Guidance Devices for the BLIND

Braille courtesy American Foundation for the Blind

A blind person needs more than an aid that will work —he needs something he can use. This article surveys approaches and problems.

by Franklin S. Cooper

Freedom means many things. For the blind, one of its essential elements is independence of movement. Yet, despite the remarkable skills of some gifted individuals, the number of those who travel by themselves is only a small fraction of all the able-bodied blind. Too often, blindness means staying at home.

But blindness is not, as people sometimes assume, a total handicap although freedom and effectiveness are often severely restricted. There is no lack of capacity for action; only the information on which to act is missing. Thus the problems of the blind are, at the base, problems of communication. Blindness may even be characterized as a cybernetic deficiency—a missing link in the feedback mechanism—though this view tends to overemphasize automatic performance as compared with conscious behavior.

Guidance for the blind, in the restricted sense of aids to travel, becomes then a matter of supplying information. This appears to be a concise statement of the problem in engineering terms and the reader might reasonably expect to find in what follows an account of that latest technological marvel, the Electronic Informer. Many devices intended to

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Franklin S. Cooper, associate research director for the Haskins Laboratories, writes that "teaching physics to a group of premedics at the University of Illinois fired my interest in the biological sciences probably more than it did the interest of the students in physics". This led to radiation biophysics for his doctorate research (at MIT) and, after an interlude at General Electric, to the Haskins Laboratories to work on borderline problems between biology and physics. Psycho-acoustics is his present work with emphasis on the psychological aspects. Dr. Cooper has been consultant to the UN Atomic Energy Commission and was liaison officer of the OSRD.

perform this function have indeed been built, but none has thus far been a practical success. So, of necessity, it is with problems rather than solutions that we must deal.

Landfalls and Pitfalls

First of all, what kinds of information are needed for independent travel? This question was asked of a group serving as subjects in a research program at Haskins Laboratories. All were totally blind, able-bodied young men accustomed to traveling alone in New York City. Their answers are most illuminating, although the views of so small a group can hardly be considered as broadly representative.

The travel diaries of the group show quite clearly that many more problem situations arise during outdoor travel than indoors. Home and office are not without the hazards of a misplaced chair or a half-open door, but these are known dangers and they exist in a familiar environment. Orientation is easily maintained here in marked contrast with travel out of doors. Constant vigilance and much ingenuity are needed, as a single excerpt from one of the diaries will illustrate:

> "Inasmuch as I have been traveling from Brooklyn to New York for approximately three months, I find that memory has helped me considerably. For example, upon getting out of the subway on Lexington Avenue, I must turn right to reach the corner before I cross. I continue walking up towards the corner looking for a very definite cue which is the Nedick's stand. This is easy to detect because of the odor of hot frankfurters. I take two more steps forward and then turn left to cross Lexington. Walking on 42nd Street across Third Avenue I follow the method of trying to keep myself a certain distance from the curb and when I feel that I am reaching the end of the block I swing wide to the left so that I may avoid the Third Avenue El stairs which I know to be there. I proceed to cross Third Avenue with assistance or with my own cues and I remember that somewhere in the middle of the block and very close to the curb extending inward for a few feet there is an obstacle which is about three feet high and on several occasions I have found myself hitting this with great force giving me temporary pain in my midsection. This obstacle I have managed to avoid through memory."

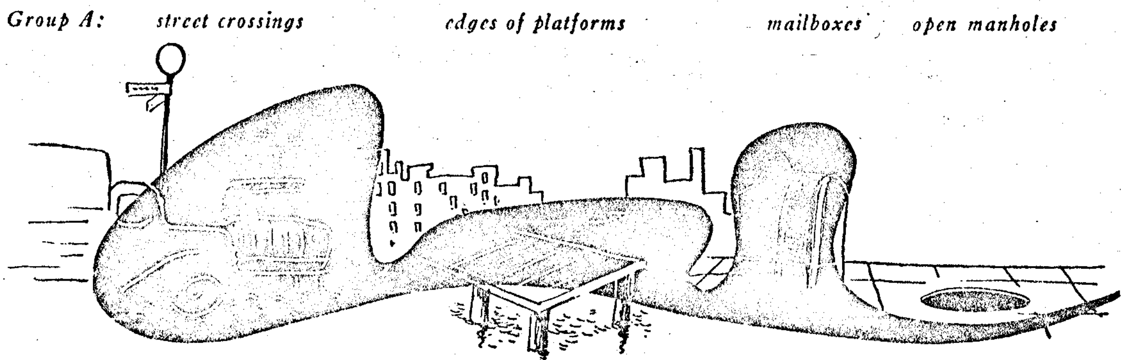
Thus, maintenance of general orientation depends on finding a succession of landmarks. These may be linked together by such mnemonic devices as step-counting where the route is exacting. Reference points are used also in the detailed operations of walking a straight line at a constant distance from the curb. The variety of cues described as useful for landmark identification is a tribute to the ingenuity of the traveler, but equally, it is an index of the paucity of information available.

Moreover, not all objects reveal their whereabouts by sound or smell. Obstacle avoidance is a second task to which constant attention must be given, a task of such importance that it is often considered almost synonymous with independent travel. The kinds of obstacles and situations which were considered most important by the group of blind subjects are shown below.

Evidently priority is assigned to a hazard on the basis of how severe might be the physical harm, and only secondarily on how often it occurs. For example, missing the edge of a platform, which may be classed as an encounter with a negative obstacle, ranks high in the list. But obstacles of a less hazardous nature can also be vexatious. Even the possibility of collision with an ash can or a fire hydrant may slow progress to a laggard's pace. Indeed, freedom to walk at a normal rate would be a major boon to the blind.

In brief, success in traveling alone is largely a matter of locating and identifying objects of the outdoor environment. Some can be heard and thus give warning or serve as landmarks. Others lie in wait, silent and inflexible.

The requirements to be met by a guidance aid are, in the main, that it permit one to walk at a normal pace without undue risk. Obviously a device for this purpose must be easily portable, reliable in operation, and not too conspicuous. Its primary function, however, which is to detect obstacles, requires more careful analysis before design specification can be formulated. A useful point of view, proposed by C. M. Witcher in a study of this sort, divides the forward area into three zones:



Typical hazards to independent travel by the blind in order of decreasing importance an outer 'awareness' region, a middle 'attention' region within which objects may require a decision to change course, and an inner 'avoidance' region, where action is imperative. Appropriate widths of the two inner zones were estimated at about four feet each, on the basis of a normal rate of walking. Figures of this sort help to determine the kind of range information which an ideal guidance device should provide.

Venerable Trio

The three aids which the blind have now are dog, cane, and obstacle sense. All have their merits as well as their limitations. The effectiveness of the Seeing Eye dog depends chiefly on rapport between dog and master. This, like the finest of human friendships, is a rare thing, and explains in part why the number of guide dogs in use in the United States is less than fifteen hundred, although there are some thirty to fifty thousand of the able-bodied blind. The cane, in skilled hands, can be an instrument of delicacy and precision. Its limitations are those of length and rate of exploration which will not ensnarl the user or antagonize bystanders.

However, most of the blind who travel independently do not rely exclusively on dog or cane. A few abjure them altogether, depending instead on an uncanny sixth sense by which they can detect most sizeable objects at distances of several feet. This faculty has been variously explained in such semi-mystical terms as facial vision, pressure sense, or more generally, obstacle sense. It appears, however, to be strictly auditory in nature involving only unusual skill in the interpretation of faint echoes returned from nearby objects.

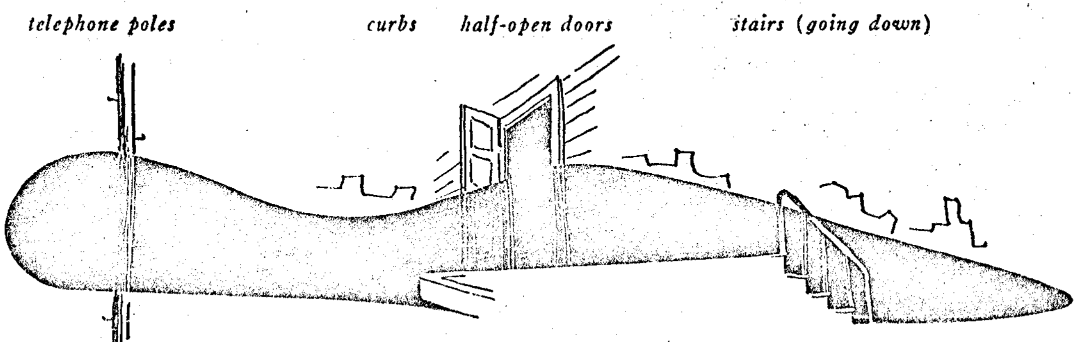
The gift of obstacle sense appears to require special insight as well as careful listening. This is borne out by individual accounts of rapid and complete mastery of the skill after years without it. If this insight could be achieved through special training, then many more of the able-bodied blind might be helped to relative independence of action without resort to instrumental aids. Some promising beginnings have been made, but much remains to be done in formulating effective training procedures. Obstacle sense is not; however, the final answer. Even those who are most skillful encounter many tasks and situations with which they cannot cope adequately for lack of data.

Earnest Efforts

Dog, cane, and obstacle sense—strange tools, nowadays, for gathering information! The anomaly has led many to consider how our fabulous new techniques might be used in building devices to give the blind greater independence of travel. An adequate account of these efforts would be too extensive for inclusion here. Besides, the subject has been fully covered in a recent book on blindness published under the joint sponsorship of the National Research Council and the Veterans Administration. (*Blindness: Modern Approaches to the Unseen Environment.* P. A. Zahl, Editor, Princeton University Press, 1950.) We can, at most, mention a few of the more recent undertakings before turning to a consideration of the devices themselves.

The most ambitious of the group efforts was that of the Committee on Sensory Devices, initiated in 1944 by Vannevar Bush as part of his wartime Office of Scientific Research and Development. This was a program of basic research on the psychological and engineering principles involved in building guidance aids, reading machines, and other devices for blinded veterans. In approach, as in initial scale of effort, it was unique, with major emphasis on the human engineering aspects of the problem rather than on gadgetry. Perhaps the principal lesson drawn by the committee from its experiences lies in a heightened awareness of the controlling role which human factors must play in the design of such instruments. Thus, as Dr. George W. Corner, then chairman of the committee, wrote in the volume, *Blindness,* "One thing [that] has surely been gained . . . is the realization by physicists,

Group B:



engineers, and mechanical inventors that when a machine is to act upon a man there are always going to be biological and psychological limitations that outweigh all the mechanical difficulties." Indeed, several of the guidance devices developed as a part of the program operated quite satisfactorily *as mechanisms,* but still failed to be of much assistance to blind users. The committee is continuing its work as an organ of the National Research Council and with assistance from the W. K. Kellogg Foundation, though now on the reduced scale befitting a war orphan. Also, some of the guidance projects started or assisted by the committee are being continued at the Franklin Institute, the American Foundation for the Blind, and Haskins Laboratories.

In a parallel program, the Signal Corps Engineering Laboratories undertook the development of an optical guidance device, and collaborative arrangements for testing it were made with the Committee on Sensory Devices. Eventually, twenty-five units were engineered and produced by Radio Corporation of America. Field tests with these units are now underway at Haverford College under the auspices of the Veterans Administration. Although both Army and Navy had extensive rehabilitation programs for blinded veterans, these did not take up the problem of developing devices for guidance.

In England a Sensory Devices Committee was formed, somewhat along the lines of its American counterpart, to coordinate the development work of different groups including St. Dunstan's Experimental and Research Department, the National Institute for the Blind, and the National Physical Laboratory. Several guidance devices were built and tested shortly after the end of the war. In Canada, also, the National Research Council undertook a program of research, including the further development of one of the devices initiated in this country.

It has, unfortunately, been necessary to describe most of these endeavors in the past tense. There are two principal reasons for this: in some cases, at least, financial support was withdrawn as men and governments strove to forget the havoc of war and, in addition, the lack of immediate success in building *useful* as contrasted with *operative* devices has been discouraging. Clearly, the problem is more complex than it had seemed, and in ways which elude the engineer.

Gadgets and Gremlins

For this reason, in examining a sample collection of the guidance devices developed during the past five or six years, our purpose will be to discover wherein these devices have failed, and what lessons may be learned for the future. Almost all of the guidance devices which have been proposed thus far are conceptual descendents of the cane; that is, they are intended to permit the location of obstacles by manual searching with an immaterial probe such as a beam of sound or light. The natural 'feel' of the cane is replaced by some other signal, auditory or tactual, which must convey the information that an obstacle has been located and that it is at a certain distance.

Supersonic methods of obstacle detection offer the advantage that range information is obtainable directly from the time of flight of a pulsed signal generated by the device. A guidance aid utilizing this property was developed for the Committee on Sensory Devices by Slaymaker, Meeker, and Larsen of the Stromberg-Carlson Company. Two magnetostrictive transducers were used, one to transmit a two-millisecond pulse at thirty-two kilocycles, and the other to receive echoes from any nearby objects. The transducers were mounted in parabolic horns about four inches in diameter which gave directional reception and a narrow transmitted beam, 6.5 degrees wide at the half-power points. The circuits were arranged to operate on the first echo only, thus restricting attention to the nearest object at which the horns were pointed. Information was passed from device to user by feeding the received

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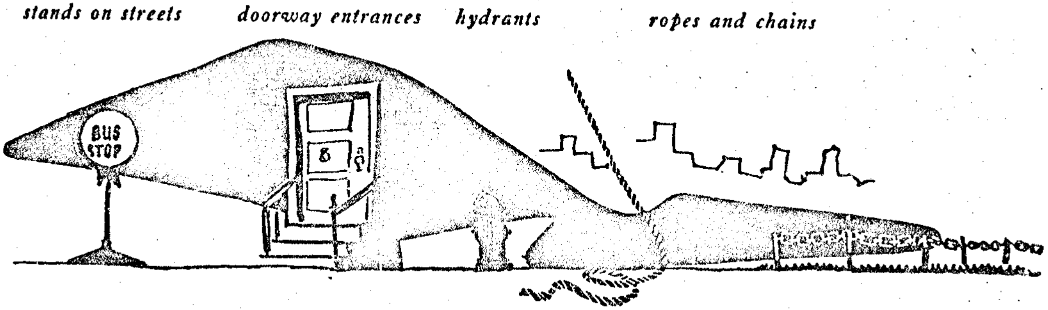

pulses into earphones or into a tactile stimulator. A first, rough model weighed about eight pounds, and was carried on a shoulder strap. The horns were mounted side by side on a handle so that they could be used like a flashlight to explore the surroundings. This handle also carried the tactile stimulator, a vibrating stylus on which a finger could be placed.

Experience with this device was typical of that obtained with a number of other supersonic guidance aids. Sensitivity was quite adequate to permit detecting objects as small as a pencil or as flimsy as a silk handkerchief at distances of several feet. For larger objects, a maximum usable range of twenty-five to fifty feet was possible, but was not used. In fact the blind subjects who tested the device preferred that no signal be given unless an object were nearer than about ten feet. The appearance of a signal then served to warn of an object near enough to require attention and yet far enough to permit easy avoidance. Range judgments were crude since the total scale of pulse rates was only five to thirty per second, an inflexible limitation inherent in the circuitry. Optimum tactile presentation would have required rates of about twenty to two hundred.

Use of the device was enormously complicated by specularity effects. Many surfaces behave like mirrors at supersonic frequencies, with the result that a smooth wall may fail to give any detectable echo whatever unless the horns are pointed directly at it. On the other hand, the right angle between two surfaces may act as a corner reflector even when the surfaces are small, returning an echo quite out of proportion to the size of the reflector. To be sure, most of the real-life objects encountered out of doors are irregular enough to give appreciable echoes. The practical problem is one of learning specialized searching techniques and the interpretation of distorted information. Even so, some objects will not be detected, the worst case being the step down from curb to street, from the edge of a platform, or from the top of a flight of stairs.

Difficulties due to specular reflection can be somewhat reduced by the use of higher frequencies, although the limit set by absorption in the air is not much above 100–150 kilocycles per second. Also, beam width could be reduced. However, the greater gain lies in reducing the size of the prospecting horns, since ease of scanning and inconspicuousness of the hand-held unit are items of very real importance to the user of a device. Moreover, a relatively wide beam is desirable in a guidance aid intended primarily for the detection of obstacles rather than for scrutiny of details. A further difficulty is encountered with supersonics: the echoes may fade and flicker due to air currents or to the varying aspect of a moving object of complex shape.

Perhaps the best of the supersonic devices developed thus far is one employing frequency-modulation techniques. A succession of pulses is transmitted by sweeping the frequency of an oscillator repeatedly across the narrow pass-band of a transducer. The returning echoes differ from the oscillator frequency by an amount which varies with the time of flight of the pulse, and thus an audible beat note is obtainable which increases in pitch with increasing object distance. A device of this sort, using sixty-five kilocycle transducers, operated very satisfactorily *as a device* in all but the step-down situation. The principal limitations arose from a mismatch between device and user. The signals provided by the device were aural, which diverted attention from the ordinary use of the ears; also, the signals were complex and therefore required careful evaluation and a slow rate of progress.

Optical guidance devices must obtain their range information by triangulation or other indirect means since time-of-flight measurements are not at all feasible. One of the apparent difficulties with triangulation is the need to search in range—a time consuming procedure if it is done manually. However, by an ingenious solution to this part of the problem, Lawrence Cranberg succeeded in building for the Signal Corps an optical guidance device which has performed very creditably in test situa-

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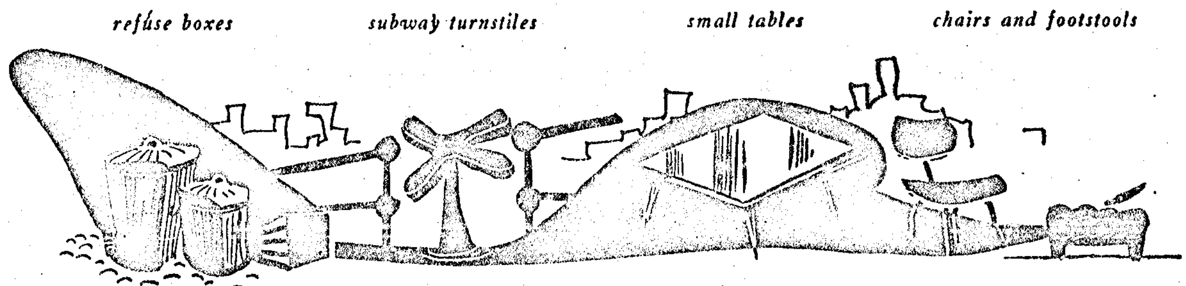
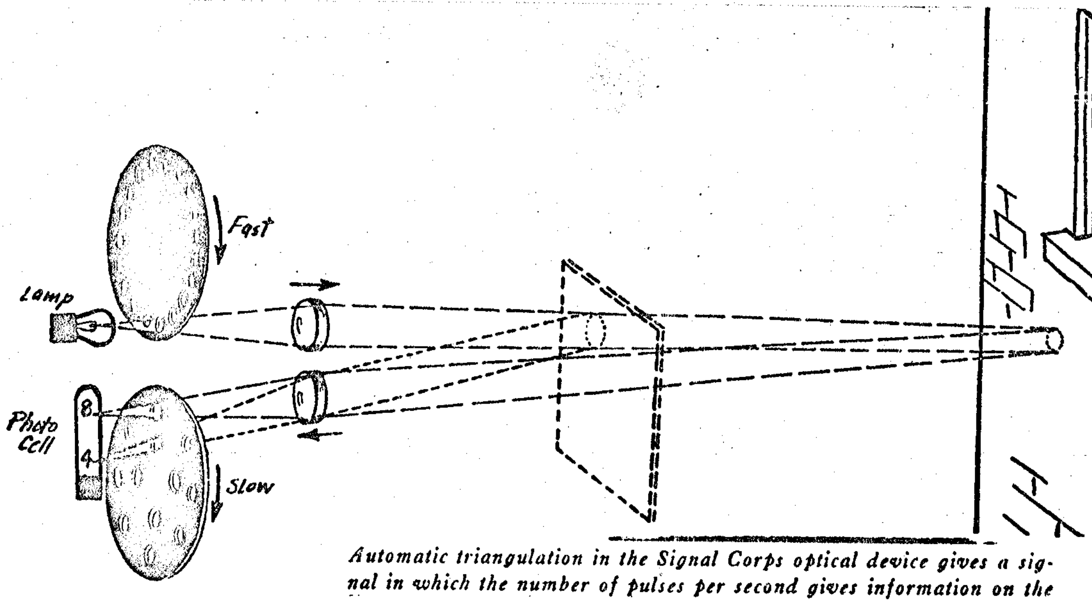
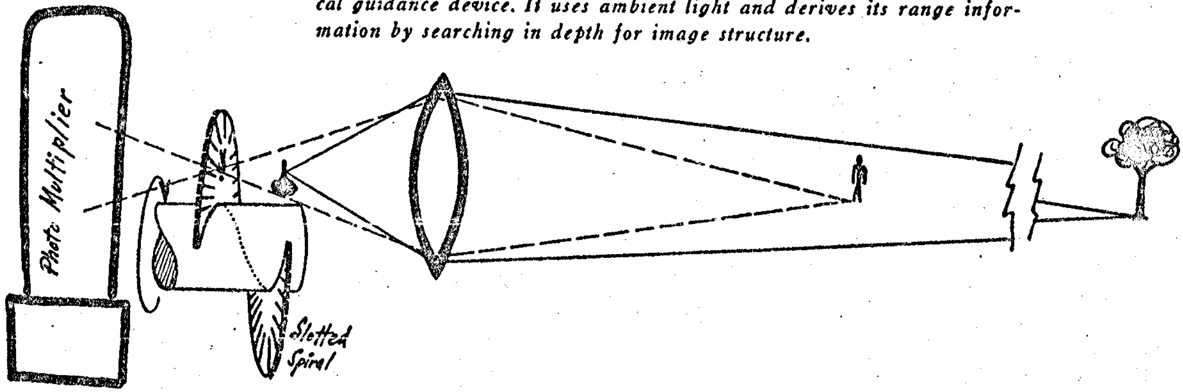




Automatic triangulation in the Signal Corps optical device gives a signal in which the number of pulses per second gives information on the range. The lower the beat, the closer is the obstacle.

OPTAR—optical automatic ranging—is what Kallmann calls his optical guidance device. It uses ambient light and derives its range information by searching in depth for image structure.



tions. It employs two optical systems with parallel axes about five inches apart, one system to project a narrow beam of light modulated at 500 cycles per second, and the other to form an image of the illuminated spot on any object which happens to intercept the beam. The image is chopped by a rotating coding disc, and converted into a rapid series of audible pulses by a photocell and tuned amplifier. The chopping rate is determined by the radial position at which the image falls on the coding disc, and this varies with the distance of the object. Pulse rates from four to thirty-two per second serve to indicate object distances between fifteen feet (maximum range) and three feet (minimum range). An early model weighed nine pounds and was housed in a box about eleven by three by six inches. It was carried at the side, like a brief case.

From the user's point of view, optical and supersonic and projected-beam optical devices differ principally in the scanning techniques peculiar to each, and in the interpretation of the signals. The very narrow beam of the Signal Corps optical device, less than one degree in width, requires that the search for possible obstacles be quite detailed to prevent unfortunate misses. On the other hand, an object of interest can be explored about as minutely as time will allow. The step down from curb to street can be detected by careful searching, but is easily overlooked. Specularity effects are much less troublesome than with supersonics, but absorption by dark colored objects is a frequent cause of weak signals. Ambient light, unlike ambient noise at supersonic frequencies, is usually intense in the out of door environment. The most careful design of photocell amplifiers is necessary to minimize overloading and spurious signals. An alternate approach, now under investigation at the Franklin Institute, is the use of ultraviolet light of wavelengths shorter than those remaining in sunlight after its passage through the atmosphere.

It would be premature to judge the performance of the Signal Corps optical device until systematic tests have been completed with the fully engineered models. The much reduced size and weight of these units will facilitate searching, and the added provision of vibratory presentation of the signals will free the ears for other duties.

A general comparison of optical and supersonic systems must be based partly on theory and partly on experience with comparatively crude devices. Each system has virtues and shortcomings peculiar to itself, but on balance they seem to be of comparable merit.

Although optical and supersonic devices which employ a projected beam of energy have received major attention, there are a number of other possible approaches worthy of notice. Optical devices dependent on ambient illumination were described as early as 1912 by Fournier d'Albe and as recently as 1950 by H. E. Kallmann. The d'Albe device used selenium cells in a bridge circuit, with unbalance indicated by a buzzing sound in a telephone receiver. With it, windows and doors could be found but not much else. A modern version, designed to simulate the primitive eye of insects, was proposed by Lashley. In appearance and in manner of use it resembled a flashlight, although of course it was used to collect light rather than to emit it. The audible signal from the device was a steady tone so long as the incoming light did not change in intensity. However, scanning across a dark to light boundary caused a momentary rise in pitch, or conversely, a decrease in pitch if the change were from light to dark. Outlines could be traced with moderate ease but interpretation proved difficult. Information about the distance of objects was not available directly; it could be inferred from apparent size only when the object could be recognized.

Kallmann's device, on the other hand, is designed primarily for ranging, and it accomplishes this result in a very ingenious manner: the image formed by a lens exists in depth as well as in area perpendicular to the axis, and it can be explored in all three dimensions by a light chopper of appropriate shape. Thus, audible signals can be generated from bright areas of the image in such a way that the time of occurrence, or the pitch, of these tones will correspond to the distance of the object. The signals closely resemble those of the frequency-modulated supersonic device and have some of the same disadvantages. On the other hand, Kallmann's device has the very important virtue that it can be made much lighter and smaller than those devices which must provide power and components for transmitting a beam of light or of supersonic energy.

Audible sounds for echo location have been employed in numerous devices ranging in complexity from steel heel-plates to stereophonic hearing aids. One of the most recent sonic devices was developed by Witcher at Haskins Laboratories and, later, at the American Foundation for the Blind. Witcher used a directional horn, small enough to be manipulated easily in the manner of a flashlight, which projected a rapid series of high-pitched clicks. Echoes from such objects as benches, cars, and trees were readily detectable at distances of eight to twelve feet, though smaller objects were often not detected. The clicking sounds did not seem to attract undue attention. The directivity of the horn, which gave a beam width of about 16° at 12 kilocycles, allowed easy scanning. In addition, the directional indications obtained by searching were confirmed by binaural localization of the apparent source of the echoes, so that the signals seemed natural and easy to use in avoiding collisions with sizeable objects. Ambient noise and specularity effects were, as expected, more troublesome than with supersonic devices, and range information was not provided directly. On the other hand, the sonic device was comparatively small and light, and did not interfere with normal use of the ears. Some experimental trials at St. Dunstan's with a somewhat similar audio-click device and with supersonic beam devices tended to favor the sonic device, without, however, establishing its utility in an absolute sense.

The Crux of the Matter

It is precisely the achievement of practical utility which is so elusive. All of the devices which have been mentioned, and many more besides, supply some information not otherwise available to a blind person. To be sure, none of them merit complete reliance in all situations, notably in detecting a step-down, and yet a few of these devices could provide enough information about most situations to permit safe and rapid movement. They could, that is, if the information were readily transferable from the instrument to its user. Devices, like Seeing Eye dogs, would be ever so much more helpful if only they could talk!

Here is the gap which remains to be bridged. The techniques required are, in the main, those of psychology rather than of engineering. Complex as some aspects of the problem undoubtedly are, the central questions can be put in simple terms: how should information be organized and presented in order that it may be most readily perceived? how long a period of learning will be required for the effective use of a device, assuming that the information which it provides is adequate and well organized?

Proficiency is certainly not to be expected until use of the device has become thoroughly automatic, and conscious analysis of its signals is no longer necessary. Ideally, the device must seem to give direct information about the external world, its signals being perceived as attributors of the objects located there without reference to the functioning of the device as an intermediary. For example, long practice will enable one to 'feel' with the tip of a cane rather than with the fingers which grasp its handle. Similarly, the high-pitched clicks from Witcher's device seem occasionally to be coming from the obstacle itself. By contrast, the signals from most devices appear to be localized at the earphone or the vibrating handle of the instrument; they fail to convey an impression of objects distributed in space, very likely because they differ from the cues normally involved in space perception.

The difficulties of the blind in dealing with space concepts serve to emphasize the unique role which vision ordinarily plays in the perception of spatial relations. Yet even vision does not yield these results without long practice. A striking example is furnished by those individuals, blind from congenital cataract, who have had their vision restored as adults. At first, they are aware only of colors and vague forms. The names of colors can be learned within a few days, but weeks of training may pass before such simple shapes as squares and triangles can be identified without resort to counting the corners. Other data also point to the conclusion that normal visual perception of objects and spatial relations, which seems so simple and immediate, is actually the result of arduous learning.

If so great a learning task is involved in attaining proficiency with an 'ideal' guidance device, then perhaps some of the existing devices would prove to be quite usable if adequate training were given. Certainly none of them have yet been subjected to such extensive trials. Fortunately, the experiment is about to be made. Thorough field trials, extending those made by the Signal Corps on its optical device, are to be conducted by T. A. Benham at Haverford College. Tests of this sort are feasible only when a device has been well engineered and at least a few trouble-free units are available. Even then the task is immense. These trials should go far toward resolving the crucial question of whether the discouraging results from early tests were due to a wholly inadequate appraisal of the learning problem or to deficiencies of the device, particularly with respect to the presentation of information. And, even though the tests employ but one specific type of equipment, the results should be broadly applicable in this respect to the whole class of probe type devices.

Field trials alone cannot wholly dispose of the problem of how best to present information. Even good results from training might conceivably have been achieved more easily with improved signals. Also, the wide range of possible signal presentations calls for simpler and more analytic procedures. For example, the choice of the sensory channel to be used as a substitute for vision involves many psychological factors amenable to study in the laboratory. If the ears must be left free for their usual functions, how can information be conveyed most effectively by the skin senses? Some preliminary experiments by Jerome and Proshansky at Haskins Laboratories suggest that direct electrical stimulation may be quite good, with the proper choice of electrodes, frequency, and waveform. Such signals are attention commanding, although not unpleasant. Will they distract attention from auditory cues, and, if so, to a greater or lesser degree than would audible signals from a bone-conduction receiver?

The questions outnumber the answers in still another area. Manual scanning is only one of several ways in which the environment may be explored. Is it the best method? Mechanical simplicity and the 'natural' way in which directional indications are conveyed to the user are evident virtues. But experience, so far as it has gone, seems to show that this sort of point by point, sequential information is very difficult to integrate into a unitary impression of the surroundings. Is mental integration of this sort a skill that can be learned, or is it inherently impossible? Automatic scanning, alone or in combination with binaural presentation, is frequently proposed as a way of providing information in more manageable form. The additional instrumentation might indeed be justified if it could be shown that the psychological assumptions were sound. Other proposals envisage an autoscanning device which presents a small relief map for tactile exploration. The analogy with Braille, which many blind persons read with ease and rapidity, is encouraging though a number of psychological factors remain obscure. Some clarification may come from studies now underway at the Massachusetts Institute of Technology, using a simulated device.

From all this it appears that the problem of the guidance device—even though it involves such diverse factors as the travel needs of the blind, the vagaries of physical phenomena, and the obtuseness of the human mind—is reducible to two specific research programs on which useful progress can now be made. Both are primarily psychological. One program concerns the amount of learning required for the efficient use of a typical probe type device, and the limit of performance attainable with it. Definitive answers may be expected from field tests with the Signal Corps optical device. The other program comprises the exploration of a number of basic psychological factors involved in the organization and transmission of information when ease and speed of perception is the goal. Very little work is underway in this area.

Emphasis on the psychological phase does not, of course, imply that the engineering solutions are completely adequate, but only that the results of field trials with one device are needed to justify further engineering effort on other probe types. Likewise, additional psychological data are essential for the design of more complex devices.

Excelsior

So much for immediate problems. Probe devices have monopolized the discussion for the very practical reason that they offer the best prospect of achieving a limited goal within a reasonable time. However, there are more exciting prospects than merely helping a man avoid obstacles. Perhaps a little speculation is a not too dangerous thing.

Actual restoration of sight by direct stimulation of the optic nerve or the visual cortex is almost certainly an illusory hope. To be sure, bright flashes can be caused by electric shocks, provided the optic nerve is intact. However, in the greater number of cases of blindness which cannot be treated surgically, the optic nerve undergoes degeneration and is not excitable. Even when stimulation is possible, the visual phenomena are diffuse and give no impression of shape.

An alternate approach is to provide patterned information via the auditory channel so that the blind can 'hear' a scene in the same sense that sighted persons see it—not piecemeal, but as a pattern of objects arranged in space. This is not perhaps so fanciful as it may appear. The underlying assumptions are that the ear can deal skillfully with patterned information, and that there exists an audio-visual transform by which distinctive shapes in visual space can be converted into equally distinctive patterns in the auditory domain.

The transformation of coordinates may, in fact, be fairly simple. The 'pictures' produced by the sound spectrograph are good enough, as visual patterns, to be read by a practiced eye, though not with quite the facility that the corresponding sounds are recognized by ear. Conversely, pictures can be turned into identifiable sounds by means of a pattern playback, an instrument with functions reciprocal to those of the spectrograph.

A comparable instrument, operating on a simple two-dimensional image of the environment, would yield audible patterns with the dimensions of frequency and time. To the extent that these sound patterns can be identified mentally with the corresponding objects, the user of the instrument would indeed 'hear' the scene in front of him.

Such a guidance device should have capabilities far greater than those of a probe type obstacle locator. It might in fact provide a substitute for vision, though doubtless a rather crude one. But can such a device be built? Probably it can, with no great difficulty. The real question—a psychological one of enormous complexity—is whether or not a man can learn to use such a device. The answer to this, until much more has been learned about auditory perception, must remain highly speculative.