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An Investigation of the Design and Performance of Traffic Control Devices

John Lees and Melvin Farman

This paper reports on a study (performed for the United States Bureau of Public Roads) involving a comparative analysis of the design elements of the major highway sign systems of the world. Shape, color, symbols, pictographs, and verbal messages were studied through design exercises, laboratory investigations, and road tests. The study—carried out by a multi-disciplinary team of psychologists, engineers, and graphic designers—also included extensive reviews of existing research on highway signs, traffic control devices, and the design of signs. The introduction examines the history of highway sign development and regulation as well as a discussion of an automobile driver's processing of information.

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

Imperial Rome provided road signs for travelers. Under Caesar Augustus, the 29 major military highways which led from the city to the outposts of the empire were provided with milestones for their first 100 miles. A law establishing compulsory measurement of these routes was enacted in 183 B.C. It took almost 200 years for a standard milestone to come into general use. Neither travel nor road signs changed significantly during the next 18 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.

Early Developments in the United States
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. Traffic control problems peculiar to railroads caused the evolution of a special set of railroad signs and signals. 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 commercial and social interaction 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, 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.

Although these commercial interests and the numerous road associations did much to provide orientation for many travelers, their multiplicity 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. 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 also led 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; 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 U.S. 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.

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 on the signs so that many were badly cluttered. Many of the signs were verbal and 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 specified pictorial conventions for uneven pavements and curves; it 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.

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.

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 50 traffic signs and was signed by about 30 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 all other systems 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.

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 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 sign 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. The present British system, among the most modern in the world today, is based primarily on the signs contained in the 1949 U.N. Protocol.

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.

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. 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; 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 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, 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 system accommodates a differentiation among signs for motorways, primary and secondary roads. Color coding is used for visual differentiation, 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.

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 and British systems 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 U.S. 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.

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. 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.

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. 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 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.

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 have 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 research has 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 later in this paper.

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 the scenery or 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 collisions.

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.

Relating Signs to the Driving Task

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; 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. 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.

THE EXPERIMENTS

Shape

Each of the world's highway sign systems uses certain shapes for specific or general types of signs. In the American system, for example, the octagon is reserved for the stop sign while the equilateral triangle, with one point downward, is reserved for the yield sign. The diamond shape is used for warning signs, and rectangular shapes are used for regulatory and guide signs. In regulatory signs, the longer dimension is vertical; in guide signs that dimension is generally horizontal. The circle, which is used extensively in other systems, is used only for advanced warning of railroad crossings and for civil defense evacuation route markers.

In the laboratory, 14 shapes were tested (Fig. 1). Approximately 30 observers were used, each for at least ten daily sessions. Each session lasted two hours in which each subject was exposed to 80 tachistoscopic stimulus presentations. (Exposure durations used were: .015, .020, .025, and .030 seconds.) Each stimulus presentation was preceded and followed in time by masking fields of visual noise of slightly higher energy.

Each observer was asked to tell which of the shapes occured on a given trial and to attach a numerical confidence rating of from one to four. They were provided with an answer sheet to record responses, as well as with copies of all of the shapes being tested. They were required to answer on each and every trial.

Results. The shapes which were found to be most distinctive and recognizable from the set in both positive and negative were those with the most accute angles; triangle, pennant, and trapezoid. Figures with more obtuse angles: octagon, pentagon, square, and diamond, as well as the circle, did not fare as well. When the data was analyzed according to negative and positive presentations, the superiority of the positive (black figure on white images) was quite clear and held true for every shape.

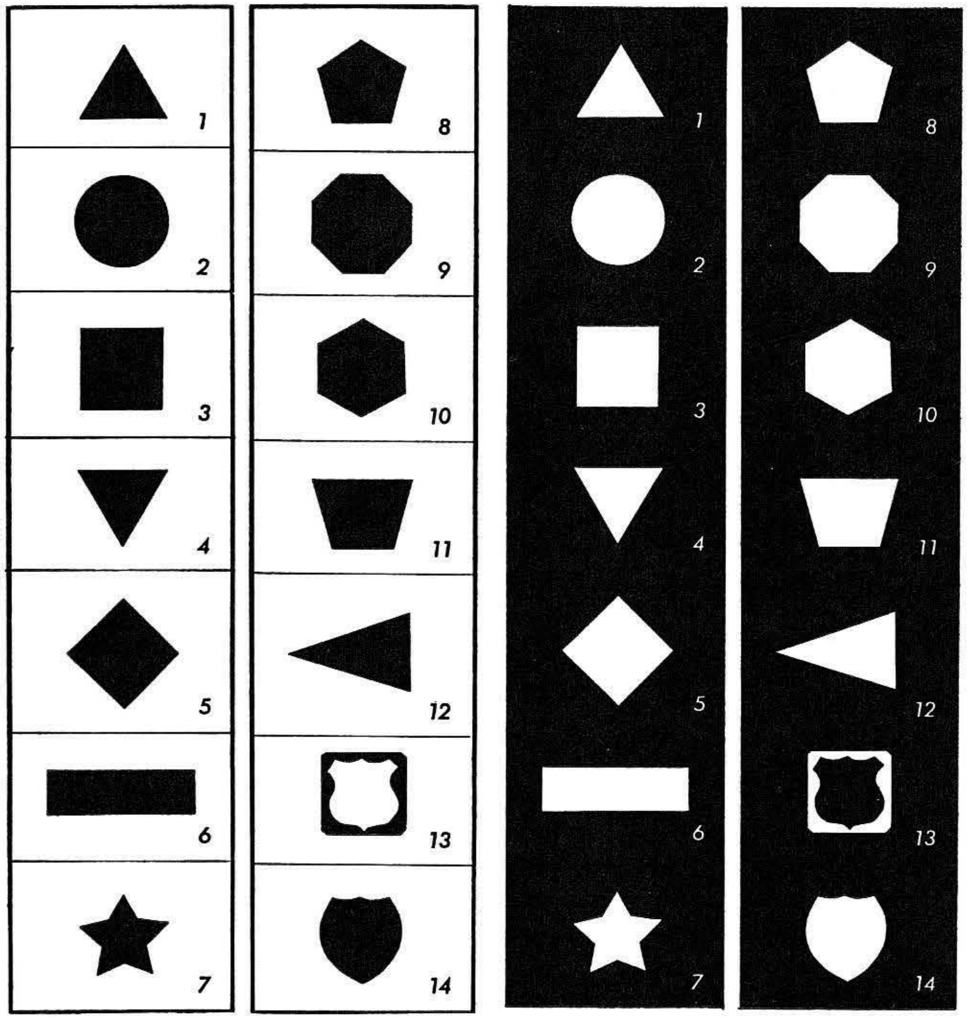


Figure 1. The shapes tested, in positive and negative image.

Arrows

Arrows are, of course, quite significant in traffic control devices. A number of different arrows are used in the various systems and variations of these systems. Seven were chosen for study (Fig. 2). Again, stimuli were presented tachistoscopically. Each presentation consisted of one of the seven arrow types oriented in one of the basic cardinal directions: up, down, right, or left. The observers were instructed to indicate the directions in which the arrow pointed, and, again, to rate their confidence in their decision on a four-point numerical scale ranging from "very sure" to "very unsure." Exposure durations were varied.

Results. Arrow type 1 proved to be clearly superior to all others. Visually, it carries directional information not only in its arrow head, but also through its tapered shaft, so that the necessary processing of the figure by the observer is reduced. The experiments also indicated that vertically oriented arrows were easier to recognize than those which were horizontal.

Recognition of Shape in Colored Shapes

Color plays a very important part in all sign systems. In this set of experiments the recognition of shape as a function of color was tested. Ten of the 14 shapes used in the shape tests (Fig. 1) were selected for testing and observers were exposed to groups of 30 randomly selected colored shapes in red, yellow, blue, and green (the colors most often used in various sign systems.) Observers were asked which of the ten shapes occurred on a given trial and to rate the confidence in their answer.

Results. The researchers found that the introduction of color effects no drastic changes in the recognition of shape.

The previous set of experiments were repeated with one exception: Observers were asked to identify color rather than shape.

Results. The tests indicated a high recognizability factor for yellow at brief exposure durations (15 mila seconds), quickly declining at longer exposure durations, and increasing again at even longer durations. The recognizability of red, blue, and green was very consistent. The limitations of the project precluded pursuing the

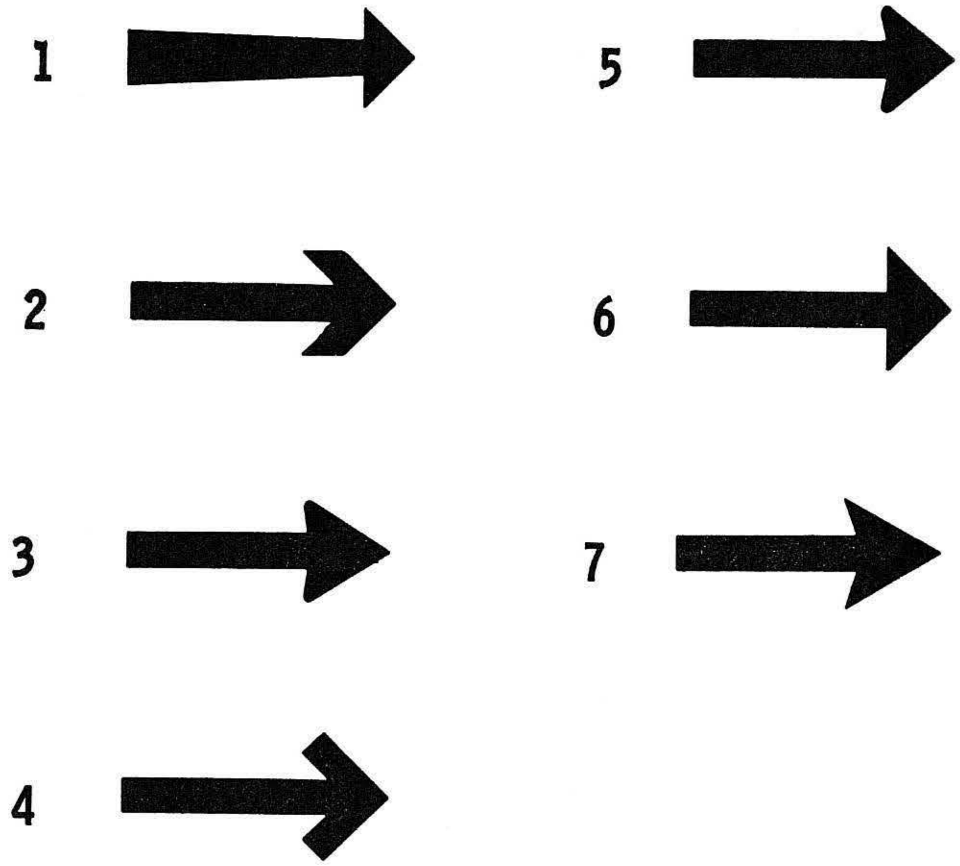


Figure 2. The directional arrows tested.

unusual reactions to yellow. It should be remembered that observers had to choose from a finite set of alternatives. It is possible that in very brief exposures, when the observers saw "nothing," knowing that it had to be one of the four, they chose yellow as the most likely alternative.

Guide Signs
Directional and informational signs are very important elements of every sign system. The researchers classified two major ways of "reading" signs: searching and discovering. In a search situation, the observer approaches a choice point with a well defined destination in mind. Expecting to find that destination on the sign, he searches through the words on the sign to find what he is seeking. In a "discovery" situation, the observer either has no well defined destination or does not expect to find it on the sign. He must then "discover" which destination names go with what directions, and then, finding the destination most properly related to his ultimate destination, he will know how to proceed.

Searching for a Destination. Three destination names on a set of guide signs were used in this series of experiments (Fig. 3). One destination went to the right, one to the left, and the third straight ahead. Any of the three destinations could appear in any of the positions of travel. Arrows indicating the directions were located all to the left of destination names, all to the right, or scattered. Signs were either positive or negative. Observers were tested at varying exposures which were basically longer than those used in previous tests, since the task was more complex.

Results. Several conclusions could be drawn from the data. Arrow placement to the right of the destination name is inferior to placement to the left or staggered presentation, the later two having about the same measure of supperiority. Positive presentations (black legend on a white background) produced better results than negative variations. The tests also indicated that the middle position of the sign is best in terms of being most easily and efficiently processed. Yet another analysis indicated that the straight ahead direction fared best in terms of identification, although this might be attributed to the fact that in the signs being tested, two of the arrows were horizontal while only one was vertical.

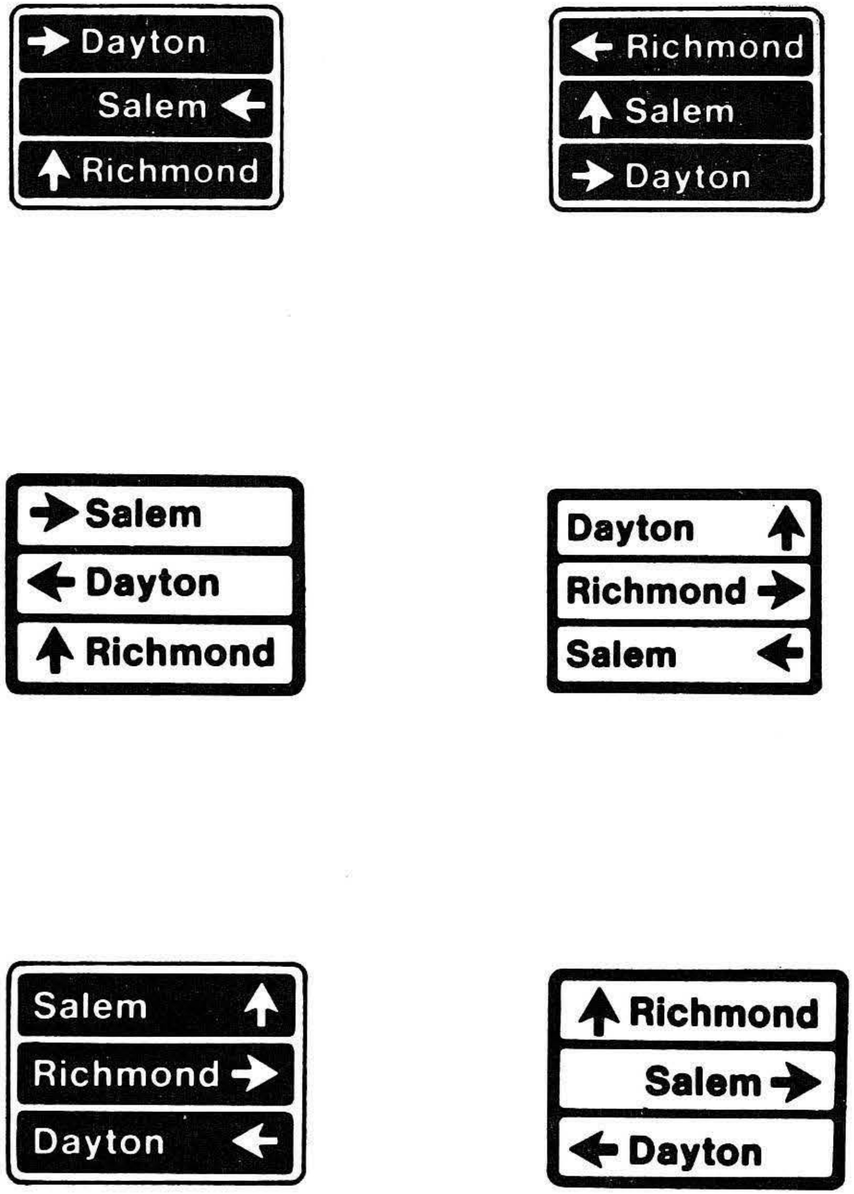


Figure 3. Specimen guide signs used in testing search for a destination.

Discovering a Destination. In the "search" test, observers had been given a list of destination names and required to respond with the associated direction of travel. In this series of tests, the observers were given the direction of travel and asked to discover the name of the destination presumed to be lying in the target direction.

Results. In these tests, data generally paralleled results of the "search" series of tests. Arrow placement to the right of the destination proved inferior to placement to the left or staggered; staggered presentations were slightly superior to placement to the left. As the previous series of tests, positive legends on negative backgrounds were far superior to their negative counterparts. Again too, "best performance" was associated with the middle position on the sign, and the "straight ahead" direction was most easily discovered.

Pictographs

The study did not undertake to compare pictographs to verbal legends. It did, however, attempt to discover which of a large set of pictographs were most easily recognizable from amongst that set. A set of 44 commonly used pictographs were used as stimulus (Fig. 4). Observers were given a list of intended meanings as a set of response alternatives.

In a second set of pictographic experiments, observers were asked to respond to each stimulus in their own words. The results were sorted into four catagories: strictly correct, generally correct, irrelevant, and contradictory. It is interesting to note that although the pictograph depicting "children crossing" was difficult to recognize, its meaning was most clear. The results of both series of pictographic tests were plotted as indicated in Figure 5.

According to this classification scheme, the best pictographs are falling rocks, slippery road, signal ahead, airplane, cattle crossing, pedestrian crossing, sheep, horn, noise, horse, elephant, and children crossing.

The worst, according to this classification scheme are: gas pump, no passing, police hat, youth hostel, fork and spoon, hump bridge, tent, wrench, dip, tar, riverbank, first aid, bus, telephone, and trailer.

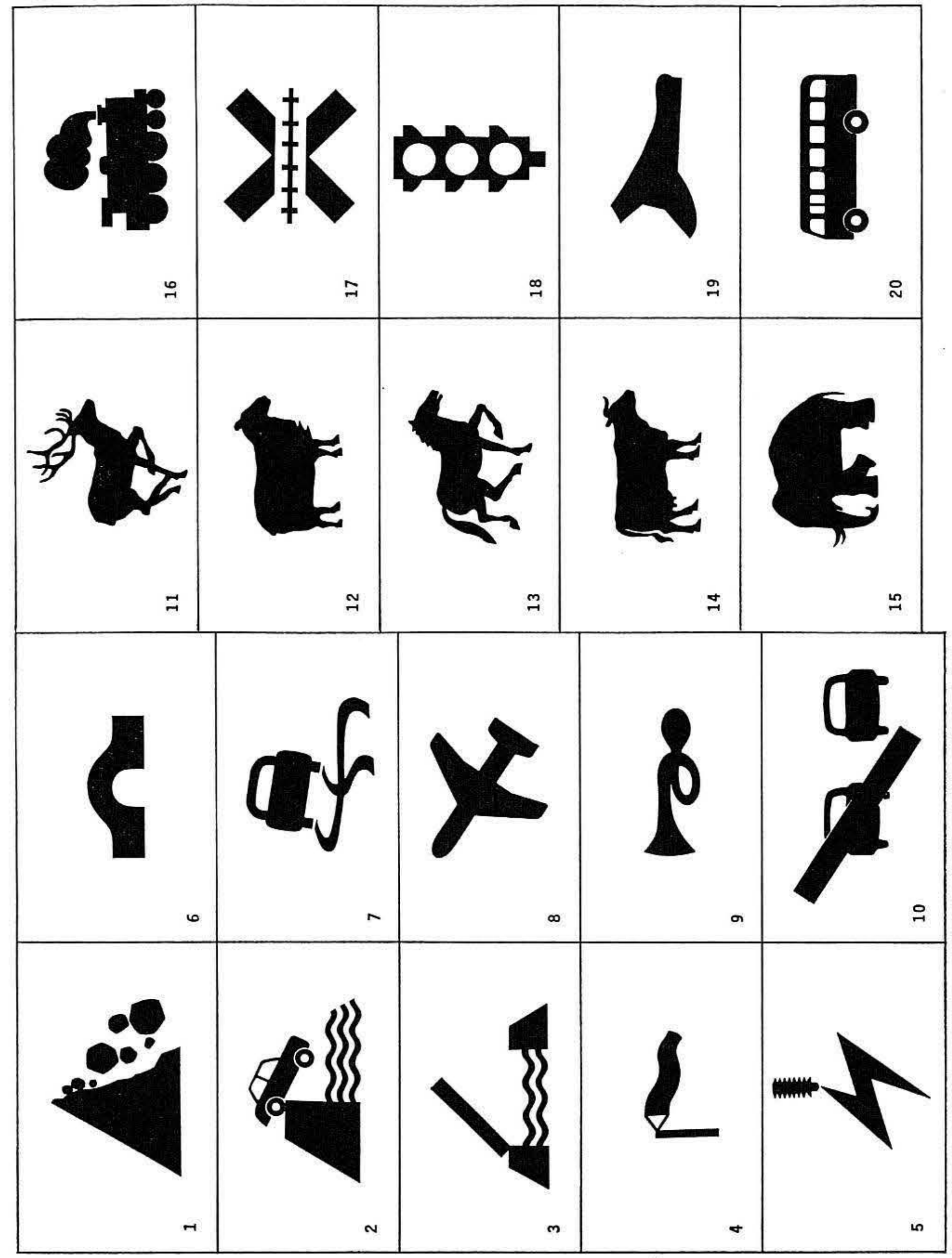
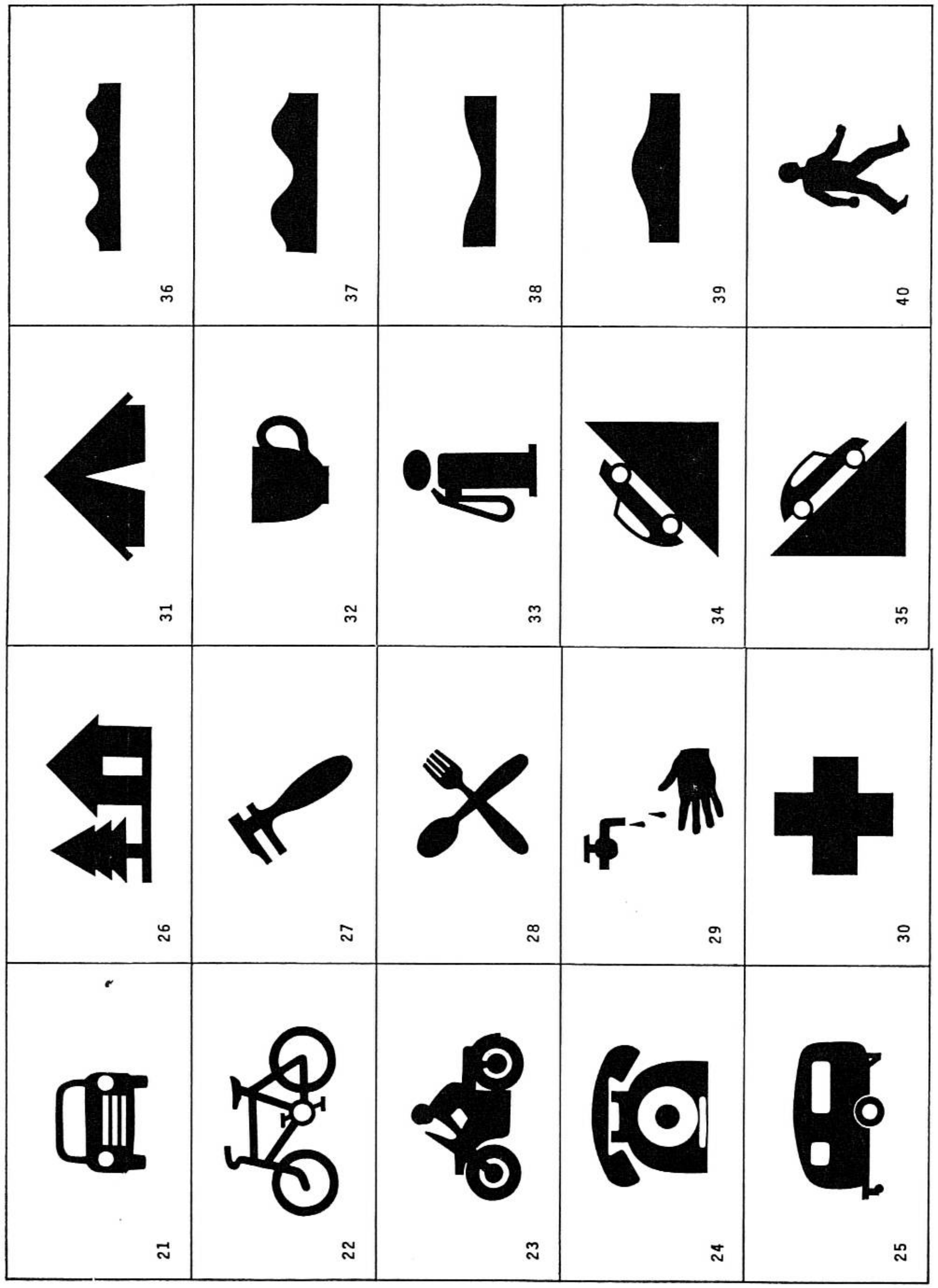


Figure 4. The set of commonly-used pictographs tested.



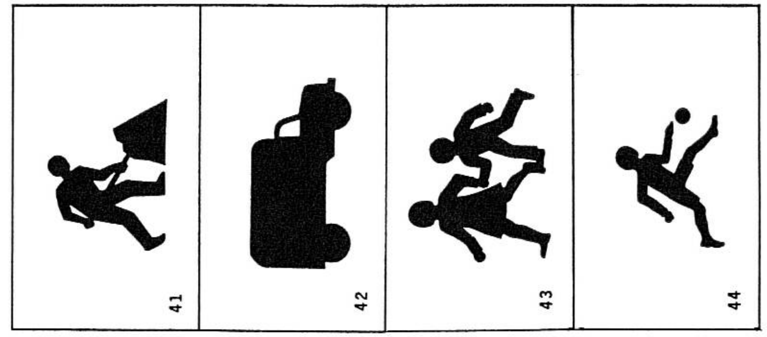
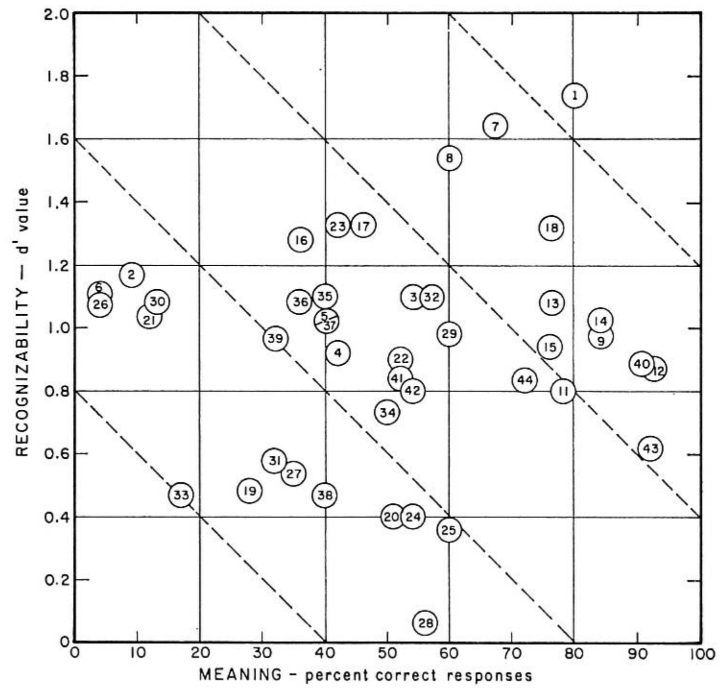


Figure 5. Combined rating scheme for the results of pictograph experiments. Numbers correspond to pictographs shown in Figure 4. Each pictograph, identified by number, is located on a grid by two co-ordinates, one its recognizability, the other its meaning transmissibility. The closer to the upper right-hand corner a pictograph lies, the better; the worst lies 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 recognizability is weighted.



Selected Signs in the Laboratory
All of the experiments mentioned previously dealt with basic design elements in their simplest and purest forms. Tests were carried to another level with a series of experiments involving ten selected signs chosen from those used in American and other systems (Fig. 6). These signs were tested in the laboratory and on a special test road.

In the laboratory, each observer was provided with a sheet containing all signs to be used in the experiment. After each exposure, they were asked to identify which of the ten signs had been flashed. As in all previous tests they were also asked to rate their choice in terms of confidence.

The same signs were tested on a test road using a car which was in as many ways as practically possible an "average" full-size American car. The track itself was an auto racing track in New Hampshire which is considered a good example of the narrow, winding, hilly country road that places considerable demands on the average driver.

A translucent screen, mounted on a helmet, was used to interrupt driver vision in the road tests. The vision interruption apparatus markedly reduces the amount of visual information a driver can process per unit time and provides a level of visual noise. Visual information processing tests will set his maximum speed everywhere on the road, making possible closer control and permitting a greater number of stimulus display locations in a relatively short length of test track.

The test signs were of standard sizes mounted at standard heights above the roadway. Observers were asked to memorize the signs prior to testing and then as they approached them on the track, to identify them to a researcher sitting in the car.

Results. The relative recognizability of individual signs varied between laboratory tests and road tests. Dividing them into three general categories, we find the following:

Recognizability Category	*Road Tests*	*Laboratory Tests*
Upper	Signs #3, 6, 9	Signs #2, 7, 10
Middle	Signs #1, 5, 7	Signs #1, 3, 8
Lower	Signs #2, 4, 8, 10	Signs #4, 5, 6, 9

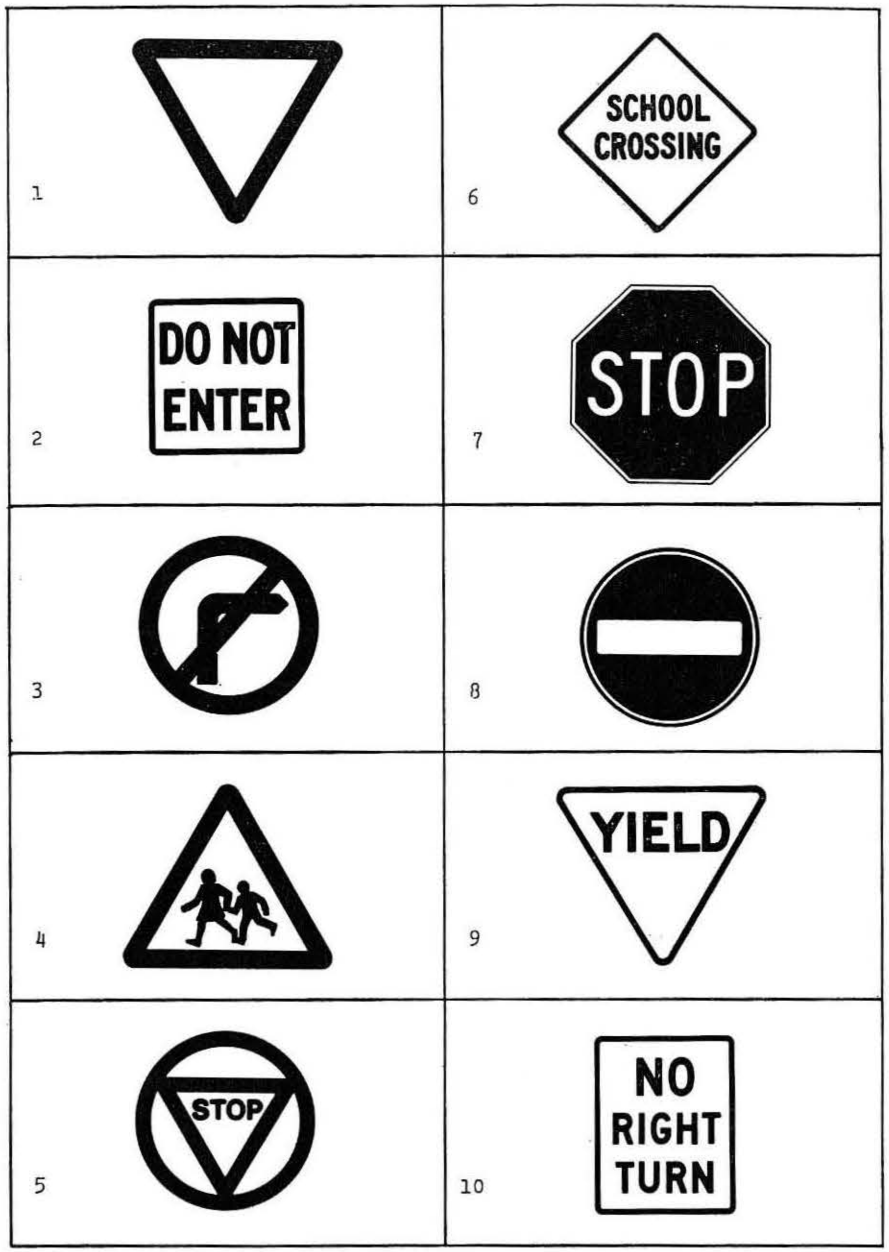


Figure 6. Signs used in the laboratory and road tests. Signs 1, 3, 4, and 5 have red borders; signs 7 and 8 are solid red; signs 6 and 9 have overall yellow backgrounds.

Conclusions

The program went far beyond testing of basic elements and signs. It included a broad literature search and a number of design experiments and explorations. These efforts, and the specific tests we have mentioned, led to a number of broad conclusions, raised many questions, and suggested a number of avenues for further exploration.

Warning Signs. Of the colors and shapes used in various systems for warning signs, there seems little doubt that the yellow diamond is less efficient carrying a verbal message than it would be were it to contain pictographs. At the same time, the diamond is a much more efficient shape for pictographs than is the triangle, which is currently used in most foreign systems.

Regulatory Signs. American regulatory signs are often cramped and awkward. The vertically oriented rectangular shape has many layout limitations. Were verbal legends replaced by pictographs, however, the problems would be greatly diminished, since the rectangle is in adequate shape for containing pictographs. Pictographs could never completely replace words, however, and there will always be a need for some word signs. The problems of alphabet are considerable enough to deserve a special section of the report, and these are included below.

Guide Signs. The problems of alphabet use are very apparent on guide signs as well as regulatory signs. In addition, the American system has many problems dealing with basic layout arrangement of elements on the sign and the make-up of these elements themselves. For example, there are the rather awkward route shields used on many signs and the lack of map-type or diagramatic signs which have proven quite successful in other highway systems.

A great deal of research has been done on legibility and lettering in highway signs. Many factors are known to have effects: letter width, stroke width, spacing between letters, proximity of borders and other lettering, contrast between colors, 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 then each does individually. As a result, the

conclusions reached in studies of individual elements have varied with those reached when factors were studied in combination.

For example, one researcher 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. Another found ratios of as low as 1 : 4 for black letters on the white background. In the alphabets specified as U.S. Standards, the stroke width varies in conjunction with the letter width (the ratio of the U.S. series E, for example, 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 improved by increasing the spacing between letters. One study 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 mportant, 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 is reduced. It has been found that the border width need be no wider than the stroke width for black letters on a white background. 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 initial capitals) is better than all capitals in direction signing, because the ascenders and descenders of some lower-case letters (such as b and y) give a characteristic shape to a name, which in turn facilitates recognition. The British Road Research Laboratory has 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 three quarters of the height of the upper-case letters.

Legibility may also be related to the details of the lettering design itself. The Road Research Laboratory has suggested for example, that serifed letters might be more legible than the sans-serif letters normally used for traffic signs. Their work indicates that the advantage in using serifed letters, if any, is small. It may be possible, however, to increase this advantage by emphasizing the distinguishing features of the letters, for example, by exaggerating the horizontal bar to a G to distinguish it from a C. It is doubtful that this could be done in any way that would aesthetically be acceptable, however.

The American Alphabets

We have indicated the American system has many weaknesses and has made little use of existing research. For example, the *Manual on Uniform Traffic Control Devices* states that better legibility can be obtained using relatively wide spacing between letters, than by using wider or taller letters with cramped spacing. As explained previously, 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 the body or block on which letter is mounted. This is a method by which spacing is determined in the *British Traffic Signs Manual* 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. (Currently the American system contains several alphabets in upper-case of varying widths, and one lower-case alphabet to be used with all of them.) The American standards also need work on word spacing, interlinear spacing, and the use of upper- and lower-case alphabets.

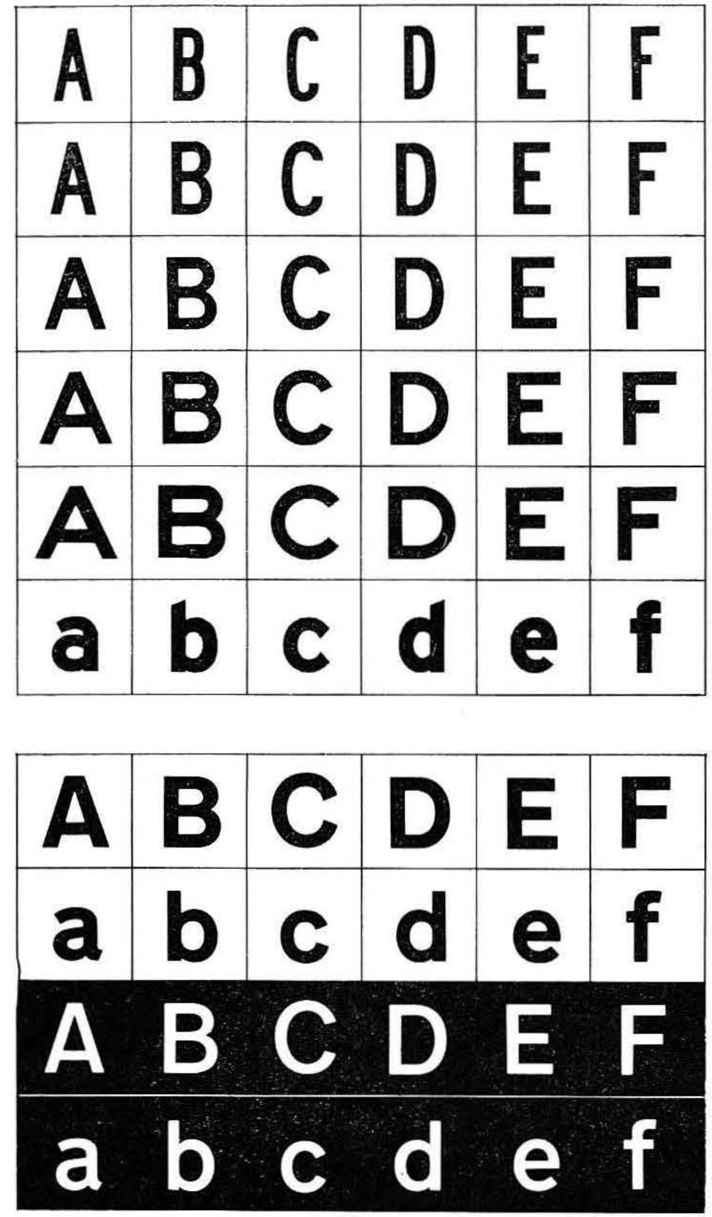


Figure 7. *Top*: Examples of standardized American highway alphabets from the *Manual on Uniform Traffic Control Devices*. *Bottom*: Examples of standardized United Kingdom transport alphabets from the *British Traffic Signs Manual*.

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. 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.

This paper has been excerpted from *An Investigation of the Design and Performance of Traffic Control Devices* (Document No. PB-182-534) which gives complete statistical information for the experiments plus an extensive bibliography of related research. The complete report also contains a detailed graphic design discussion of the problems of signs in the urban environment. Copies are $3.00 from the Clearinghouse for Federal Scientific and Technical Information, 5285 Port Royal Road, Springfield, Virginia USA 22151.

Ligature Design for Contemporary Technology

Joseph S. Scorsone

Computer-aided composition has eliminated restrictions on the number of characters that can be stored practically in a font of printing type. A system of 27 ligatures was designed as an addition to both sans-serif and roman fonts. The development of the ligatures in News Gothic and Century Schoolbook typefaces is discussed and illustrated.

In a recent article, Aaron Burns (1968) writes of a new age of typography—a photo-electronic era which is about to revolutionize the present system of type composing. The computer, he points out, can be programmed to solve problems of letter spacing which, since the invention of movable type, were complicated by the walls of metal around each letter. Without this limitation, type can be set extremely close, which may contribute to its legibility as well as its aesthetic quality.

This new photo-electronic technology not only helps solve problems of spacing but also a problem Gutenberg faced when he attempted to cut his first alphabet. Gutenberg's first job case consisted of 290 different letters, ligatures, and abbreviations (Zapf, 1968). His first letters were fashioned after those of the medieval scribes; he copied many of the ligatures they employed in order to create a printed page indistinguishable from the hand-drawn manuscript. As the technology of printing evolved, the size of the printer's type case decreased because it was neither practical nor economical to have such a large assortment of ligatures. The ligatures in use today which have survived this evolution are ff, fi, fl, ffi, ffl, æ, and œ. With photo-electronic technology, the size of the font is no longer a problem since an infinite number of letters and ligatures can be stored in the memory of the computer.