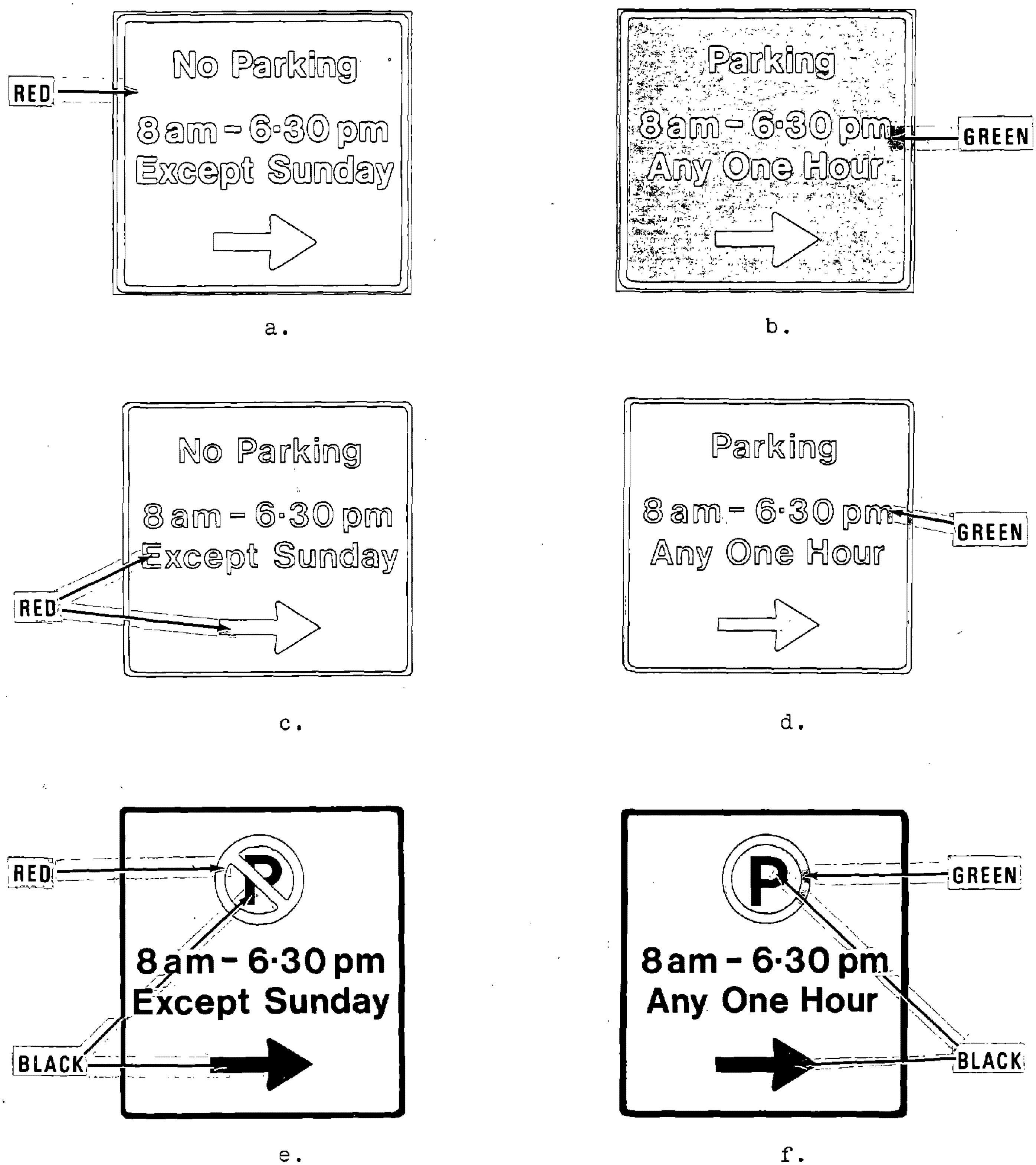


FIG. 6-7 EXAMPLES DISCUSSED IN SEC. 6.4.1.

color coding. Probably, research would indicate that the meaning of color is lost when it is diffused in this way.

In addition, the contrast between the colored letter and the white background is less than optimal and probably leads to a reduction in the visibility of the lettering.

Figure 6-7 (e and f). The use of colored symbols on a white background might provide strong color coding identification without causing any of the confusion engendered by the use of a solid color background. The area of the symbol itself is cohesive enough so that the color is not diffused as it is with lettering. It is not so strong, however, as to reduce the impact of the specific message. The symbol remains distinctive and stands out on the sign. We feel that this is a most worthwhile area for further exploration.

Figure 6-8 (a and b). Color-coded blocks or strips appear in many urban parking signs today and are included in the *U.S. Manual on Uniform Traffic Control Devices.*

As presently used, however, the color strip provides emphasis for the least important part of the sign's message. For example, we doubt whether "tow-away zone" is the most important part of any sign. In addition, the use of white lettering on a small colored band placed on a larger white background is, from a visual point of view, less than satisfactory. The primary contrast is between the colored band and its white background, resulting in greatly diminished visibility of the lettering. However, color-coded strips could possibly be used effectively in an urban sign system, and we feel that their use should be further explored.

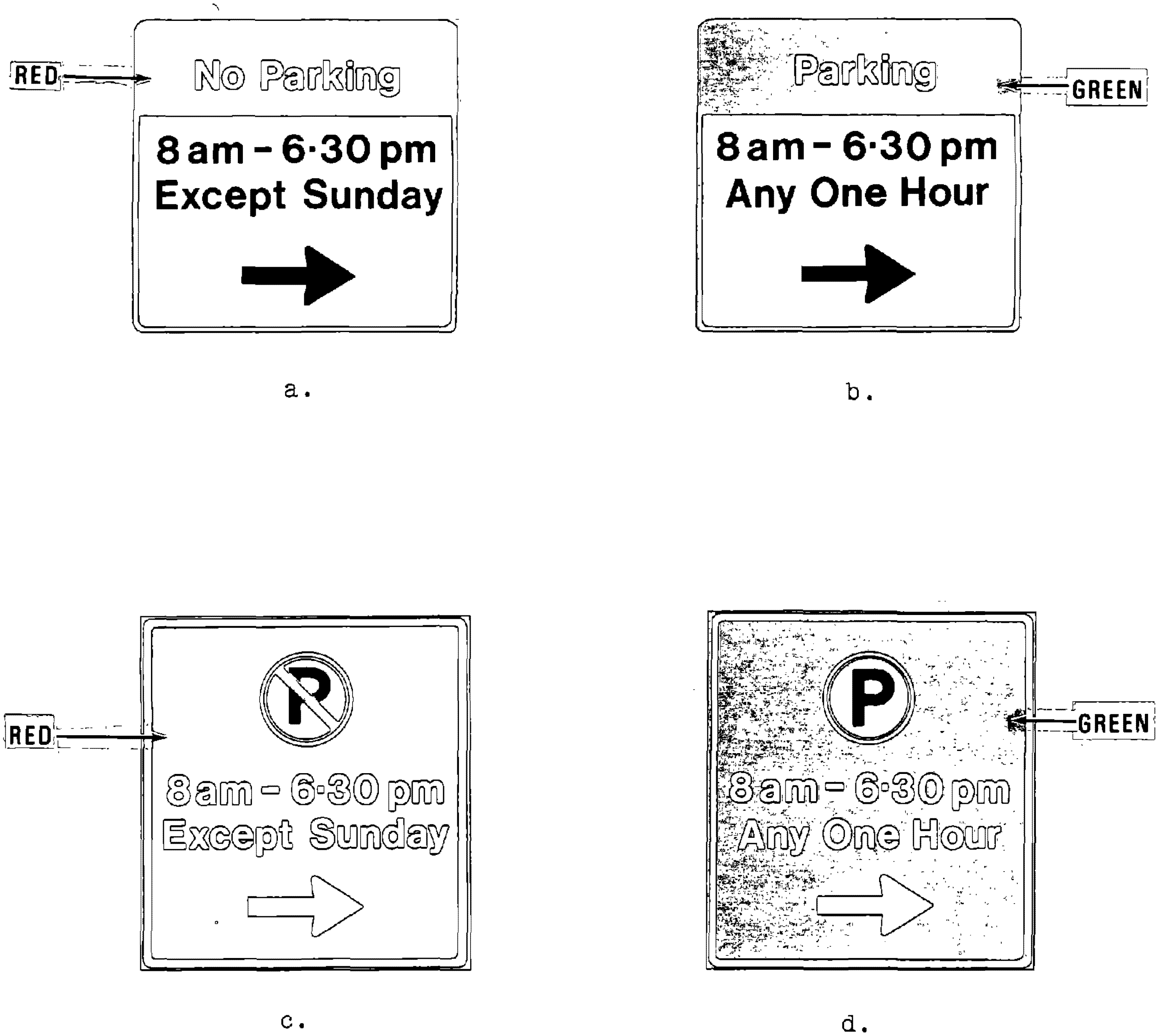


FIG. 6-8 EXAMPLES DISCUSSED IN SEC. 6.4.1.

Figure 6-8 (c and d). Use of a white symbol on a solid background deserves some brief exploration. This approach has the weaknesses inherent in the use of solid color background and so we may expect that this avenue will not be highly fruitful. The possibility should be included in any comprehensive exploratory program.

Figure 6-9 (a and b). These illustrations represent two approaches to the multiple message urban parking sign: the first is incorporated into street furniture, while the second stands alone. The first also incorporates a slat system which we feel should be explored in urban signing. Each slat is a modular unit that may be combined with any number of others to create a complete sign. In this example, all redundancies have been eliminated, greatly reducing the visual clutter. In this example, symbols have also been used to minimize verbal confusion.

Figure 6-9(b) shows the incorporation of strips that would be preprinted on a reflective adhesive-back material. These strips could then be affixed to standard width sign forms. Forms could be made in varying lengths to accommodate the messages.

Both of these methods are indicative only of potential approaches aimed at reducing the number, the visual clutter and the unnecessary redundancies of signs. Probably, a number of other approaches should be attempted experimentally in order to reach the same objectives. The basic argument here is for a highly flexible system that would accommodate all messages in a consistently uniform fashion.

Also built into this example is the chronological ordering of sign messages in a consistent fashion. Where different regulations may

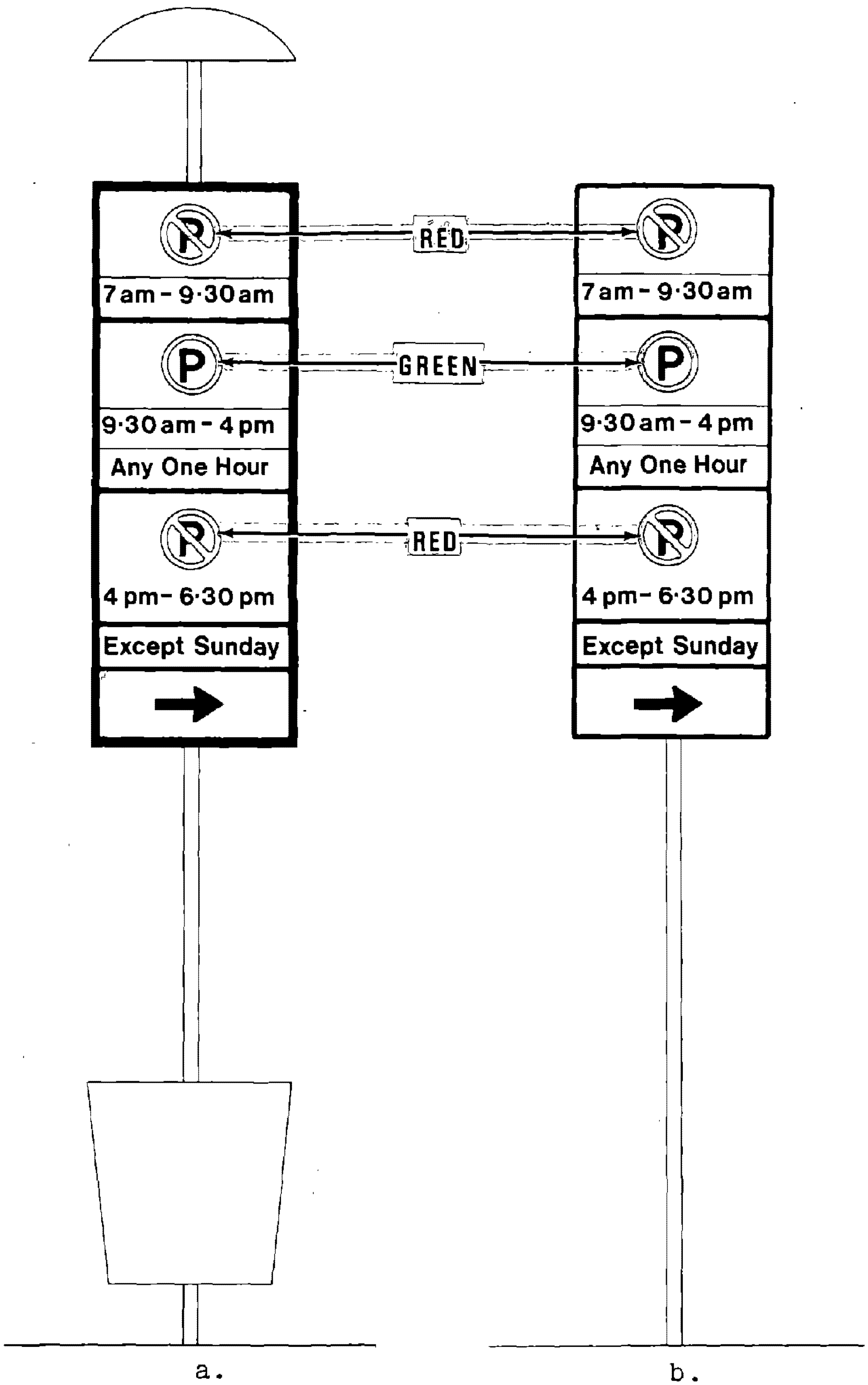


FIG. 6-9 EXAMPLES DISCUSSED IN SEC. 6.4.1.

apply at different times in the day, information should be transmitted in a logical, consistent manner. The example goes chronologically from top to bottom.

6.4.2 Urban guide signs

As is the case elsewhere, these illustrations do not represent actual design recommendations, but are meant only to illustrate and suggest the types of signs which might be used in a comprehensive urban guide sign system.

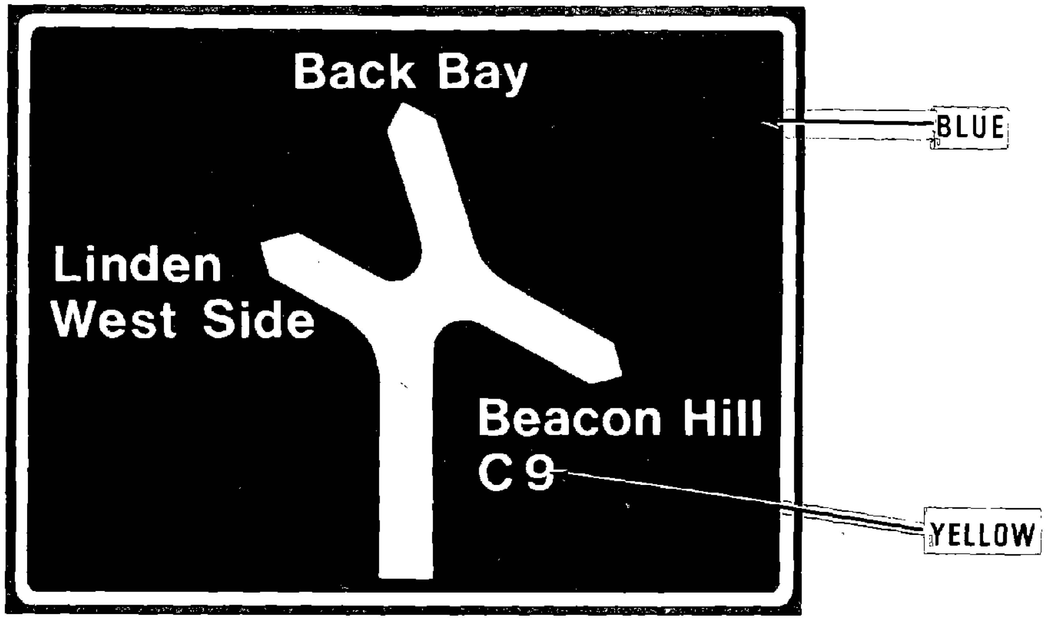
If one were to interpret the current MUTCD liberally, then all of the signs included in this section would be permissible. Our argument again is that the MUTCD should provide more than permissiveness; it should provide specific instructions along with specific illustrations.

6.4.3 Major guide and destination signs

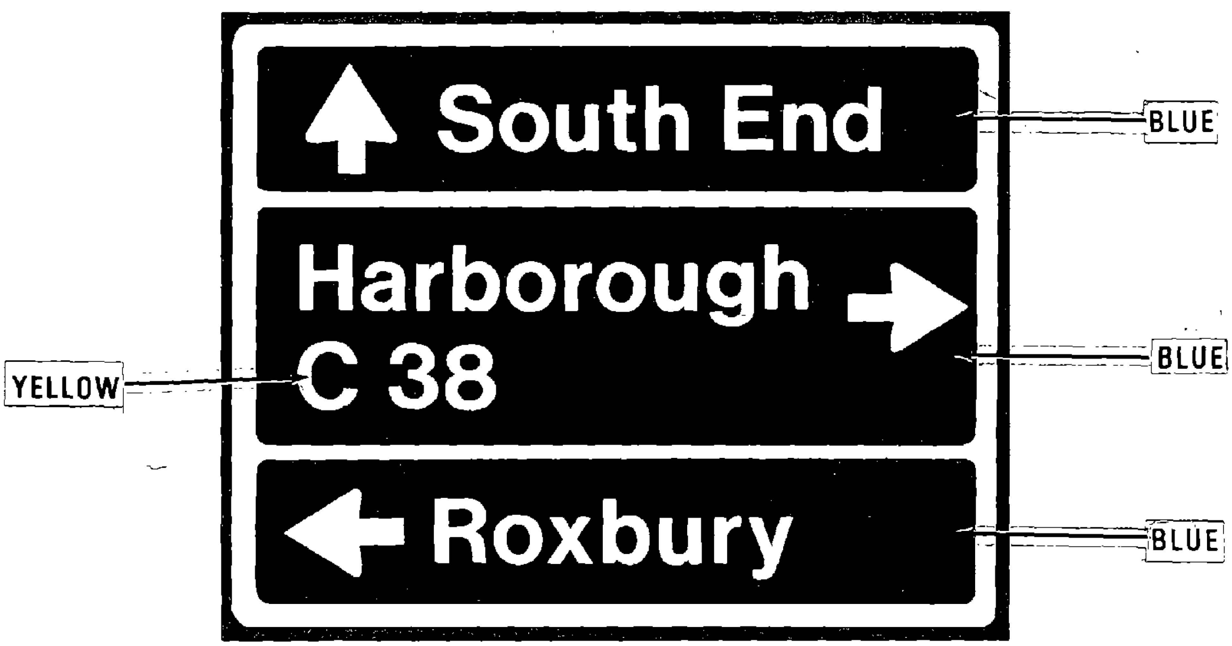
We have illustrated two types of major guide and destination signs: the first [Fig. 6-10(a)] is the map-type; the second [Fig. 6-10(b)] is a stack-type sign. Both represent elements of an intermediate subsystem, which would come between expressway destination signs and those used for purely local guidance.

These signs would relate to the expressway signs through the use of color, specifically, their green backgrounds. Their relationship to the local system would be established, of course, by their content.

As a rule we would expect that the map-type sign would be more appropriate for complex junctions, whereas the stack-type would be



a.



b.

FIG. 6-10 EXAMPLES DISCUSSED IN SEC. 6.4.3.

quite adequate for simple junction situations. (For a more detailed discussion of the two types, please refer to the guide sign section of Chapter 4.)

6.4.4 Minor guide and destination signs

The information contained in the major guide signs should be extended into a subsystem of more local destination signs. Here we assume the driver is within the city, away from expressways and other major arteries, and may be seeking local destinations such as universities, hospitals, parking areas, major shopping areas or other landmarks or institutions within a very limited radius of the sign location [Fig. 6-11(a)].

The insistent use of blue, either as a background or a border on these signs, would lead to their recognition as elements of local information only.

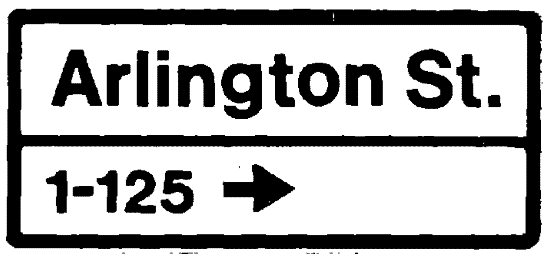
6.4.5 Street name signs

In this suggested system, street name signs would also be predominantly blue [background or border and letterings as shown in Fig. 6-11(b)]. In addition to providing the street name, they would also provide street numbers for the relevant block.

Major streets could be indicated by advance information signs. In Fig. 6-11(c), the fact that a major street intersects three blocks ahead is indicated.

There are, of course, a number of variations possible on advance information signs and careful attention must be paid to systematic content that would provide the user with logical and predictable sources of local information.

a.



b.

c.

FIG. 6-11 EXAMPLES DISCUSSED IN SECS. 6.4.4 AND 6.4.5.

6.4.6 Pedestrian signs

The most local information would be included in pedestrian signing. In both Fig. 6-12(a) and 6-12(b), the blue border has been used to remind the user of the local nature of the information.

Placement of pedestrian signs would be critical in that they should not provide distraction for automobile drivers and that they should be easily visible to pedestrians.

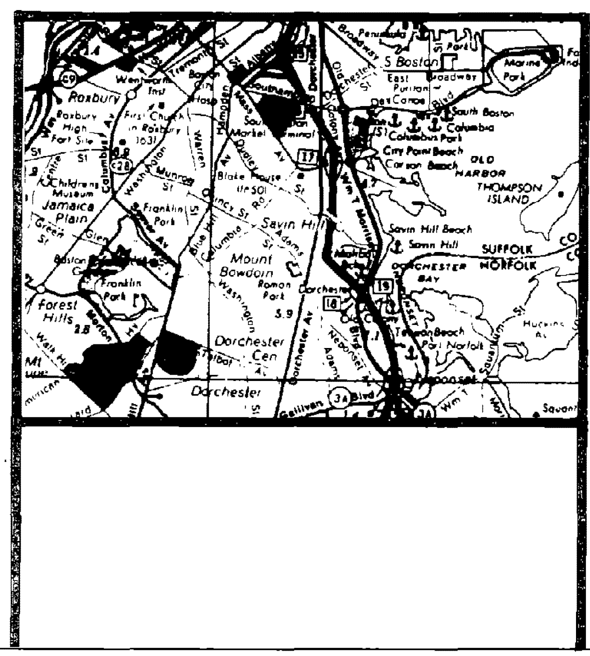
Pedestrian maps would be a very useful addition to a city's public information system. As we have indicated, these maps should be carefully coordinated with transportation maps and other information vehicles available to the city.

Such maps should be primarily located at transfer points, parking areas, public plazas and malls, wherever a major point of transfer or decision exists for pedestrians.

Maps should be primarily of those areas within walking distance of the map's location. Maps of adjacent areas might be included in miniature or on a roller system (which might provide vandalism problems).

In constructing a pedestrian sign system, some consideration should be given to private sign problems which may be of public interest. For example, it may be feasible to have special structures which would accommodate local advertisements, perhaps even political handbills, and other "bulletin board" information. Any such structures would need to be carefully planned and located if they are to be effective and if they are to escape damage or destruction by vandalism.

a.



b.

FIG. 6-12 EXAMPLES DISCUSSED IN SEC. 6.4.6.

6.4.7 Combination of regulatory and guide signs

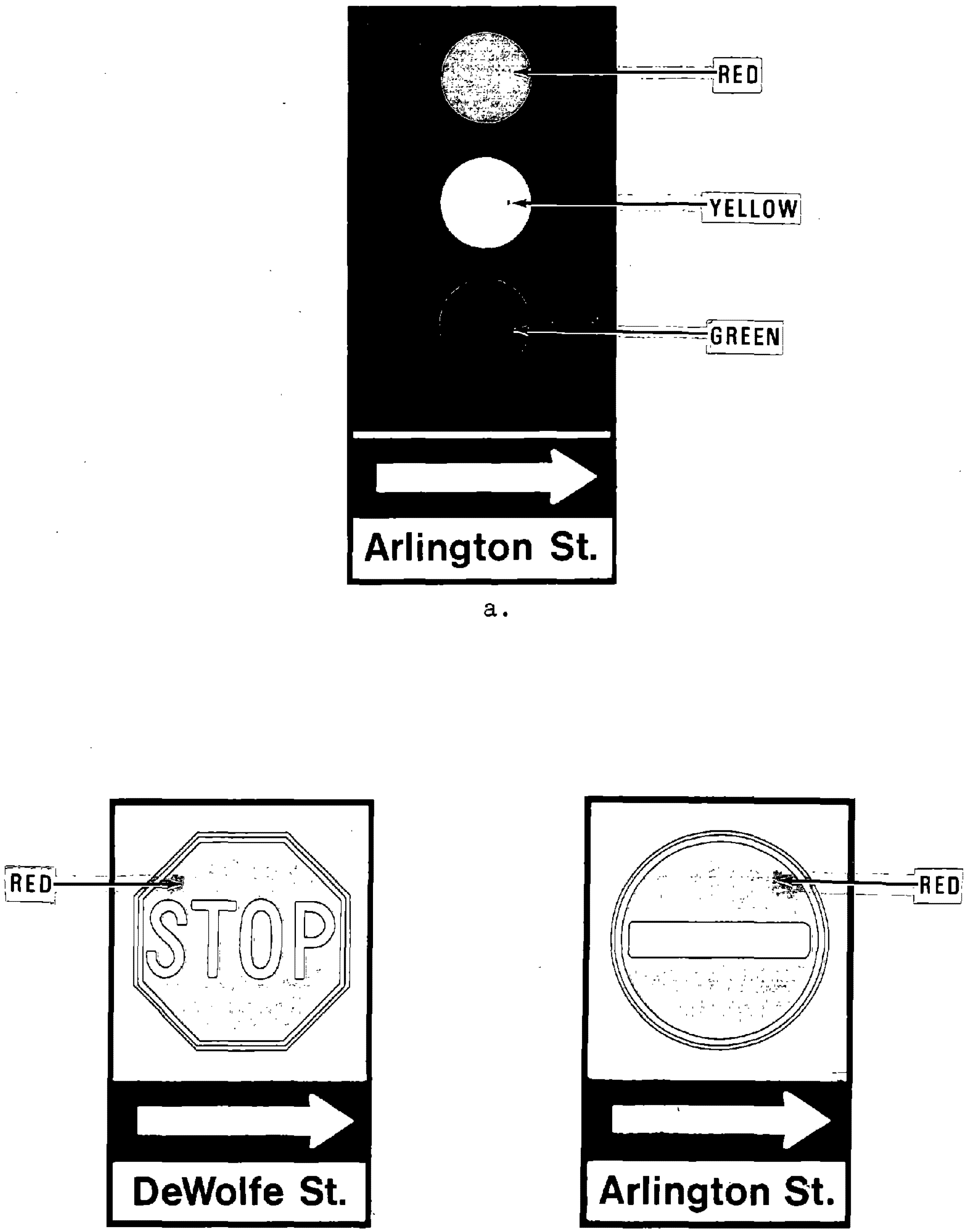
To reduce the number of separate signs in the urban environment, it may also be possible to combine certain regulatory and guide sign functions on a single standard or structure. This is particularly true where the regulatory sign also serves something of a guide function as in a ONE-WAY situation. Some examples that illustrate these suggestions are shown in Fig. 6-13. Not all such combinations are workable, and the loss of important cues such as shape is usually unacceptable.

6.5 Urban Expressways

Urban expressways also present a number of unique problems and should, it is felt, be dealt with independently. Again, the fact that a road is in the city (or over it or under it) makes it very much different from the same type of highway cut across the countryside. The multiplicity of exits and heavy congestion create unusual pressures on traffic control and on the sign system.

The present MUTCD acknowledges some of the problems by allowing for close placement of advance exit signs. Other sign systems – even the British with its detailed guide and information signs – make no particular accommodation for the urban expressway.

There seems to have been very little work done in connection with the relation of the urban expressway to the city around it. In part, this may be a matter of orienting the driver in relation to landmarks, districts, and major streets in the area through which he is traveling. This must be counterbalanced, however, by the very real fact that there is little opportunity for casual browsing of signs on an urban expressway. Decisions must be made quickly and often in a fast-moving stream of closely-packed traffic.



a.

b.

c.

FIG. 6-13 EXAMPLES DISCUSSED IN SEC. 6.4.7.

A very well-planned lane-use control system should be designed to guide drivers through and off the expressway. Exit information should be amplified at the end of every exit ramp, where the driver slows or stops before joining the stream of city traffic. At this point the driver should be able to identify and use a subsystem of guide signs extending from and related to the system he has just left.

Signs in the city should also guide the driver to the expressway and inform him where the expressway goes. Extra precautions must be taken to help avoid "wrong way" drivers. Signs at entrance and exit ramps are of critical importance.

Highway planners are currently very conscious of the highway's relation to the city. Whereas once the major arteries seemed ugly slashes created only to expedite traffic, many of today's highways are being planned by those who have a sincere concern for the history and integrity of the city and for its aesthetic values. The signs on the expressways and in the city should reflect the same consideration.

Summary

The urban environment provides the setting for many complex and critical problems, many relating to traffic flow, the relationship of expressways to the city and the visual plight caused by the proliferation of urban traffic signs.

None of the sign systems of the world deal with the urban sign problem in any significant manner. The *U.S. Manual on Uniform Traffic Control Devices* hardly acknowledges the problems and provides very little in the way of guidance for those responsible for the implementation of urban signs.

The urban sign problem requires special attention in that it should be approached comprehensively.

Information needs must be defined as accurately as possible. The delineation of user groups may be useful in determining these information needs. The relationship of other visual cues in the urban environment to signs must be considered in the process of determining information content.

Other modes of transportation must also be considered in addition to auto traffic. A total communications system, of which traffic signs are the major components, must consider every form of transportation and every information need in the city.

In order to help reduce the proliferation of signs while expediting communications, special subsystems of signs should be explored for particular user groups.

The proper definition of information needs and the detailed structuring of a truly comprehensive urban information system will require a great deal of time and effort. In the interim there are many things which can be done to improve significantly the design of specific signs and of types of signs. This Chapter has included illustrations of the type of design direction which should be explored.

In all of this, of course, the authors have been concerned only with public signs in the city. Although private signing is beyond the scope of this study and beyond federal control, it is nevertheless an important factor in the city's visual environment. The relation of private signing to the overall visual environment in general, and to public signs in particular, should be explored and examined. The results of such an examination may be very useful in developing new standards for public signs and perhaps for suggesting approaches to the problems of private signs in the urban environment.

Signs and the Environment

This report has stated that the development of urban sign systems must be approached with a primary concern for communications needs in the city and how these needs may best be met by signs and other communications generators. One should, however, be very sensitive to the urban environment in the creation and modification of any sign system. One should not only seek ways to reduce visual clutter wherever possible, but should also try to enhance the environment and complement the light and color of the cityscape.

Eliminating unnecessary sign messages and combining signs wherever possible will help to alleviate some of the clutter, but the efforts must go further, however.

One area worthy of exploration is the combination of certain signs with other curbside structures. This Chapter illustrated a slat sign system incorporated into a piece of street furniture. The development of a structure to include traffic signals and certain signs is another example of such exploration. It may also be possible to combine parking meters and sign structures. Experiments indicate that this, too, is a feasible method of minimizing sign proliferation. In any case, wherever a single structure can efficiently contain the functions now being performed by several signs, then we will have progressed in the right direction.

Still another avenue for exploration, and perhaps in the long run the most significant, is the assumption of sign functions by other communications devices. We have already spoken of the underutilization of pavement markings as sign substitutes. The painting of curbs also has a place in the total communications scheme. In areas where weather conditions sometimes obscure curb and pavement markings, ancillary devices such as relatively short reflectorized posts may be used. Electric lights are another possibility. A system using red and green lights to indicate times of parking and no parking has been suggested.

Signal lights are in themselves a very complex problem which have not been studied in any detail during this program. They, too, represent an opportunity for improvement and, as we have indicated, for integration with other communications elements.

In general, the more simple abstract communication elements (such as markings and lights) that can be built into the city sign system, the less interference there will be with the urban environment. In fact, flashing lights and colored signals can, if done properly, be a positive aesthetic factor in the environment.

If we are to provide highly effective communication while enhancing the urban environment, more attention must be paid by and to urban planners with regard to public signs in the city. Historically in urban renewal situations, signs have been put up after construction is finished and have been imposed on the street in accordance with local ordinances, the MUTCD, and, in some cases, the whims of the local traffic engineers. A large section of a city may be meticulously planned and carefully constructed to fit that plan while appearance and placement of signs has no relationship to the plan whatsoever. More work needs to be done to help integrate signs with other aspects of urban planning.

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