a GUIDANCE DEVICE for the BLIND

By T. A. Benham

IN 1943 the Signal Corps began the development of a travel aid which was to be used to help the blinded of World War II in their rehabilitation program. The scope of the problem soon developed to include all blind people, civilians as well as veterans. The research on a suitable guidance device went through several stages [1, 2] and finally reached the point where RCA was contracted by the Signal Corps to manufacture 25 prototypes for test and evaluation. Subsequently, a contract was entered into between the Veterans Administration Research Division and Haverford College for the express purpose of giving the Signal Corps Sensory Aid a realistic series of field tests. Before describing the results of these tests let us say a few words about the instrument itself.

The Signal Corps Sensory Aid is an electronic device intended to aid blind people in travel. The function of the instrument is to warn the user of discontinuities in the terrain and of obstacles in his path. The principle of operation [3] is briefly as follows: A beam of light interrupted 500 times per second emanates in a narrow beam from an optical system, strikes an object, or the ground, and is partially reflected back into the second optical system. This second optical system focuses the image of the spot of light reflected from the object on a perforated coding disk behind which is located a photo-electric cell. The output of the photoelectric cell is fed through an electronic amplifier to a vibrator in the handle of the instrument. The amplifier and vibrator are resonant at 500 cycles per second, the same frequency at which the light beam is "chopped". The coding disk interrupts the reflected light 4, 8, 16, or 32 times per second, depending on the distance to the object. Thus, repetition rate of the 500-cycle pulses in the handle informs the user as to the distance to an obstacle or discontinuity in the terrain, while the position of the handle indicates the azimuth, that is, whether the obstacle is to the left, to the right, or straight ahead. Figure 1 is a block diagram of the device, Figure 2 shows how the instrument is used to locate a curb, and Figure 3 is a photograph of the instrument. The light from the transmitting lens *T* strikes the ground at the edge of a down curb at point *A* and is reflected back to the receiving lens *R*, giving a distance signal of 6 feet (the instrument is held so that the light from *T* strikes the ground about 6 feet in front of the user). As the user advances slightly the beam of light from *T* misses the edge of the curb and hits the ground at *B* and reflects back to *R*. This causes the distance signal as observed by the user to increase suddenly from 6 feet (*T* to *A*) to approximately 7 feet (*T* to *B*).

This sudden change in range of one foot is detected by a very subtle change in the signal presented by the vibrator in the handle of the instrument. Furthermore, obstacles cannot be detected until they are closer than 6 feet, although if step-downs are neglected and the beam is projected horizontally obstacles can be detected when they are 10 or 12 feet away. This method of employing the instrument requires that the user be constantly attentive to a continual signal in which extremely subtle changes occur.

It should be emphasized that the purpose of the testing program referred to above was to determine whether the principles embodied in the sensory aid were worthy of further consideration, what primary improvements were indicated and to gain some experience in methods of training blind people in the use of this type of travel aid.

THE testing program ran for one year. It consisted of 10 one hour lessons distributed over two weeks and then two weeks during which the subject had the instrument full time to use as he or she saw fit. Dur-

[1] Preliminary tests were made at the Valley Forge Army Hospital under the supervision of Dr. R. E. Hoover and at the Haskins Laboratory in New York under the direction of Dr. Franklin Cooper.
[2] Cooper, Franklin. "Guidance Devices for the Blind", *Physics Today*, III:7:6. July 1950.
[3] For a technical discussion of the instrument, see *Electronics*, March 1946, page 116 (McGraw-Hill).

T. A. Benham, assistant professor of physics at Haverford College, received a Presidential citation in 1951 in recognition of outstanding efforts in promoting equal opportunity in employment for the physically handicapped.

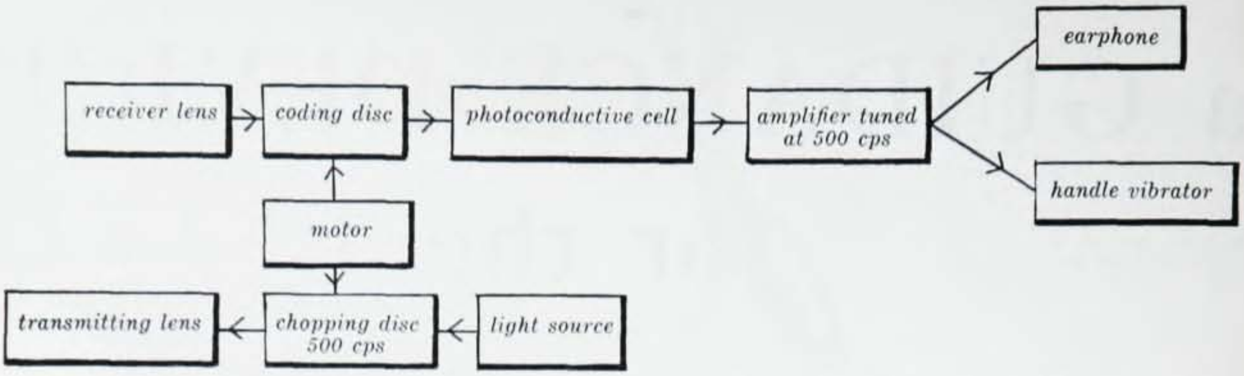

Fig. 1. Block diagram of Signal Corps sensory aid

Fig. 2. Use of sensory aid in locating curbs

Fig. 3. Signal Corps sensory aid

ing the latter two weeks, the subject used the instrument for travelling in both familiar and unfamiliar territory in his home town and elsewhere, and under both day and night conditions. The subjects were contacted during this two-week period in order to observe their performance and ascertain whether they were continuing to use the instrument as they had been instructed.

67 subjects, representing a cross section of the blind population, were tested. Of these, 46 were males and 21 females, ranging in age from 9 to 78. None had vision enough to travel unaided or to be able to see curbs and the like. 9 were using seeing-eye dogs as guides, 16 used canes as guides, 40 used sighted persons as guides, and 2 used no guide. Eight of the cane users were willing to change from cane to sensory aid; the other 8 preferred the cane. 3 of the cane users said, "I prefer the feeling of firm contact with the ground which a cane affords."

There seemed to be no characteristics displayed by the subjects that would make it possible to predict whether they were going to be good, fair, or poor in their use of the instrument. Some of those of whom a good performance was expected fell into the "poor" category and vice versa. Subsequent to the testing program each subject was required to traverse an unknown course and his performance was graded according to the number of mistakes, speed of travel, etc. The 67 subjects were rated as shown in Table 1. 6 of the "dropped" category resulted from sickness of the trainer. The trainer traversed the course at normal walking speed in order to establish the time for a sighted person to make the circuit. It was decided to choose $\pm 20\%$ of the normal time for a sighted person as a maximum permissible deviation; anyone who traveled slower was considered as being too slow for proper evaluation of the instrument. Of the 67 subjects, only 19 (see Table 1) came within the $\pm 20\%$ tolerance, but this does not mean that the instrument was not of considerable value or aid to the others. It is felt that proper use of this sensory aid does not place the user in any greater danger of injury than other guidance devices. Of course, they are called upon to exercise intelligence, but that is the case no matter how they travel except, perhaps, with a person as guide.

The chief characteristics exhibited by the subjects might be listed as follows: 37 experienced difficulty in

Table 1: Performance rating of 67 blind subjects whose use of guidance instrument was tested. Results for the 19 subjects in ±20% tolerance group are included.

		Results of subjects in ±20% tolerance		
Performance classification	*Number of subjects*	*Slower than trainer (11)*	*Same as trainer (4)*	*Faster than trainer (4)*
Excellent	9	1	2	2
Good	9	1	1	1
Fair	23	8	1	1
Poor	15	1		
Dropped	11			

detecting curbs, 8 had no trouble detecting up and down curbs, 12 had difficulty detecting obstacles, 6 were unable to perform the scanning motion properly. 4 found the change in reflectivity of different surfaces bothersome. 20 said that the weight of 4.5 pounds was excessive (6 of these were children under 12, and of the others, 8 were male, 6 female). All subjects found the continual signal presentation quite tiring. In an effort to discover what would happen if the instrument were used over a prolonged period, 5 subjects were provided with sensory aids to be used in their everyday life over a period of 6 months to a year. The *novelty did not wear off*, the subjects became *more and more dependent* on the sensory aid. They were most anxious to have the instrument repaired when failure resulted and they used it as much as or more than they had their previous travel aid. Of these, 4 were cane users and one used no aid at all. At the close of the period one of the cane users said he still preferred a cane, but said the instrument was potentially marvelous; all of the others expressed enthusiasm.

RESULTS of this program leave no doubt as to the efficacy of the basic principle of the Signal Corps Sensory Aid. It is apparent that the two most important improvements required for future development are: (1) separate curb and obstacle detectors, which remain quiescent until there is information to be transmitted, (2) separate curb and obstacle signals (stimuli), which are sufficiently distinct, one from another, so that the user has no difficulty recognizing them. As was noted above, 12 had trouble with obstacles. This was because the beam had to be kept on the ground all the time in an effort to find curbs or other discontinuities. The resulting continual signal at the 6 foot level (the beam hit the ground at about 6 feet in front of the subject) was *very tiring*. The slight changes in this continual signal were not sufficiently emphatic to alert the subject under all conditions; especially after the first 10 or 15 minutes, when fatigue set in. 37 subjects had trouble with curbs. This was chiefly due to the fact that the curb signal was an extremely *subtle and fleeting change* in the distance signal which occurred when the beam of light passed over the edge of either an "up" or "down" curb. An "up curb" was evidenced by a momentary slight decrease in distance; while the "down curb" appeared as momentary increase in distance. False curb signals were very frequently obtained because of the change in distance to the point where the spot of light fell on the ground as a result of the slight jiggling of the instrument as the user walked. This indicates the need for a curb detector which is not affected by these irregular movements.[4]

It is also apparent that aural presentation of stimuli is very unsatisfactory because the ears of the user should remain unencumbered so as to enable him to make full use of the aural cues normally encountered during travel. It should be clearly understood that any travel aid should supplement, not replace, these cues.

The testing program has indicated conclusively that in the final production of a satisfactory travel aid, models of varying complexity should be provided. Some blind people are not capable of assimilating information at as high a rate as others and are confused by having more information presented than they are capable of interpreting. In order to serve as many blind people as possible, it is desirable to make available to them instruments which present them with information at a rate compatible with their ability to interpret it. Perhaps as they grow accustomed to the type of information which can be presented by such an instrument, they could progress to instruments of increasing usefulness.

NEAR the end of the testing program a conference was held at Haverford College, at which members of the Veterans Administration, Signal Corps, and the writer were present. The future development of the instrument was discussed. It was agreed that all efforts would be bent toward initiating a development program to carry out the improvements which the testing program showed to be necessary, and that separate curb and obstacle signals would receive first consideration.

Another conference was held at which Warren Bledsoe and R. E. Hoover, consultants to the Veterans Administration in matters pertaining to the blind, and the writer were present. At this conference an ideal program for future development was drawn up which consisted of three one-year periods during each of which development would be made, the results tested, and at the conclusion of the third year, the results would be reviewed and recommendations made for the final production model. A list of the desired improvements arranged in order of importance are:

1. Separate obstacle and curb locators
2. Two-channel presentation
3. Automatic scanning for obstacle detector
4. A simplified design for use
5. Feature to aid user in walking a straight line[5]
6. Eliminate moving parts
7. Facility for rendering beam invisible
8. Reduce "noise" due to bright sunlight
9. Reduce weight
10. Carry instrument so both hands are free
11. Progressively complex models
12. Keep acoustical noise low

[4] Clifford M. Witcher, staff member, Research Laboratory of Electronics, Massachusetts Institute of Technology, is currently engaged in developing a satisfactory curb locator.

[5] It is not known how this would be done. It is included to encourage thought on the subject.

The development program outlined above got under way on February 1, 1953, by the signing of a contract between the Veterans Administration and Haverford College at Haverford, Pennsylvania. The actual development has been subcontracted by Haverford College to Biophysical Instruments Inc., a small enterprising company in Philadelphia interested in the interrelationships among electronics, medicine, and psychology. They were chosen to carry out the work because of their special interests which are closely allied with the scope of the problem, and because they are close to Haverford. This makes it possible for the writer, who is director of the development, to keep in close touch with the details and the progress of the program.

The first item on the list of improvements is that of providing separate curb and obstacle locators which are quiescent until there is useful information to be transmitted to the operator. However, the results of much consultation and thought showed that there would have to be several other matters taken up before this goal could be realized. It was desired to construct a model of a travel aid that did not employ any moving parts and which required much less battery power. To make a simple, probe-type obstacle detector would not be difficult, but to produce a satisfactory curb finder is much more difficult, as Dr. Witcher has indicated. Consequently, it was decided to proceed with the design of a simple obstacle detector employing no moving parts, whose circuitry could be adapted to the curb-finding problem when that was considered. In fact, since Dr. Witcher has already made very great progress in this regard, it would seem to be a good idea to implement his design according to the findings in the obstacle development.

SINCE the contract got under way, considerable progress has been made. The first experimental obstacle detector is nearing completion. Figure 4 shows a block diagram of this experimental model. Instead of the relatively cumbersome motor, chopper, and incandescent lamp which consumes about 600 milliwatts, a pulsed gas-discharge lamp was used having a power consumption of 100 milliwatts. The lamp, which was made especially by Westinghouse, is pulsed by a push-pull transistor oscillator—producing a pulse of 100 microsecond duration, and operating at a frequency of 200 cycles per second. The light reflected from an obstacle impinges on a photosensitive germanium diode. The signal from this diode passes through a multistage transformer coupled transistor amplifier, and then through a phase sensitive detector. The pulse which gates the detector is derived from the power supply for the lamp. Because of the delay in the amplifier, it is necessary to pass the gating pulse through a delay line so as to cause the detector to "turn on" at the proper instant to pass the amplified obstacle signal. The output of the phased detector passes into a dc amplifier. The output of this gates an amplifier which in turn activates the tactile stimulator in the handle of the instrument. The signal for this tactile stimulus amplifier is derived from the lamp power supply. In this way the signal amplifier and phase detector do not have to supply power to the tactile stimulator, but simply serve as a switch. Since this amplifier is gated by the incoming signal, the vibrator is "silent" except when there is information to be given to the user. The total battery drain for the complete system is 15 milliamperes at 22 volts or 330 milliwatts. It is felt that in the next model, this should be reduced materially.

Judging from the performance of the laboratory bench model, this obstacle detector should be about as effective as the Signal Corps device but with the following advantages: no moving parts; less battery drain; very much longer lamp life; gradual lamp failure instead of abrupt as with an incandescent lamp; a much lighter battery supply; and lighter over-all weight, about 40% less.

When the present model is finished, it will be given a series of tests in order to discover any aspects that require modification. Then two prototypes will be constructed. These prototypes will be subjected to a series of field tests similar to those given the Signal Corps instruments. By the end of this year we hope to know whether this system warrants being associated in the same box with Dr. Witcher's curb finder. There is every expectation at this time for success and satisfactory results. Before production of an acceptable guidance device can be considered, a complete prototype including obstacle and curb detectors must be completed and thoroughly tested. This prototype is at least two years away. Let us do all we can to make it no longer. Unusually good fortune would shorten the time, but we dare not pin our hopes to fortune. The help of many people, and the application of much diligence is a far better basis for hope of a successful conclusion to the research in the field.

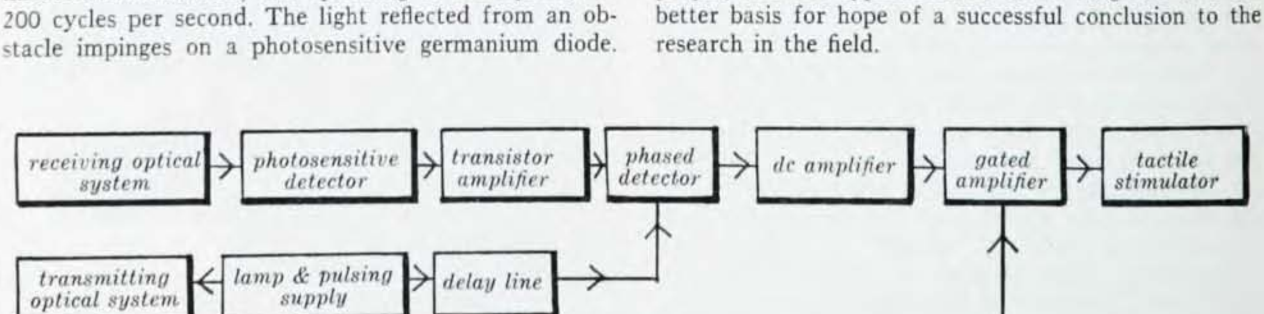

Fig. 4. Block diagram of transistorized obstacle detector