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A NEW CLOSED CIRCUIT TELEVISION SYSTEM FOR THE VISUALLY IMPAIRED

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Closed circuit television (CCTV) systems for the visually impaired have been commercially available for some years, at least on the American market. Several research institutes and organizations have also been involved in making prototypes which will eventually produce improved systems. Perhaps best known is the system developed by Genesky[1-4] at the Rand Corporation, but many others exist. A list of people working with these problems is found in Reference 4.

We began construction of the prototype CCTV system at our laboratory in November 1971. Basic criteria for the construction were:

1. Portability,
2. Ease of operation for persons of little or no technical education,
3. Provision for variable magnification up to 35 times,
4. Possibility for contrast reversal and contrast enhancement,
5. A depth of focus of a few centimeters.

The total cost of the system should be, of course, as low as possible.

Almost all existing CCTV systems use an x-y coordinate movable table on which the reader puts his text, and then scans the lines of text by pushing and pulling the table. Early experiments showed that it is difficult to get a stable picture on the monitor if the table is manually controlled and at the same time easy to move.[5] We soon decided to eliminate the table and try to scan the text with a movable mirror. Our final construction and first prototype is shown in Figure 1. The Vidicon camera is mounted almost vertically in a lightweight sheet metal stand. The 5X zoom lens (Canon Camera Corp.) points upwards. A construction called an optical head is mounted on the lens. The reader puts his text close to the rim of the metal stand. Light from the text is picked up by a movable mirror in the optical head, and is reflected along the axis of the tubes comprising the head. In the lens end another mirror reflects the light down into the zoom lens.

The optical head consists of three concentric tubes, the middle one supporting the other two. The movable mirror which can turn around its axis is fastened in the outer

Figure 1. Prototype CCTV System

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tube. This motion causes a scanning of the mirror along the lines of the text. To scan up and down the page the mirror can turn itself around an axis perpendicular to the axis of the tubes. The motions of the mirror are driven by two small dc motors mounted on the optical head.

With this construction the scanning functions perfectly, except that the lines of text on the monitor lean to the left and right when the mirror looks at the left and right ends of the lines of text. (The same thing occurs if one tries to make a periscope scan the complete horizon with its objective end but where the ocular end always points in the same direction.) To compensate for this phenomenon one has to insert an erecting prism in the light path. The inner tube of the optical head contains such a dove prism, which turns half the angle of the outer tube with the mirror. This is accomplished by a slot in the inner tube. The slot is milled 30° to the axis of the tube. A pin from the outer tube goes into the slot and forces the tube to turn at the correct angle. A collimating lens is also mounted in the inner tube since the dove prism works only with parallel light.

The speed of the scanning motors is controlled by a single spring-loaded joystick. Normally, when the reader does not touch the joystick, both motors stand still. A slight pressure in one direction starts slow-speed operation of one of the motors. Increasing the pressure causes faster scanning. There is also the possibility of having the line-scanning motor go at a constant speed without touching the joystick. Adjustable margin locks, consisting of microswitches which break the voltage to the line-scanning motor, are mounted on the optical head. A comb disc which automatically returns the mirror to the first line of the page when the last line of an *a* page has been reached is mounted on the axis of the up-and-down motor. This speeds page shift considerably.

The total distance between the text and the zoom lens is about 65 cm., which means that a large depth of focus is easily achieved. With normal illumination from two 40-W bulbs mounted on the metal stand, the depth of focus is about 4 cm. Thus, one can read a relatively thick book without refocusing the lens.

Many persons who are sensitive to light (due to lens cataracts or retinal diseases) require contrast reversal. Black letters on a white background are presented on the monitor as white letters on a dark background. In the first prototypes we have modified the monitors and added an inverting stage. We have also included a circuit which makes it possible to remove the gray scale and have only two video levels, black and white. With this circuit we achieved a large contrast enhancement. One disadvantage of this circuit is that Swedish safety regulations forbid making any changes in previously approved electrical installations. Thus it would be much better to have a battery operated "black box" which could be connected between the camera and the monitor. Such a circuit is described by Genensky[4]. With his circuit one can also electronically insert a window of variable size on the monitor screen. It is our intention to build such a device and include it in future systems.

The transportability of the system is made possible by a hinge on the baseplate which allows one to fold up the system for packing in a moderate-sized suitcase. The TV camera employed is provided with both video and high-frequency output which allows one to connect it to any TV receiver. However, the signal-to-noise ratio, and thus the quality of the picture, is improved with a video monitor.

The magnification of the system is dependent on the focal length of the zoom lens and on the size of the monitor. Between the camera and the zoom lens a zoom extender can be mounted which lengthens the focal length from 1.5 to 4 times without reducing picture quality noticeably. Thus, with a 4X zoom extender and a 25-inch monitor the maximal magnification is 50 times (a magnification which hitherto no one has needed). Most of the persons tested with this system have used a magnification between 10 and 24 times. This system can of course be used not only for reading, but for writing and for looking at diagrams, tables, and small objects. With an accessory it can be used with a typewriter to look at the characters just typed. The prototypes are now being tested on 15 patients with varying visual acuity and various types of impairment. Persons with a visual acuity as low as 1/60 in the best eye have been able to read relatively quickly after five minutes of training with the system. (Results of the tests will be published shortly.)

Two improved systems are now being made at our laboratory for use by university students. Meanwhile negotiations have been started with several firms for a small serial production of different parts of the system. Estimated total cost of the system will be about $1,400 (U.S.).

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to Mr. T. Delmefors who made excellent working parts for the system from hasty sketches. Thanks are due to the Swedish Handicap Institute and the Swedish Board for Technical Development who supported the project financially. I wish to thank all my colleagues at the Research Laboratory of Electronics who have contributed stimulating discussions and suggestions to the work.

REFERENCES

1. Genensky, S. M., et al. "A Closed Circuit TV System for the Visually Handicapped," *Research Bulletin* No. 19, American Foundation for the Blind, June 1969, pp. 191-204.

2. Genensky, S. M. "Some Comments on a Closed Circuit TV System for the Visually Handicapped," *American Journal of Optometry and Archives of the American Academy of Optometry*, Vol. 46, No. 7, July 1969, pp. 519-24.

3. Genensky, S. M., H. L. Moshiu, and H. Steingold. "A Closed Circuit TV System for the Visually Handicapped and Prospects for Future Research," *Annals of Ophthalmology*, Vol. 2, No. 3, June 1970, pp. 303-08.

4. Genensky, S. M., et al. "Advances in Closed Circuit TV Systems for the Partially Sighted," Report from Social and Rehabilitation Service, U.S. Department of Health, Education and Welfare, Project No. 14-P-55285/9, April 1972.

5. Marr, C. and P. Miller. "Improvement of Control in a CCTV Low Vision Reading Aid," from Department of Mechanical Engineering, MIT, January 1970, unpublished results.

AN AUDITORY DISPLAY CAPABLE OF PRESENTING TWO-DIMENSIONAL SHAPES TO THE BLIND

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ABSTRACT

The purpose of the research was to develop a way of presenting simple pictures or patterns to blind people by means of sound. A binaural display was developed which made it seem to subjects that a source of sound, or a dot, was moving around in front of them. The dot traced out two-dimensional patterns.

With one-half hour of training, subjects could understand pictures consisting of dots and lines. The positions of up to six dots in a picture, and the positions and orientations of lines in a picture were understood. With two to four hours of training, depending on the subject, more complex patterns could be understood. Stars with as many as 11 points were identified and accurately described by blind subjects from 9 to 56 years of age. The orientations of the figures, as well as their shapes, were clearly understood.

The minimum amount of time in which a pattern could be presented depended on its complexity. Circles, triangles, and squares could be presented in two seconds or less, while a six-pointed star required 12 seconds.

The work described in this paper was done to find how to code pictures by means of sound. Each set of experiments answered questions concerning how many horizontal lines should be in a picture, how quickly pictures could be presented, how the audio amplitude for each ear should vary as a function of horizontal position, and so on. When these parameters were sufficiently optimized, a system using a slow-scan TV camera (Robot Research Model 80) was built.

The TV camera was used to scan objects which were placed in front of it. So far, four sighted subjects and one blind subjects have been tested with the TV-camera system. All subjects were able to identify common objects which were placed in front of the camera. The blind subject was 10 years old and had been completely blind for about three years at the time of the test. With one hour of training he learned to identify seven different objects as they were placed in front of the camera lens. The objects he identified were a hammer, wire cutters, pliers, scissors, a screw driver, a jar, and a cube. Each scan lasted eight seconds and contained 30 horizontal lines. The blind subject required at most two scans of any object in order to identify it.

METHOD OF CODING

The auditory system is like the visual system in that it can interpret stimuli as two-dimensional patterns or displays. Sound sources can be localized with respect to left and right. Stereo music is based upon this principle. Left-right direction (horizontal position) is perceived because of differences in the sounds which reach

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each ear. These may be differences in interaural intensity, phase, or time delay. Also, recent work (Roffler, 1967) has shown that below 7000 Hz the location of a source of sound in the vertical plane is identified by the auditory system. This identification is incorrect: high frequency tones seem to originate from high positions while lower frequency tones seem to come from lower positions even though all the tones may have come from one fixed source. This incorrect method of vertical localization occurs in children who do not know the meaning of the words high and low pitch, in blind subjects, and in sighted adult subjects (Roffler and Butler, 1968a and b). Some people have not accepted this work, arguing that subjects are easily tricked into believing this is what they perceive. In any case, the phenomenon provides a useful dimension for an auditory display.

Thus, a properly coded auditory stimulus can make it seem that a sound source is high, low, left, right, or somewhere in between. A picture can be presented as an array of dots with different positions and intensities, similar to the way in which pictures are printed in newspapers. A picture can be painted by presenting sounds of different intensities which seem to come from a number of different locations.

Figure 1 shows how a pattern would be scanned by the system.

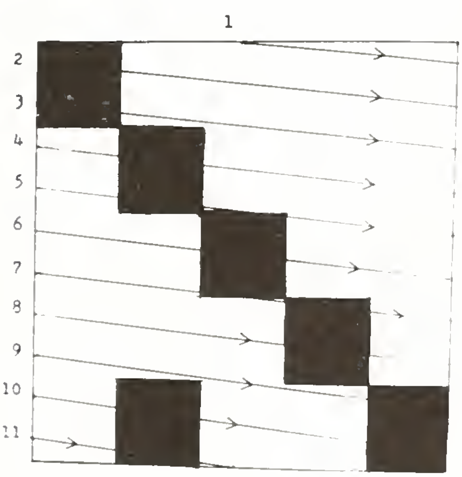

Figure 1. The Method of Scanning a Pattern

When the scan line crosses a darkened area, a tone is produced. The frequency of the tone is 7000 Hz at the top of the picture and 70 Hz at the very bottom (numbers refer to the first set of experiments). When the scan line is at the left edge of the picture, the amplitude in the left headphone is 40 db greater than in the right headphone. At the right edge, the right amplitude is 40 db greater than the left. In the center they are equal. The variation of frequency with vertical position, as well as the variation of interaural amplitude difference with horizontal position, is gradual and exponential in nature.

A most important feature of the display which has been developed is that it presents information in a way that is understood by the natural, built-in decoding mechanisms of the auditory system. It is so natural and easy to understand that nine- and ten-year old blind children have learned to identify patterns as complex as nine and eleven pointed stars with only four hours of training. One ten-year old blind subject learned to identify seven different objects which were placed in front of a TV camera in order to be coded. He was able to do this one hour after being introduced to the auditory display.

REVIEW OF RELATED RESEARCH

Tactile and Electrocutaneous Image Presentation

The work which has been done with tactile and electrocutaneous image presentation is relevant to a discussion of the auditory imaging in this paper. Experiments with the tactile systems have shown how much useful information can be extracted by the human brain from a display of limited resolution. It has been shown that a blind person can learn to understand three-dimensional cues from a flat picture.

Tactile-mobility aids present pictures of a person's surroundings by stimulating the skin. As many as 400 mechanical vibrators have been applied to the back, and smaller numbers have been applied to the forehead and other areas of the body

(Bach-y-Rita *et al.*, 1969; Bliss, 1970; Garrison, 1971; and Bach-y-Rita, 1967). Images produced in this way have less resolution than images provided by the eye, but they are detailed enough to be of practical value. With the Bach-y-Rita system of 400 vibrators, subjects can learn to distinguish objects such as telephones, chairs, and cups.

Collins and Madey (1971) applied 256 electrodes to the skin of the abdomen. Pictorial information from a TV camera caused various combinations of the electrodes to pass a small current which the subject could feel. There was a point-to-point correspondence between areas on the TV camera and areas on the stimulator matrix. Subjects were able to interpret these patterns and to scan their environment. They could recognize familiar objects and were able to locate, walk to, and pick up specific objects. After four or five hours experience with the portable vision aid, subjects reported that the electronic images no longer appeared to be projected on the skin, but were perceived as originating from the objects in space in front of them. The authors believe that the electrocutaneous visual prosthesis appeared to become an "electronic extension of the sensory perceptual system." Blind subjects could essentially "see" through their skin (Collins and Saunders, 1969).

Using an 8 X 8 array of electrodes, Collins (1971a) produced a portable seeing aid prototype which allowed subjects to navigate through a laboratory environment, searching for desired objects and avoiding harmful ones. They could detect the position and number of targets in front of them and determine the relative size and brightness of objects in their surroundings. This eight-line TV system gave a picture of 64 points.

Using a bank of 400 vibrators in a tactile imaging system, Collins (1970 and 1971b) was able to have subjects recognize faces. With this 400-point picture system, subjects were able to recognize a "vocabulary" of 25 common objects. At first recognition times were five to eight minutes. As the subjects became more familiar with the objects and their different orientations, the recognition time fell to five to 20 seconds. This was after ten hours or more of training (Bach-y-Rita *et al.*, 1969).

As with the electrocutaneous displays, the vibrating tactile systems produce a feeling that the stimulus is out in space, in front of the subject (Bach-y-Rita, 1970). Not only do objects seem to be in front of the subject, but their three dimensional relationships with each other and the subject are clearly perceived. A number of stimulus aspects seem to be important in helping subjects understand three dimensional relationships. The visual angle subtended by an object will be larger if it is closer to the subject (White *et al.*, 1970). An object which is closer will seem to extend higher up in the visual field if its height can be judged from a reference plane such as a floor or table top. Close objects will occlude farther ones (Bach-y-Rita *et al.*, 1970). Linear perspective plays a role in understanding three-dimensional relationships. That is, parallel lines appear to converge with increasing distance. Coarse surfaces seem to grow smoother as distance increases. If the subject can move the camera, cues will result from parallax and the relative amounts of apparent movement of objects (Scaddon, 1969).

It is interesting to compare the performance of blind and sighted subjects using sensory aids. Sighted subjects using the tactile vision substitution systems are able to transfer techniques of analysis from visual experiences to the new situation. With training, however, the blind are often able to match the performance of the sighted fairly rapidly (Scaddon, 1969). There have not been marked differences between the congenitally blind and sighted subjects when learning form discrimination (White *et al.*, 1970).

Auditory Codes

When learning the tonal code of the Visotoner or the spelled-speech code of the Cognodictor, people who have highly developed hearing skills have an advantage. Thus newly-blind veterans will not, in general, understand such auditory codes as quickly as people who have been blind for longer periods of time. Many of the best potential candidates for such tonal codes are congenitally-blind people (Lauer, 1971).

Black (1968) has presented dots to subjects which seem to be localized in a plane. He coded left-right position by causing a delay between the presentations to the ears, and coded the vertical position or height by varying the repetition rate of 100-microsecond pulses. The repetition rate varied from 100 to 400 pulses-per-second. The system described in this paper is analogous to Black's system. There are a number of differences between the two systems, the most significant being that our system scans pictures.

EXPERIMENTAL PROCEDURES

The First Set of Experiments

Equipment was built, and experiments were performed to test the feasibility of coding two-dimensional patterns by means of sound. The first experiments used a 5 X 5 matrix of photocells which was connected to an analog computer by means of a digital interface. The computer was built for this project. It allowed parameters of the display to be changed by simply changing patch-cord positions.

The matrix of photocells provided a means of dividing the display area presented to the subject into 25 equal parts. Each photocell corresponded to 1/25 of the picture which the subjects heard.

The computer produced a scan composed of horizontal and vertical components similar to that used in ordinary television. When the scan position corresponded to the position of a photocell which had enough light falling on it, an audio tone (sine wave) was presented to the subject through binaural earphones. The frequency of the tone corresponded to the vertical position of the scan and of the photocell. The intensity of the tone in each earphone was a function of the left-right position of the photocell.

Interaural intensity differences of 40 dB were the maximum used. Vertical position was coded by a sine-wave tone which varied from about 70 Hz to 7000 Hz. Variations in intensity and variations of frequency were approximately exponential because, to a first approximation, the ear responds logarithmically to these parameters.

When interpreting the sounds, subjects did not learn a code signifying the position of each dot or photocell, but rather it seemed to the subjects that the sound source was a little above center and all the way to the left, for example. One problem associated with this method is that a tone does not sound like a tone unless enough cycles of it are presented. To be recognized, each point in the picture must be presented for at least four milliseconds, or even longer, depending on the frequency.

Figure 1 shows the method of scanning a picture. The pictures which could be produced with the 25-photocell (5 X 5) system were limited to combinations of square dots and vertical, horizontal, and diagonal lines. When the scan line crossed a part of the pattern to be presented, the tone was turned on. There were 10 to 12 scan-lines-per-picture on the first training tape, called the proposal test tape. Thus a dot which filled 1/25 of the picture would be crossed two or three times during each scan of the picture. Picture 1 in Figure 2 would start off with a high frequency tone burst which was significantly louder in the left headphone. Its frequency would decrease slightly as it seemed to move from the extreme left to a point 1/5 of the way to the right. Picture 6 in Figure 2 would sound like a series of tone bursts on the left which decrease in frequency.

The time it took to scan each picture in this first set of experiments was about two seconds. Each horizontal scan line lasted 180 milliseconds. There was then a 20-millisecond retrace time during which no sound was presented. Each tone burst, produced when a scan line went across one dot horizontally, lasted 36 milliseconds.

The proposal test tape was used to train and test subjects in the first set of experiments. It contained an introduction to the method of coding, examples of patterns which could be coded, and tests to see that the code was understood. Figure 2 shows the patterns which the subjects were asked to identify when listening to the proposal test tape. Some of the patterns had not been played to the subjects before they were asked to identify them. Thus the subjects were identifying patterns they had never heard before. These patterns were numbers 10, 11, 12, 14, 15, 16, 17, and 18. This meant that the subjects were learning a coding system. They were not simply memorizing sounds which stood for certain patterns.

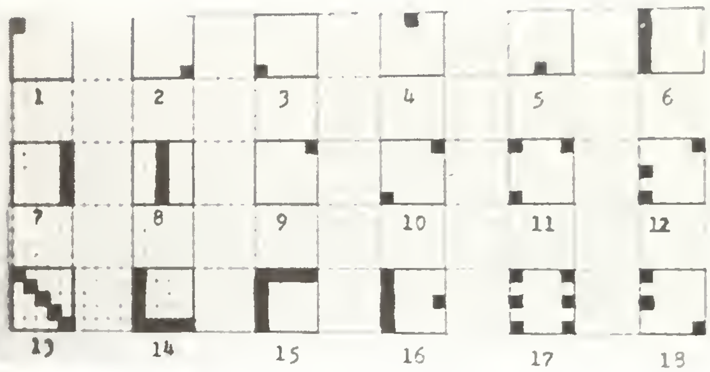

Figure 2. Test Patterns for the First Set of Experiments

The first set of experiments showed that the 25-point picture was not sufficient for determining how complex a picture subjects could interpret. Pictures, or patterns, containing two lines, and patterns containing up to six dots were identified by many subjects even though they had less than one-half hour of training. Also, many test patterns were pictures the subjects had never heard before. It was, therefore, decided to add to the computer in order to make it capable of presenting arbitrarily complex shapes.

The Second Set of Experiments

Figure 3 shows the cardboard patterns which were scanned by the system. These cardboard figures were scanned by a flying spot-scanner system which was part of the expanded computer setup. They were scanned in order to produce sounds which represented their shapes. These sounds were recorded on magnetic tape so they could be played to subjects. After the recordings were made, the cardboard figures were pasted on a large piece of cardboard so that subjects could look at or feel them when learning to interpret the tonal patterns.

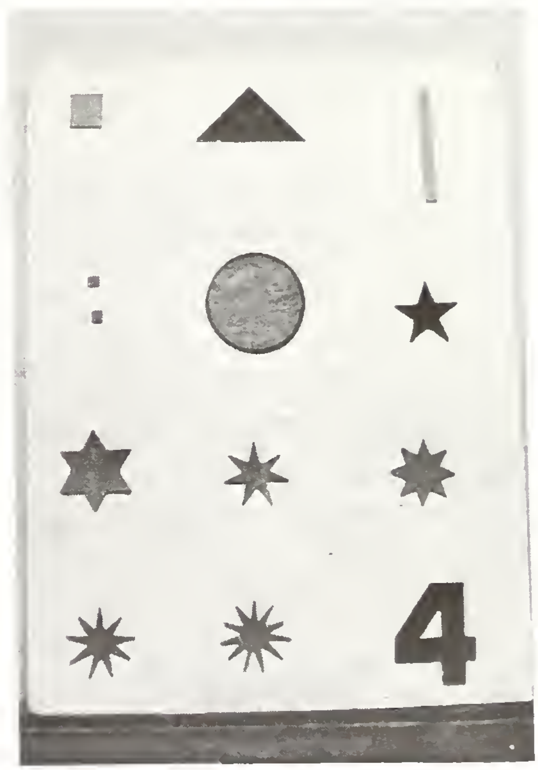

Figure 3. Cardboard Patterns Used to Make Tapes 9, 10, and 11. (These patterns, used in the second set of experiments, were felt by blind subjects when they were learning to interpret the tonal display. The straight line in the upper right corner is 2-1/2 inches long.)

Most subjects were trained using the sequence of tapes given in Table 1. Usually, 10 or 15 minutes of tape number 10 was skipped when training subjects. It contained review material which most subjects did not need. Test tape 9 lasted 45 minutes if played straight through, but most subjects finished the test in 30 minutes.

TABLE 1

Training Program

Experiment Set	Tape Number	Time, Minutes
1	Proposal Tape	30
2	10	60
2	11	20
2	9: Test	45
3	12	60
3	13: Test	60

During training, subjects were allowed to hear patterns over if they were not sure of them. They were also allowed to skip repetitious parts of the tapes when they understood patterns from the first few presentations. When being tested, subjects were again allowed to hear patterns repeated if they wished.

Tables 2, 3, and 4 list the patterns presented in tapes 10 and 11. Test tape 9 patterns are shown in Figure 4; this shows the patterns which subjects were asked to identify at the end of their training. About 60 horizontal scan lines were used in presenting the patterns on Tape 9.

TABLE 2

Patterns on the First Half of Tape 10

Diagonal line: upper left to lower right
Diagonal line: upper right to lower left
Dot in upper left corner and vertical line in center
Triangle
Diamond
Circle
The letter Z
The number 2 (test question)
The number 4 (test question)
5-cornered star, two orientations
6-cornered star, two orientations
5-cornered star (test question)

TABLE 3

Patterns on the Second Half of Tape 10

High, middle, and low dots
Vertical lines: left; right; left and right; center
Diagonal line: upper right to lower left
Triangle
6-pointed star
7-pointed star, two orientations
8-pointed star, two orientations
6-pointed star (test question)
7-pointed star, two orientations (test questions)

TABLE 4

Patterns on Tape 11

8-cornered star, two orientations
9-cornered star
9-cornered star with echo
11-cornered star
Triangle in upper left corner and square in lower right corner of picture

It was found that the time it took to present most patterns could be reduced significantly if the speed of the scan was increased when no sound was being produced.

It is difficult to understand what the patterns sound like without actually hearing them. The description which follows should be read with this in mind. The triangle, Picture 2 in Figure 4, starts out with a very brief tone burst. It has a high frequency and seems to be coming from the center of the picture. The following tone bursts last longer. They start farther to the left and end farther to the right, as the triangle is a solid, filled-in pattern. The frequency, or pitch, of each succeeding tone burst is lower. The last horizontal scan line may end somewhere in the center of the picture because the "horizontal" scan lines are actually slanted slightly. This is because the vertical position, generated by a sawtooth oscillator, decreases constantly during every horizontal scan line. The scan lines go downward slightly as they go from left to right. Also, if the triangle were tilted even slightly, several horizontal lines might end somewhere in the center.

Pattern 4 in Figure 4 is a seven-pointed star. It starts out sounding like a triangle. As the second and third points are encountered by the scan lines, additional tone bursts are heard. When this happens the subject hears a tone on the left, a tone in the center, and a tone on the right. These gradually come together to form the solid body. This gets narrower and then expands down to the fourth and fifth points. As these are passed, the scan suddenly becomes about 1/3 as wide. After a few of these shorter scans, two tone bursts are heard. One is on the left, and one is on the right. All of the time, the frequency has been decreasing. Near the very top and the very bottom of the figure the scan moves down more quickly than when near the center. This is because the scan is speeded up when not on the figure.

The circle and diamond can be distinguished by noting how quickly the figures change shape at the top and bottom. The circle widens much more quickly than a diamond of equal height and width.

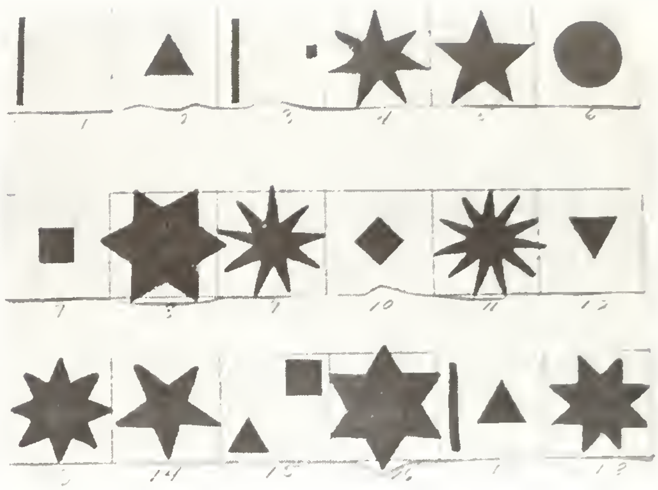

Figure 4. Tape 9 Test Patterns; Test Patterns for the Second Set of Experiments

The Third Set of Experiments

A third set of experiments was done to find approximately how quickly patterns could be presented to and understood by a well-trained subject. Two well-trained sighted subjects were tested.

These experiments were done with three different waveforms. The first was a sine wave similar to that used in all the previous experiments. The second was a triangular wave, and the third was a square wave. The 12 different patterns coded with these waveforms are listed in Table 5 along with the number of horizontal-sweep lines and the durations of the scans.

There were two major differences between these experiments and the first two sets of experiments. First, outlines of patterns were presented in most cases. Because the scan was speeded up when not on the figure, this increased the speed of the presentation. Second, the frequency range was changed so that it went from 200 Hz to 5000 Hz. The sensitivity of the ear is greatest at about 2000 Hz and decreases as the frequency is raised or lowered. Also, older people lose the ability to hear higher frequencies (Rothe, 1966). For these reasons, restricting the frequency range made the tones seem to have more nearly the same amplitude as the frequency changed.

As can be seen from Table 5, there were 41 presentations of patterns at various speeds. Each was done with three different waveforms, making a total of 143 pictures. These were first presented to subjects on Tape 12 to train them. The patterns were then arranged in a fairly random order on Tape 13 which served to test the ability of the subjects to identify the patterns. All the sine-wave patterns were presented on the test first. The triangular-wave patterns were next, followed by the square-wave patterns.

TABLE 5

The Number of Scan Lines and Duration of Patterns in the Third Set of Experiments

Pattern	Lines/scan	Durations of scan, seconds
Triangle.	20	2, 6
	40	1.5, 4, 9.5
Circle.	20	1, 4
	40	1.5, 3, 4.5
Square.	20	2, 4
	40	2, 4
6-pointed star, one point up. . .	40	2, 5, 13
6-pointed star, two points up . .	20	3.5, 5
	40	5, 12
5-pointed star, one point up. . .	20	3.5, 5
	40	5, 10
5-pointed star, one point down. .	20	2, 4
	40	4, 10
7-pointed star, one point up. . .	20	3, 9
7-pointed star, one point down. .	20	1.5, 6
11-pointed star	30	6, 10, 21
9-pointed star, one point up. . .	26	14
	40	5, 25
9-pointed star, one point down. .	40	5, 16

EXPERIMENTAL RESULTS

The First Set of Experiments

The coding system was found to be easy to understand. The proposal-test tape, which was described in the previous section, was mastered by most subjects with one-half hour of training. These subjects, including six blind subjects, were able to identify the positions of various dots and the positions and orientations of vertical, horizontal, and slanted lines. Subjects found it easy to project. That is, they imagined the tones to be originating from a plane a few feet in front of them, similar to a television screen.

In all, 23 subjects, including six blind subjects, were tested with the proposal-test tape. The sighted subjects correctly identified an average of 16.7 of the 18 patterns shown in Figure 2, The blind subjects averaged 13.6, counting subjects 8 and 9 as one subject. They were trained together and each was asked to identify only half the patterns. If the four and one-half year old blind subject is not included, the average score for blind subjects is 15.5 out of 18.

The Second Set of Experiments

The subjects did so well in identifying the patterns of the first set of experiments that it was decided to code arbitrarily complex shapes and find how well subjects could identify these. The second set of experiments ended with the test on Tape 9, as was discussed in the previous section. Figure 4 shows the patterns which the subjects were asked to identify.

Patterns 12, 15, and 17 were different from any patterns with which the subjects had been trained. Subjects were able in most cases to identify these patterns even though the figures were new to them.

Again, this is an indication that the subjects were learning to interpret the code rather than memorizing patterns. The large number of different patterns also supports this belief.

Information about the subjects is given in Table 6. Subject 8 was 10 years old and had been blind since age 2. Subject 9 was almost 10 years old when tested and had been blind since birth. Neither subject was completely blind. Subject 8 had some light perception, and subject 9 could see the cardboard patterns if he held them to within about 2 inches of his eyes. These two subjects were trained together and took the test together. They went through the test twice, taking turns answering the questions. All other subjects heard Tape 9 only once.

In all, six blind subjects took the test on Tape 9. Except for subject 20, they each identified 14 or more of the 18 patterns correctly. Subject 20 was younger than the rest, and more time should have been taken in training him. From the data in the Appendix it can be seen that blind subjects from 9 to 56 years of age learned to identify the patterns with at most four hours of training.

When taking the test on Tape 9, subjects were allowed to hear the patterns repeated as many times as they wished. Usually, however, they identified the patterns after one or two presentations and jumped to the next pattern on the tape recording. Some of the sighted subjects were asked to draw the patterns which they heard. The drawings showed that the subjects clearly understood the exact orientation of each of the figures as well as their shapes. For example, Patterns 8 and 16 of Tape 9 are both six-pointed stars, but one may be considered to be a version of the other which has been rotated 30 degrees.

The blind subjects were asked to describe the patterns in words clearly or to trace out the shapes with their hands in the air or on a table top. Often it was sufficient to say that the patterns was, for example, a seven-pointed star with one point straight down. Even when this was the case, subjects were often asked to trace out the shape to make sure that they were understanding the spatial relationships between various parts of the figure. It turned out that if a subject could identify a pattern, he understood its shape fairly well. In other words, if a subject was able to say that a pattern was a seven-pointed star, and not a six- or eight-pointed star, he knew fairly accurately where each of the points was.

The Third Set of Experiments

A third set of experiments was doen to find how quickly the patterns could be presented. Table 7 lists the shortest presentation times which

TABLE 6

Information About Blind Subjects

Subject Number	8	9	11	12	13	20	21
Age (Years, Months)	10,2	9,9	38	56	17	9,0	4,6
Sex	M	M	M	M	F	M	F
Blind since age (years, months)	2,0	0,0	0,0	25	0,0	0,6	0,0
Present extent of blindness	LP	*	LP	LP	LP	*	LP

LP - light perception, but no form discrimination.
* - see text.

were repeatably understood for some of the patterns. It can be seen that simple patterns, the triangle, circle, and square, could be identified even if the presentation time were two seconds. The actual amount of form discrimination possible in this short time is difficult to judge from these results because subjects were choosing from only 12 possible patterns.

These last experiments have relevance to the construction of a mobility aid. They show that pictures can be transmitted in a few seconds. The pictures in the experiment were outlines of patterns. This corresponds to an image picked up by a TV camera which was coded using edge detection. Coding using edge detection consists of playing tones to subjects only when a change from light to dark or from dark to light is encountered. Construction of such a TV camera system has just been completed.

The results from the third set of experiments also showed that a restricted frequency range can be used. This would allow the use of less expensive headphones and would allow older people with high frequency hearing loss to hear the tones. The tests also showed that triangular and square-wave audio tones can be understood. Subjects found the tones generated by a sine-wave audio oscillator to be pleasant to listen to. The triangular waveforms were less pleasing. A number of subjects found that tones generated using a square audio waveform were unpleasant.

CONCLUSIONS

A method of presenting two-dimensional pictures or patterns to blind people by means of sound has been developed. Experiments have shown that pictures consisting of complex shapes could be understood. Stars with as many as 11 points were identified and accurately described by blind subjects from 9 to 56 years of age. The orientations of the patterns, as well as their shapes, were clearly understood. At most four hours of training was required to teach subjects to understand these patterns. The experiments

TABLE 7

The Fastest Presentations Understood in Third Set of Experiments. Both Subjects: 2 of 3 Waveforms Each

Pattern	Lines/scan	Duration of scan, seconds
Triangle.	20	2
	40	4
Circle.	20	1
	40	1.5
Square.	20	2
	40	2
6-pointed star, one point up. . .	40	5
6-pointed star, two points up . .	20	5
	40	12
5-pointed star, one point up. . .	20	3.5
5-pointed star, one point down. .	40	10
7-pointed star, one point up. . .	20	9
11-pointed star	30	21
9-pointed star, one point up. . .	26	14
	40	5

also showed that simple patterns such as circles, triangles, and squares could be distinguished even when the picture was presented rapidly. These patterns were presented in two seconds and were understood by subjects.

From these results it can be seen that a good deal of two-dimensional information can be presented to the blind using an audio code. The code which was developed took advantage of the natural decoding mechanisms of the auditory system. As a result, it was easy to interpret. It was mastered by blind children in just a few hours.

Initial tests have been conducted with a system using a slow-scan TV camera to obtain the image which is coded with the auditory display. The one blind subject who was tested learned to identify seven different objects with only one hour of experience with the auditory display. He was not one of the subjects who had been tested in the three sets of experiments described above.

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APPENDIX

DATA AND INFORMATION ABOUT SUBJECTS

The First Set of Experiments

Information about the blind subjects is listed in Table 6. Subject 9 had "finger vision at three feet" which means that he could distinguish fingers held three feet in front of him. This was adequate vision for mobility purposes. Subject 20 had no vision in the left eye, but had 20/400 vision in the right eye with glasses. Subject 13 could see small objects when she was a child, but had almost no light perception at the time of the tests. Subjects 11 and 21 had never seen any shapes, and Subject 8 had seen shapes only before the age of two.

The scores of subjects taking the test on the proposal-test tape (the first set of experiments) are given in Table 8. When the "number tried" was not 18, the subject was not asked to identify all patterns. This was the case with Subjects 8 and 9 because they were trained and tested together. Subject 16 heard a copy of the tape which had the last pattern missing.

The Second Set of Experiments

The performance of subjects taking the test on Tape 9 is shown in Table 9. By referring to Figure 4, one can see which patterns were missed by each subject.

The Third Set of Experiments

The patterns which were repeatedly identified by the subjects are listed in Table 7.

TABLE 8

Proposal Tape Data: First Set of Experiments

Subject number	Age years, months	Number correct	Number tried	Score, %	Blind?	Hours of Previous Training
1	29	17	18	94.5	no	0
2	23	17	18	94.5	no	0
3	24	16	18	89	no	0
4	24	18	18	100	no	0
5	16	10	18	55.5	no	0
6	22	16	18	89	no	2
7	26	18	18	100	no	20
8	10	11	11	100	yes	0
9	9,9	7	9	78	yes	0
10	18	18	18	100	no	0
12	56	16	18	89	yes	0
13	17	18	18	100	yes	0
14	15	16	18	89	no	0
15	26	18	18	100	no	0
16	23	16	17	94	no	0
17	38	16	18	89	no	0
19	21	17	18	94.5	no	0
20	9,0	12	18	67	yes	0
21	4,6	6	18	33	yes	0
22	24	18	18	100	no	1/2
23	24	18	18	100	no	1/2
24	21	17	18	94.5	no	0
25	20	18	18	100	no	0

TABLE 9

Test-Tape 9 Data

Subject number	Age years, months	Score, %	Patterns missed*	Blind?	Hours of Previous Training
6	22	72	6/9/13 16/17	no	4
7	26	100		no	30
8	10	82.4	6/10/15	yes	4
9	9,9	78	6/14/15 17	yes	4
10	18	89	10/16	no	1.75
11	38	83	16/17/18	yes	2
12	56	78	6/10/16 17	yes	3
13	17	94.4	5	yes	2.5
15	26	94.4	16	no	2
19	21	83	6/9/15	no	2.5
20	9,0	33.3	4/6/8/9 10/12/13 14/15/16 17/18	yes	3
17	38	89	4/15	no	2
24	21	78	6/8/13/18	no	2.5
25	20	78	4/9/16/17	no	2.5

*Refer to Figure 4 to see which patterns were missed by each subject.

REFERENCES

Bach-y-Rita, P. "Sensory Plasticity." *Acta, Neurologica Scandinavica*, Vol. 43, 1967, pp. 417-26.

Bach-y-Rita, P. "Neurophysiological Basis of a Tactile Vision-Substitution System." *IEEE Transactions on Man-Machine Systems*, MMS-11, March, 1970, pp. 108-10.

Bach-y-Rita, P., C. C. Collins, F. A. Saunders, B. White, and L. Scadden. "Vision Substitution by Tactile Image Projection." *Nature*, Vol. 221, 1969, pp. 963-4.

Bach-y-Rita, P., C. C. Collins, L. A. Scadden, G. W. Holmlund, and B. K. Hart. "Display Techniques in a Tactile Vision-Substitution System." *Medical and Biological Illustration*, Vol. 20, 1970, pp. 6-12.

Black, W. L. "An Acoustic Pattern Presentation." *Research Bulletin No. 16*, American Foundation for the Blind, 1968, pp. 93-132.

Bliss, J. C. "Dynamic Tactile Displays in Man-Machine Systems." *IEEE Transactions on Man-Machine Systems*, MMS-11, 1970, p. 1.

Collins, C. C. "Tactile Television-Mechanical and Electrical Image Projection." *IEEE Transactions on Man-Machine Systems*, March, 1970, pp. 65-71.

Collins, C. C. "A Portable Seeing Aid Prototype." *Journal of Biomedical Systems*, Vol. 2, 1971a, pp. 3-9.

Collins, C. C. "Tactile Vision Synthesis." In T. D. Sterling, E. A. Bering, Jr., S. V. Pollack, and H. G. Vaughan, Jr., (eds.). *Visual Prosthesis, the Interdisciplinary Dialogue*. New York: Academic Press, 1971b.

Collins, C. C. and J. M. Madey. "Electrocutaneous Visual Prosthesis." *24th ACEMB*, 1971, p. 174.

Collins, C. C. and F. A. Saunders. "Tactile Television: Electrocutaneous Perception of Pictorial Images." *Abstracts of the Neuroelectric Conference*, Vol. 5, 1969, pp. 55-64.

Fish, R. M. "A New Auditory Display for the Blind." *24th ACEMB*, 1971, p. 175.

Garrison, W. "Electricity and Physiology." *Popular Electronics*, January, 1971, pp. 27-31.

Lauer, H. "The Evaluation of the Visotoner." October 28, 1971. (Typewritten, 13 pages.)

Roffler, S. K. "Sound Localization in the Vertical Plane." Unpublished Ph.D. dissertation, University of Chicago, 1967.

Roffler, S. K. and R. A. Butler. "Factors that Influence the Localization of Sound in the Vertical Plane." *Journal of Acoustical Society of America*, Vol. 43, 1968a, pp. 1255-9.

Roffler, S. K. and R. A. Butler. "Localization of Tonal Stimuli in the Vertical Plane." *Journal of Acoustical Society of America*, Vol. 43, 1968b, pp. 1260-6.

Rothe, C. F. "The Ear." In E. E. Selkurt (ed.) *Physiology*. Boston: Little, Brown and Company, 1966.

Scaddon, L. "A Tactile Substitute for Sight." *New Scientist*, March, 1969, pp. 677-8.

White, B. W., F. A. Saunders, L. Scadden, P. Bach-y-Rita, and C. C. Collins. "Seeing with the Skin." *Perception and Psychophysics*, Vol. 7, 1970, pp. 23-7.

A STUDY ON THE DISCRIMINABILITY OF TACTUAL POINT SYMBOLS

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ABSTRACT

Thirty tactual-point symbols were tested for discriminability by the method of pair comparisons. The 194 visually-handicapped subjects included schoolchildren, adults who read braille, and adults who were nonbraille readers. The results indicated that 13 point symbols met the criteria of discriminability suggested by Nolan and Morris (1971).

INTRODUCTION

Tactual maps and diagrams are composed of three categories of symbols: line symbols to designate boundaries or lines, areal or texture symbols for areas, and point symbols to show specific locations or landmarks. This study is concerned only with point symbols.

The three major factors influencing the discrimination of tactual symbols are:

Size. Tactual symbols have to be constructed at a much larger size than visual ones because of the relative inadequacy of touch when compared with vision. Nolan and Morris (1971) found that symbols of 5 mm. side length were considerably less confused than those at a smaller size. This prompted the recommendation that point symbols should not be smaller than 5 mm. The shortcoming of trying to define a minimum size for point symbols is that difference in size may be one of the major factors contributing to legibility among point symbols.

Height. Psychophysical studies of stimulus height or relief have been mainly concerned with the braille dot. For instance, Meyers (1955) found that differences of 0.025 mm between heights of neighboring dots could be distinguished with 68 percent accuracy, and this improved to near 100 percent when the height differed by 0.127 mm. This indicates that variation in the height of tactual symbols may be a good distinguishing feature. Variation in height has been used to differentiate between point, areal, and line symbols in the context of a tactual map (Wiedel, 1969) but not within these categories of symbols.

Schiff (1967) suggested that a pattern or a pattern unit providing differential rates of digital skin deformation gives an excellent basis for tactile discrimination in that this provides an intensity basis for tactile perception. Schiff, Kaufer, and Mosak (1966) developed a tactual line whose properties specify direction, in that the line felt smooth in one direction and rough in the other direction. Schiff and Isikow (1966) studied the effect of redundant information in a tactual histogram and found that a redundant presentation provided the fewest errors when size differences were small.

Form or Configuration. A low two-point limen, or threshold of touch, for the fingers is important in determining the form or configuration of a tactual symbol. Boring (1942) and Weinstein (1968) found this was 2.3 mm for static touch. This corresponds to the interdot spacing for standard braille. The two-point limen is reduced if active touch is employed and allows "micro-dot" braille (1.9 mm spacing) to be legible. However, braille reading speed is considerably reduced when the interdot distance is reduced to 2 mm (Calvin and Clark, 1958; Meyers, Ethington, and Ashcroft, 1958).

Schiff and Dytell (1971) recommend that "although the terms tactual and tactile are used interchangeably throughout most of the literature, we suggest that tactual specify the active use of part of or the entire hand as a 'sense organ system' (Gibson, 1966), including the obtaining of stimuli from muscles and joints as well as the skin, while tactile should specify skin sensitivity per se, implying 'passive' touch (Gibson, 1962) in most cases."

Major (1898) tested both solid and outline circles and triangles. He ranked the outline circles as the easiest to discriminate and the solid circles as the most difficult. Zigler and Barrett (1927) tested solid, outline, and punctate symbols and found that the outline figures gave the most accurate scores. It appears that the pad of the finger feels an outline shape more easily than a solid one, but this does not hold when the size is reduced. Austin and Sleight (1952) examined the static and active discriminability of both outline and punctate point symbols and found that outline figures with tactual reading were the most discriminable.

The two-point limen of touch may be lowered by the use of active touch and by training (Boring, 1942; Weinstein, 1968). Consequently, these factors may be important in the discrimination of embossed symbols.

Nolan and Morris (1971) studied 12 point symbols embossed in plastic at 5 mm size and found 8 to be discriminable. They also tested 19 symbols embossed in paper of which the largest was 14 mm and found 11 to be discriminable. Wiedel and Groves (1969) tested 15 point symbols and found 3 to be discriminable, but details of their testing procedures are not reported.

The aim of this experiment is to study the discriminability of 5 mm tactual point symbols for four groups of subjects. The four groups of visually-handicapped subjects are schoolboys, schoolgirls, adults who read braille, and adults who are non-braille readers. The data obtained from this experiment is to be used in the future design of tactual maps and diagrams.

EXPERIMENT 1

Method

Subjects. Forty-five blind schoolboys, 52 blind schoolgirls, 32 blind adults who read braille, and 27 blind adults who do not read braille were used as subjects; they were not paid for their services. The adults were a convenience sample of those who agreed to be tested at various centers for the blind. The mean ages for these groups are shown in Table 1.

For the schoolchildren, IQ scores, ages, and braille reading speeds were obtained from the schools. They assessed braille reading speed in the following way:

1. The child read braille text out loud to the whole class for 3 minutes,
2. A score was taken for the number of braille lines completed,
3. The number of lines completed was then multiplied by 0.75 to give an average speed in pages of braille per hour.

The adults were asked for their age, date of becoming registered blind, degree of blindness, and their experience with tactual maps. Braille readers were defined as those who said they were proficient Grade 2 braille readers. The degree of blindness, as reported by the subjects, was specified as three groups--totally blind (T), perception of light (PL), and perception of hand movement (HM). Experience with tactual maps was subdivided into--a good deal (A), some (B), and very little or none (C). The results are summarized in Table 2.

TABLE 1

Ages and Length of Time Registered Blind in Years

	Boys	Girls	Adult Braille Readers		Adult Non-Braille Readers	
	age	age	age	onset	age	onset
Mean	15.1	15.7	44.6	29.2	54.4	13.7
S.D.	2.1	2.0	15.8	21.4	13.4	17.1

TABLE 2

Number of Adult Subjects by Sex, Degree of Blindness and Experience with Tactual Maps

	N	Sex		Degree of Blindness			Experience with Maps		
		male	female	T	PL	HM	A	B	C
Braille readers	32	18	14	23	4	5	5	12	15
Non-braille readers	27	11	16	6	7	14	0	3	24

Selection of symbols. A pilot study was conducted using symbols based on those tested by Nolan and Morris (1971), Schiff (1967), Wiedel and Groves (1969), and those in current use in Britain. Symbols consisting of groups of dots were rejected since these were considered to be multiple symbols. Fifty different symbols with a maximum side length of 5 mm were produced in 0.18-mm semi-rigid vinyl sheet with 1.5-mm relief. The symbols were vacuum-formed from a master made by a computer-aided production system (Gill, 1972).

Following a pilot study, 30 symbols were chosen for testing and divided into three groups of ten (Figure 1). The allocation into different groups was done so that symbols thought likely to be confused were in the same group.

Apparatus. The apparatus is shown in Figure 2. The screen excluded the use of residual vision. The symbols were mounted 50 mm apart on three disks, 55 pairs on each disk. The disks were rotated by the experimenter so that the symbols were in the same place under the subject's fingers. The order of the pairs and the order of presenting the pairs was determined randomly. The order of presenting the disks and the direction of rotation was also determined randomly, giving 18 different orders of presentation.

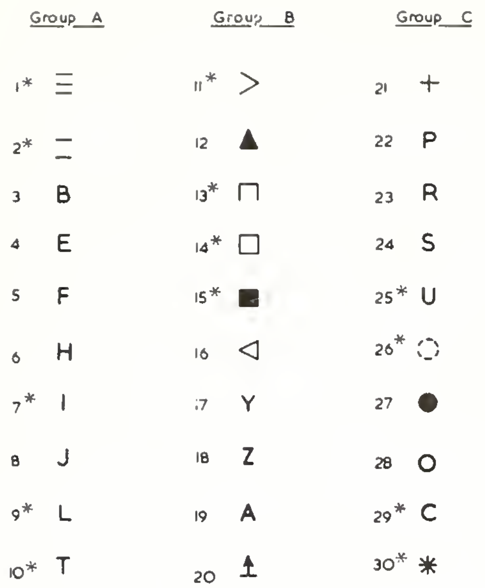

Figure 1. The thirty point symbols. Asterisks identify a discriminable set.

Design

Symbols within each set were tested by means of paired-comparison; each symbol in a set was compared with itself and every other symbol. Each group of 10 symbols gave 55 combinations. Four sample pairs, which were not included in the experiment, were used to familiarize the subjects with the procedure.

Procedure

Three examiners tested the subjects. Standard instructions are shown in Figure 2. Each subject examined every pair of symbols and had to report whether they were the "same" or "different." To prevent knowledge of results only one stroke of the pen was made by the examiner in a "right" or "wrong" column on the scoring sheet.

Criteria

Nolan and Morris (1971) report the following arbitrarily selected criteria as being the most useful in selecting discriminable tactile symbols for the blind:

1. Average confusion with other acceptable symbols must be five percent or less.

2. Confusion with itself or any other single symbol, acceptable by Criterion 1, should be 10 percent or less.

3. Any symbols acceptable by Criteria 1 and 2 must be independent of academic grade differences.

Criteria 1 and 2 were adopted for the purpose of this study.

Standard Verbal Instructions

1. Please put both hands onto the two symbols in front of you (guide hands if necessary).

2. You have to say whether the two symbols are the same or different. You just say "same" or "different."

3. There is no time limit and I will not be timing you, but remember once you have made a decision you cannot change your mind.

4. Lift your fingers off the symbols when you have made your decision and do not put them onto the next pair of symbols until I say "now."

Figure 2. Experimental Apparatus

5. We will have four test symbols and I will tell you if you are right or wrong.

6. Are there any questions?

7. We are now beginning to experiment and from now on I cannot tell you whether you are right or wrong. Do not spend time worrying about small details. The experiment consists of three parts of about five minutes each.

Results

Tables 3 to 14 show the percentage of errors for the three groups of symbols for each of the four groups of subjects. Table 15 summarizes the results using the Nolan and Morris criteria.

TABLE 3

Percentage of Errors - Schoolboys, Symbol Group A, N = 45

	1	2	3	4	5	6	7	8	9	10
1	2.2	0	2.2	0	2.2	0	0	0	0	0
2		4.4	0	0	0	0	0	0	0	0
3			24.4	0	2.2	6.7	0	0	0	0
4				13.3	2.2	0	0	0	0	0
5					8.9	0	0	0	0	2.2
6						17.8	0	0	0	0
7							0	0	0	2.2
8								4.4	6.7	0
9									2.2	0
10										13.3

TABLE 4

Percentage of Errors - Schoolboys, Symbol Group B, N = 45

	11	12	13	14	15	16	17	18	19	20
11	0	0	2.2	0	0	0	2.2	0	0	0
12		6.7	2.2	0	2.2	44.4	0	0	28.9	6.7
13			4.4	0	0	0	0	0	0	0
14				8.9	4.4	0	0	0	0	0
15					4.4	2.2	0	0	0	0
16						15.6	2.2	0	15.6	17.8
17							6.7	0	2.2	0
18								11.1	0	4.4
19									2.2	4.4
20										31.1

TABLE 5

Percentage of Errors - Schoolboys, Symbol Group C, N = 45

	21	22	23	24	25	26	27	28	29	30
21	27.8	4.4	4.4	11.1	2.2	0	0	0	0	0
22		26.7	2.2	2.2	0	0	0	0	0	0
23			24.4	8.9	6.7	0	2.2	4.4	0	4.4
24				15.6	0	2.2	0	4.4	0	4.4
25					6.7	0	0	4.4	2.2	0
26						6.7	0	13.3	0	2.2
27							0	11.1	0	24.4
28								8.9	0	0
29									11.1	0
30										8.9

TABLE 6

Percentage of Errors - Schoolgirls, Symbol Group A, N = 52

	1	2	3	4	5	6	7	8	9	10
1	0	0	0	1.9	0	1.9	0	0	0	0
2		3.8	0	1.9	0	0	0	0	0	1.9
3			15.4	0	0	1.9	0	0	0	0
4				5.8	1.9	0	0	5.8	0	0
5					9.6	3.8	0	0	1.9	9.6
6						3.8	0	0	0	0
7							1.9	0	0	0
8								7.7	19.2	0
9									1.9	1.9
10										1.9

TABLE 7

Percentage of Errors - Schoolgirls, Symbol Group B, N = 52

	11	12	13	14	15	16	17	18	19	20
11	1.9	0	1.9	0	0	0	1.9	0	0	0
12		1.9	0	0	3.8	50.0	3.8	1.9	17.3	5.8
13			3.8	0	0	0	0	0	0	0
14				1.9	3.8	1.9	0	0	0	1.9
15					0	1.9	0	0	1.9	1.9
16						7.7	0	1.9	7.7	11.5
17							9.6	0	5.8	0
18								11.5	0	1.9
19									5.8	5.8
20										11.5

TABLE 8

Percentage of Errors - Schoolgirls, Symbol Group C, N = 52

	21	22	23	24	25	26	27	28	29	30
21	11.5	0	0	1.9	1.9	1.9	0	1.9	1.9	0
22		19.2	0	0	1.9	0	1.9	0	0	3.8
23			19.2	3.8	7.7	0	1.9	3.8	1.9	11.5
24				21.2	5.8	0	0	3.8	1.9	7.7
25					3.8	3.8	0	7.7	0	1.9
26						1.9	0	5.8	0	0
27							25.0	5.8	0	34.6
28								3.8	0	1.9
29									3.8	1.9
30										3.8

TABLE 9

Percentage of Errors - Adult Braille Readers, Symbol Group A, N = 32

	1	2	3	4	5	6	7	8	9	10
1	0	3.1	0	6.3	0	9.4	0	0	0	0
2		0	0	0	0	0	0	0	0	0
3			15.6	3.1	15.6	28.2	0	0	3.1	3.1
4				12.5	0	3.1	0	6.3	0	0
5					3.1	3.1	3.1	3.1	0	31.2
6						21.7	0	0	0	3.1
7							6.3	3.1	0	3.1
8								0	15.6	3.1
9									3.1	3.1
10										15.6

TABLE 10

Percentage of Errors - Adult Braille Readers, Symbol Group B, N = 32

	11	12	13	14	15	16	17	18	19	20
11	9.4	6.3	6.3	3.1	0	6.3	6.3	3.1	6.3	3.1
12		9.4	3.1	12.5	6.3	65.6	0	0	25.0	21.7
13			3.1	6.3	3.1	0	3.1	3.1	0	6.3
14				9.4	9.4	3.1	0	3.1	0	0
15					3.1	3.1	0	3.1	3.1	0
16						3.1	12.5	3.1	28.2	21.7
17							12.5	6.3	9.4	6.3
18								3.1	6.3	18.7
19									9.4	6.3
20										6.3

TABLE 11

Percentage of Errors - Adult Braille Readers, Symbol Group C, N = 32

	21	22	23	24	25	26	27	28	29	30
21	9.4	18.7	6.3	21.7	12.5	15.6	3.1	0	6.3	3.1
22		6.3	15.6	9.4	9.4	3.1	6.3	6.3	3.1	9.4
23			15.6	9.4	21.7	0	6.3	9.4	6.3	21.7
24				12.5	15.6	12.5	0	15.6	6.3	12.5
25					15.6	9.4	3.1	21.7	6.3	9.4
26						6.3	0	18.7	0	6.3
27							3.1	18.7	0	46.9
28								12.5	3.1	12.5
29									6.3	0
30										6.3

TABLE 12

Percentage of Errors - Adult Non-braille Readers, Symbol Group A, N = 27

	1	2	3	4	5	6	7	8	9	10
1	7.4	0	11.1	11.1	11.1	14.8	0	3.7	0	3.7
2		11.1	3.7	7.4	0	11.1	7.4	3.7	7.4	11.1
3			22.2	11.1	25.9	48.1	11.1	3.7	7.4	18.5
4				33.3	11.1	22.2	3.7	22.2	22.2	24.8
5					18.5	22.2	18.5	25.9	3.7	59.2
6						22.2	0	3.7	3.7	7.4
7							3.7	14.8	7.4	18.5
8								29.6	37.0	18.5
9									29.6	14.8
10										25.9

TABLE 13

Percentage of Errors - Adult Non-braille Readers, Symbol Group B, N = 27

	11	12	13	14	15	16	17	18	19	20
11	33.3	0	7.4	0	3.7	7.4	14.8	7.4	7.4	3.7
12		25.9	0	25.9	37.0	55.5	3.7	3.7	51.8	18.5
13			18.5	3.7	0	0	3.7	3.7	3.7	0
14				18.5	25.9	33.3	0	3.7	3.7	3.7
15					11.1	29.6	3.7	0	14.8	14.8
16						33.3	11.1	14.8	40.7	40.7
17							44.4	22.2	22.2	14.8
18								22.2	7.4	44.4
19									22.2	25.9
20										29.6

TABLE 14

Percentage of Errors - Adult Non-braille Readers, Symbol Group C, N = 27

	21	22	23	24	25	26	27	28	29	30
21	18.5	22.2	29.6	33.3	18.5	18.5	3.7	3.7	14.8	7.4
22		51.8	37.0	29.6	22.2	3.7	0	29.6	3.7	14.8
23			62.9	18.5	40.7	7.4	25.9	29.6	3.7	44.4
24				44.4	25.9	25.9	3.7	22.2	14.8	25.9
25					29.6	22.2	18.5	22.2	14.8	22.2
26						18.5	14.8	44.4	25.9	14.8
27							18.5	33.3	3.7	66.7
28								22.2	3.7	40.7
29									25.9	3.7
30										25.9

TABLE 15

Mean Number of Errors per Subject and the Number of Discriminable Symbols in the Three Groups

Group	Mean Number of Errors per Subject	Number of Discriminable Symbols on the Three Disks		
		A	B	C
Schoolboys	3.6	6	6	3
Schoolgirls	3.3	8	7	5
Adult Braille Readers	7.1	5	6	4
Adult Non-braille Readers	18.2	2	0	0

EXPERIMENT 2

By combining the results of the schoolboys and schoolgirls, there were seven discriminable symbols in group A, six in group B and five in group C (N = 97). The previous experiment only demonstrated that they were discriminable within their own group. In this experiment the 18 symbols were compared with the symbols in the other two groups and with themselves. This resulted in 125 pairs.

The experimental procedure was identical to the previous experiment except that only two disks were used. Thirty-eight blind schoolboys were used as subjects.

The results are shown in Table 16. Subjects made an average of 2.8 errors. The discriminable symbols are indicated by an asterisk in Figure 1.

TABLE 16

Percentage of Errors - Schoolboys, N = 38

	1	2	4	5	7	9	10	11	13	14	15	17	19	25	26	28	29	30
1	1.5							0	0	0	2.6	0	0	0	0	0	0	0
2		3.7						2.6	0	2.6	0	2.6	0	0	0	0	0	0
4			11.2					0	0	0	0	0	0	0	2.6	0	15.8	0
5				11.9				2.6	2.6	0	0	7.9	7.9	0	0	0	0	2.6
7					1.5			0	0	0	0	2.6	0	0	0	0	0	0
9						2.2		5.3	0	0	0	0	2.6	0	0	0	2.6	0
10							9.6	7.9	0	0	0	26.3	2.6	0	0	0	0	0
11								2.2						0	0	2.6	2.6	2.6
13									3.0					0	0	0	0	0
14										4.4				0	0	13.2	0	0
15											2.2			2.6	0	0	0	0
17												8.9		0	0	0	0	2.6
19													7.4	10.5	0	0	2.6	0
25														7.4				
26															3.7			
28																5.2		
29																	8.2	
30																		8.2

DISCUSSION

The statistical analysis (Tables 17-19) indicates that there is no significant sex difference in performance. Nolan and Morris' (1971) third criterion of discriminability was that there should be no significant difference in performance by academic grade. In the second experiment there was no significant correlation with grade or age for the schoolchildren although there was a significant correlation with I.Q. for the schoolboys but not the schoolgirls. Nolan and Morris (1971) found no significant difference in performance with academic grade although this was significant in an earlier experiment (Morris and Nolan, 1963).

TABLE 17

Statistical Results - Spearman Correlations

Expt. No.	Subject Group	Variable/Number of Correct Decisions	Spearman's Rho	*t* for Significance of Rho	DF	Correlations	Significance
1	School-boys	braille reading speed	0.230	1.556	43	+	No
1	School-boys	age	-0.037	-0.246	43	-	No
1	School-boys	IQ	0.507	3.853	43	+	Yes $p < 0.001$
1	School-girls	braille reading speed	0.030	0.185	39	+	No
1	School-girls	age	-0.060	-0.428	50	-	No
1	School-girls	IQ	0.024	0.130	30		No
1	Adult Braille Readers	age	-0.417	-2.516	30	-	Yes $p < 0.02$
1	Adult Braille Readers	onset of blindness	-0.268	-1.526	30	-	No
1	Adult Braille Readers	age	-0.284	-1.482	25	-	No
1	Adult Braille Readers	onset of blindness	-0.059	-0.294	25		No
2	School-boys	braille reading speed	0.175	1.055	35	-	No
2	School-boys	age	-0.252	-1.561	36	-	No
2	School-boys	IQ	0.393	2.56	36	+	Yes $p < 0.02$

TABLE 18

Statistical Results - Kruskal-Wallis Analysis of Variance

Expt. No.	Subject Group	Variable	Kruskal-Wallis *H*	*DF*	Significance
1	Braille Readers	map experience	7.853	2	Yes $p < 0.02$
1	Braille Readers	degree of blindness	2.772	2	No
2	Schoolboys	grade	0.423	2	No
1	Non-braille Readers	degree of blindness	2.172	2	No

TABLE 19

Statistical Results - Mann Whitney *U* Test

Expt. No.	Subject Group	Variables	Mann-Whitney *U*	*N*1	*N*2	Significance
1	Adult Braille Readers	performance of males and females	121	18	14	No
1	Adult Non-Braille Readers	experience with maps/ correct decisions	33	3	24	No
1	Adult Non-Braille Readers	performance of males and females	84	11	16	No
1	School-children	performance of females and males	1097	52	45	No
1	Adults	performance of braille readers and non-braille readers	133	32	27	Yes $p < 0.01$

For the adult braille readers there was a negative correlation with age. The subjective assessment by adult braille readers of their map experience provided a significant correlation with performance. It is not possible to assess whether this would also hold for the nonbraille readers since very few had had any experience with tactual maps (Table 2).

The authors observed that the method of inspection varied between subjects. Some subjects just placed their fingers on the symbols, but others moved their fingers round the edges and in the center of the symbol. The latter group seemed to perform better than those who used just passive touch. This agrees with the findings of Austin and Sleight (1952).

Jansson (1972) found that the following kinds of point symbols are often confused:

1. Evenly-embossed surfaces of different form,

2. Closed contours of different form,

3. Open contours of different form,

4. Combinations of similar units.

The last group was excluded from this experiment.

In this experiment, ten of the discriminable symbols were of the open-contour type while two were of the closed-contour type, and only one was an evenly-embossed surface.

The use of the method of paired-comparison for studying the discriminability of tactual symbols has been questioned by Schiff (1967):

> "The method of paired-comparison yields results of limited value in tactile discrimination studies related to diagrammatic presentation of information, since it leads one to assume better discriminability than actually present, because as amount of information to be discriminated is increased, lines or symbols of other sorts lose their discriminability."

In a tactual map a point symbol is usually used in context. For instance, in a street map a traffic circle only occurs at a road junction. This means that a symbol may be discriminable in context on a map although it was not found to be discriminable in a paired-comparison experiment.

Another disadvantage of using the method of paired-comparison is that the number of tests is $N(N + 1)/2$ where N is the number of different symbols to be tested. In order to keep this experiment to a reasonable length it was necessary to split the symbols into three groups of ten. This still gave 165 tests per subject and meant that the whole experiment required 25,740 tests. The monotony of the experiment may have caused an increase in the number of errors.

In the second experiment test-retest was used on the like pairs for 20 subjects, but the sample size was too small to use this as a measure of the precision of the experiment.

This experiment has demonstrated that 13 point symbols can be discriminated by the blind school children used as subjects. It must be taken into account that the experiment only used symbols in one size, at one elevation and in one orientation. If multi-height and variation in symbol size are included then the set of discriminable symbols may be increased in number. The experiment did not study the discriminability and minimum spacing of the symbols when used on a tactual map in the presence of noise.

For over a decade research has been carried out on the discriminability of tactual symbols, but the symbols have not been chosen by any scientific analysis of their structure. Future work should involve more imaginative design of symbols, and their discriminability should be analyzed in the context of a tactual map or diagram.

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REFERENCES

Austin, T. R. and R. B. Sleight. "Accuracy of Tactual Discrimination of Letters, Numerals and Geometric Forms." *Journal of Experimental Psychology*, Vol. 43, 1952, pp. 239-47.

Austin, T. R. and R. B. Sleight. "Factors Related to Speed and Accuracy of Tactual Discrimination." *Journal of Experimental Psychology*, Vol. 44, 1952, pp. 283-7.

Berla, E. P. "Behavioral Strategies and Problems in Scanning and Interpreting Tactual Displays." *The New Outlook for the Blind*, Vol. 66, 1972, pp. 277-86.

Boring, E. G. *Sensation and Perception in the History of Experimental Psychology.* New York: Appleton, 1942.

Calvin, J. S. and J. Clark. "Influence on Type Characteristics on Braille Reading." Unpublished manuscript, American Printing House for the Blind, 1958.

Dreyfuss, H. *Symbol Source Book.* New York: McGraw-Hill Book Company, 1972.

Gibson, J. J. "Observations on Active Touch." *Psychological Review*, Vol. 69, 1962, pp. 477-91.

Gibson, J. J. *The Senses Considered as Perceptual Systems.* Boston: Houghton Mifflin, 1966.

Gill, J. M. *Computer Production of Tactile Diagrams and Maps.* The Leonard Conference, Cambridge, England, January 1972, pp. 73-7.

James, G. A. "Problems in the Standardisation of Design and Symbolisation in Tactile Route Maps for the Blind." *New Beacon*, Vol. 56, No. 660, April 1972, pp. 87-91.

Jansson, G. "Symbols for Tactile Maps." In B. Lindqvist and N. Trowald (eds.) *European Conference of Educational Research for the Visually Handicapped.* Project: PUSS: VIII. Report No. 31, 1972, pp. 66-73.

Major, D. P. "Cutaneous Perception of Form." *American Journal of Psychology*, Vol. 10, 1898, pp. 143-7.

Meyers, E. "July Progress Report." Unpublished Report, American Printing House for the Blind, 1955.

Meyers, E., D. Ethington, and S. Ashcroft. "Readability of Braille as a Function of Three Spacing Variables." *Journal of Applied Psychology*, 1958, Vol. 42, pp. 163-5.

Morris, J. E. and C. Y. Nolan. "Minimum Sizes for Areal Type Tactual Symbols." *International Journal for the Education of the Blind*, Vol. 13, No. 2, December 1963, pp. 48-51.

Nolan, C. Y. and J. E. Morris. "Improvement of Tactual Symbols for Blind Children." Report of Department of Health, Education and Welfare. Project No. 5-0421, 1971.

Pick, A. D. and H. L. Pick. "A Developmental Study of Tactual Discrimination in Blind and Sighted Children and Adults." *Psychonomic Science*, Vol. 6, 1966, pp. 367-8.

Schiff, W. *Using Raised Line Drawings as Tactual Supplements to Recorded Books for the Blind.* Final Report, RD-1571-S, Recordings for the Blind, New York, June 1967.

Schiff, W. and R. S. Dytell. "Tactile Identification of Letters: A Comparison of Deaf and Hearing Children's Performances." *Journal of Experimental Child Psychology*, Vol. 11, No. 1, February 1971, pp. 150-64.

Schiff, W. and H. Isikow. "Stimulus Redundancy in the Tactile Perception of Histograms." *International Journal for the Education of the Blind*, Vol. 16, 1966, pp. 1-11.

Schiff, W., L. Kaufer, and S. Mosak. "Informative Tactile Stimuli in the Perception of Direction." *Perceptual and Motor Skills*, Vol. 23 (Monograph Supplement 7), 1966.

Siegel, S. *Nonparametric Statistics for the Behavioural Sciences.* New York: McGraw Hill Book Company, 1956.

Weinstein, S. "Intensive and Extensive Aspects of Tactile Sensitivity as a Function of Body Part, Sex and Laterality." In D. R. Kenshalo (ed.) *The Skin Senses.* Springfield, Illinois: Charles C. Thomas, 1968, pp. 195-222.

Wiedel, J. W. and P. A. Groves. *Tactual Mapping: Design, Reproduction, Reading and Interpretation.* Final Report RD-2557-S, 1969, Department of Health, Education and Welfare.

Zigler, M. J. and F. Barrett. "A Further Contribution to the Tactual Perception of Form." *Journal of Experimental Psychology*, Vol. 10, 1927, pp. 184-92.

SONIC GLASSES FOR THE BLIND
PRESENTATION OF EVALUATION DATA

Leslie Kay*

INTRODUCTION

A progress report on the evaluation of the Binaural Sensory Aid (Sonic Glasses) in Research Bulletin Number 25 described the Sonic Glasses and the method for evaluating the usefulness of these for blind people.

The purpose of this paper is to present the evaluation data collected from questionnaires sent to 94 blind users of the device and 25 teachers who have been involved in their training.

PREPARATION OF THE QUESTIONNAIRE

Since the opinions of the teachers and the users was to form the major part of the evaluation, the preparation of the questionnaires was of great importance. They did in fact form the main evaluation instruments.

One of the difficulties with a questionnaire is its design, which usually is undertaken by someone with experience in both the design of questions and the subject matter to be studied. In this highly-specialized field there was no one who could readily play this dual role. It was, therefore, necessary that a designer be engaged who knew nothing about mobility for the blind but who was readily available for frequent discussions on the form of questions to be used. This, however, was seen to weaken the complete independence of the evaluation instrument since those who were available to guide the designer were also the people who had been most closely involved in the design of the device and the development of the training methods.

To reduce bias to a minimum, each member of the team supervising the evaluation program wrote down as many relevant questions as came to mind over a period of time. Together these formed the background from which the designer worked. They fell into various categories dealing with trainee characteristics, the training program, attitudes towards the device, mechanical and design inadequacies of the device, and ratings of skills for which the device was supposed to be useful.

Two questionnaires were designed; one for the teacher and one for the user. There was frequent consultation between the designer and the evaluation team on the relative importance of certain questions, and as the wording of the questions reached finality discussions were held on their relevance and possible ambiguity. By this time the designer had become very familiar with the aims of the program and the broad coverage we were seeking from the data to be collected. In consequence, he played the major part in determining the type of information we would get from the answers, and the way in which it would be sought.

The questions asked, together with the replies, are in Appendices 1 and 2.

GENERAL DISCUSSION

The two questionnaires are discussed by the designer, Dr. P. W. Airasian in a separate paper, which follows this. He points out that we were not seeking votes, and

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therefore the data should be carefully considered in relation to the questions.

Quite clearly, when asked the question about the basic concept of the device, a high percentage of the replies must be favorable before one would consider providing blind people with such an aid. When, on the other hand, a specific skill which is thought to be difficult is considered, a low rating could be expected and a 30- to 40-percent success rating may be very encouraging. It may also suggest that more attention be given to this specific skill.

Many of the replies were as expected, since the team had observed many trainees and had discussion with them after their training. Nevertheless, some surprises did arise, particularly in the form of differences of opinion between teacher and trainee. When teachers were asked the value of the aid in crossing a street in a downtown area, for example, two thought it had great impact, three thought only moderate impact, but 15 felt it had only small impact. The blind users were divided in their opinions too. Of the long cane users 68 percent felt that their mobility in this respect was better, 7 percent thought it was worse, and 19 percent believed there was no change, 5 percent had not encountered the situation. When, on the other hand, the guide dog users replied, their answers were very different. Only 18 percent felt there was an improvement; 82 percent felt there was no difference.

When the several cane users were personally questioned about these differences of opinion the answer was simple. Some had come to understand the sounds of the device sufficiently well after training to use the aid effectively when crossing a street, but during training their understanding was too limited for this complex situation.

An interesting and valuable response when questioned about some of the answers, was the frequent retort that new skills had been learned some time after the training program had been completed. This usually came from a greater awareness of the subtle sounds produced by the device.

While the data presented here does not show the difference between guide-dog user and long-cane user (they are grouped together) there were often significant differences between these groups which have affected the combined result. For example, 54 percent of the dog users have a better understanding of the environment at the "strongly agree" level, while 27 percent "disagree." Of the cane users 32 percent "agree" and 46 percent "strongly agree." Only 12 percent "disagree."

There are interesting correlations which give confidence to the replies. Twenty-five percent of the users felt that the sounds of the aid produced hearing fatigue while 32 percent liked the device to be loud. Those people who have the device loud *will* suffer auditory fatigue. All were trained to use the aid on low volume.

On the question of reliability and maintenance, several teachers indicated specifically in their replies that the device was too unreliable to justify teaching many more blind people at this stage. They all agreed the *concept* of the aid was useful yet remained reserved in a number of areas. Forty-four percent of the trainees experienced failure of the device during training and this frustrated many teachers. At the time of asking, 85 percent of the users were satisfied with the reliability and 82 percent felt it was reasonably maintenance free.

CONCLUSION

The evaluation exercise has taught us all a great deal. Considerable data is now available for detailed studies of the training methods and the skills which can be acquired. Some of these aspects will be discussed in a later paper.

APPENDIX 1

SONIC GLASSES EVALUATION QUESTIONNAIRE

Replies From Trainers

The purpose of this questionnaire is to obtain information about your attitudes and experiences with the sonic glasses. The questions are intended to gather information about a number of areas, ranging from the training period to the device's reliability.

If you have difficulty remembering a specific fact asked for, please try to answer as best you can. You are not required to put your name on the questionnaire and all data analysis will be performed upon groups, so that no individual respondent will be identifiable.

(The number following each choice indicates the response.)

1. How many years experience in mobility training have you had?
   a. 0-2 years)
   b. 3-5 years) 15
   c. 6-9 years)
   d. 10-15 years) 5
   e. more than 15 years)

2. How long have you been training the blind in the use of sonic glasses?
   a. 1-4 months 6
   b. 5-8 months 5
   c. 9-12 months 7
   d. more than 12 months 2

3. In that time, how many students have you trained in the use of sonic glasses?
   a. 1-3 students 15
   b. 4-6 students 4
   c. 7-10 students 0
   d. more than 10 students 1

4. Have most of the trainees been residents at the training center or have they travelled each day from their homes?
   a. most have been residents at training center 8
   b. most have travelled to the training center each day 10
   c. about half and half 2

5. About how much of your teaching time is devoted to teaching the sonic glasses?
   a. all my time 1
   b. nearly all my time 3
   c. about half my time 4
   d. about one-third 2
   e. less than one-third 10

6. Would you like to continue teaching the sonic glasses?
   a. yes, full time 2
   b. yes, part time 17
   c. no 0

7. In general, based upon your experience as a teacher of the sonic glasses, do you think the glasses will be helpful to a large, medium, or small segment of the *totally blind mobile* population?
   a. large segment 3
   b. medium segment 7
   c. small segment 10

8. What do you think is the average number of *hours* needed to train a person with the glasses?
   a. 0-20 hours 0
   b. 21-40 hours 4
   c. 41-60 hours 12
   d. 61-80 hours 1
   e. more than 80 hours 3

9. Perhaps your experience has enabled you to suggest what type

of person learns best with glasses. For example, do young people learn better than old, or smart better than not-so-smart? List below those characteristics which you think are *most* essential to being successfully trained in the use of sonic glasses.

10. Based upon your experience thus far, do you think the concept, that is, the use of this form of coded sound to aid mobility is a useful one?
    a. yes 20
    b. no 0

Following is a series of statements about the sonic glasses. For each statement circle
- SA if you *strongly agree* with the statement
- A if you *agree* with the statement
- N if you *neither agree nor disagree* with the statement
- D if you *disagree* with the statement
- SD if you *strongly disagree* with the statement

	SA	A	N	D	SD
11. The number of mobile blind currently being trained in the use of the glasses should be increased	2	11	6	1	0
12. More O and M instructors should be trained in the use of glasses	2	9	5	3	1
13. It would be extremely useful to have each trainee fitted with a back up set of glasses in case his original set malfunctions during training	4	8	2	5	1
14. The blind that I trained in the use of the glasses were highly motivated to learn	8	7	3	1	0
15. My preparation for teaching the glasses was adequate	0	12	3	4	1
16. I should have liked more training in the teaching of the glasses	2	12	3	3	0
17. I have often heard trainees comment enthusiastically about the glasses	2	11	4	3	0
18. For training to be really successful, the student must practice a great deal on his own	8	6	6	0	0
19. In general, mobility for the people I trained could have been increased as much by additional training in their primary mobility aid as with the glasses	0	4	3	9	3
20. After teaching the use of the glasses, my attitude toward the glasses is favorable	3	15	2	0	0
21. The benefits of the glasses justify the training period	4	14	2	0	0
22. Blind persons could learn to use the glasses without any formal training	0	0	0	3	17
23. For training to be successful, there should be more follow-up of students	7	9	2	0	1

24. Have you observed or heard of any of your pupils learning completely new skills as a result of using the glasses (for example, taking their place in a line, finding an empty table, etc.)?
    a. yes 14
    b. no. 6

25. What new skills have you observed or heard of?

26. For the average trainee, what percentage of training time is devoted to indoor travel situations?

a. 0-10 percent	9
b. 11-20 percent	8
c. 21-30 percent	1
d. more than 30 percent	2

27. For the typical trainee, how many hours per day are usually spent in supervised training, that is, training with you supervising the activities?

a. less than 1 hour	0
b. 1-2 hours	16
c. 3-4 hours	4
d. more than 4 hours	0

28. When training required the use of training areas away from the agency, did you travel to the areas in private cars or in an agency vehicle?

a. in private cars	8
b. in agency vehicles	10
c. in both private and agency vehicles	2

Following is a list of situations which you or your clients may have encountered during the training period. For each situation, please indicate, by *circling* the appropriate answer, whether

- A The situation was not encountered during training
- B The situation was encountered but caused only minimal inconvenience
- C The situation was encountered and caused moderate inconvenience
- D The situation was encountered and caused severe inconvenience

	A	B	C	D
29. The cable caught on objects	10	5	5	0
30. The press of my other duties made it difficult to organize the training program	4	11	4	1
31. The exercise poles were not ready on time	10	3	3	1
32. Transportation problems occurred from lessons requiring different training areas	15	2	3	0
33. The glasses were not available on schedule	8	2	4	6
34. Too much of the organizational planning (e.g., preliminary client screening, selecting training areas, making poles, etc.) was left to the instructor	8	9	2	1
35. The device broke down during lessons	6	6	3	5
36. Ear fittings (tubes or molds) were uncomfortable	7	7	5	0
37. Ear tubes fell out	13	4	1	1
38. Ear fittings (tubes or molds) occluded ambient sounds	15	5	2	0
39. Lesson time was spent checking device for malfunctions	7	11	2	0
40. Monitoring causes static in client's aid	4	6	9	1
41. Monitor cable got in the way	2	5	10	3

Following is a series of questions concerning your experience when teaching the use of the glasses. Answer each question "yes" or "no," according to your personal experience with the glasses. *Circle* your answer.

	Yes	No
42. Are the audible signals of the glasses easily interpreted by the trainees?	14	3

	Yes	No
43. Do the signals from the glasses enable the trainee to discriminate fairly well between different types of objects (e.g., tree vs. pole, hedge vs. fence, etc.)?	15	4
44. Do the trainees often become fatigued from the audible signals?	12	7
45. Is the range of objects which the glasses enable trainees to detect adequate for mobility?	17	2
46. Do the glasses provide more aid in orientation or in recognition of landmarks in familiar areas than the long cane?	17	1
47. Do the glasses provide more aid in orientation or recognition of landmarks in unfamiliar areas than the long cane?	14	3
48. Do the trainees tend to use the glasses too loud at the beginning of training?	19	0
49. Do the trainees tend to use the glasses too loud as the end of training?	4	14
50. Do the signals from the glasses often create confusion in orientation?	6	13
51. Do the glasses give reliable information on objects in the line of travel?	17	1
52. After training can trainees readily determine the direction of objects from the audible signals while traveling at their normal rate?	18	0
53. Do the glasses improve the trainee's line of travel?	12	6
54. Is walking speed increased with use of glasses?	5	14
55. Is walking speed reduced with the use of glasses?	9	10
56. Towards the end of training, do most trainees become relaxed and comfortable using the glasses?	19	0
57. After training do most trainees indicate they have mastered the use of the glasses sufficiently to feel confident using glasses on their own?	18	0

Following is a list of skills blind persons may acquire. For each skill, indicate whether you think the training program with the sonic glasses can have a great, a moderate, or a small impact on helping the blind attain these skills. We are interested in what skills you feel can be taught well, moderately well, or not at all well using the sonic glasses. For each skill *circle*

- G if training with the glasses can have a great impact
- M if training with the classes can have a moderate impact
- S if training with the glasses can have a small impact

	G	M	S
58. Locating landmarks	11	8	0

		G	M	S
59.	Avoiding other pedestrians in crowded areas	6	13	1
60.	Avoiding obstacles in one's path	12	8	0
61.	Following sidewalks bordered by grass	0	0	20
62.	Locating doorways	11	7	1
63.	Guidelining (shorelining)	7	8	4
64.	Following paths with hedgerows	7	10	2
65.	Following a path along store fronts	11	8	1
66.	Following a path in hallways	7	11	2
67.	Locating a clerk in a store	6	7	7
68.	Taking one's place in a line	9	8	3
69.	Locating a seat in a restaurant	3	8	9
70.	Crossing a street in a downtown area	2	3	15
71.	Traveling in moderate pedestrian traffic	4	12	3
72.	Finding a specific store downtown	5	12	3
73.	Seeking pedestrian assistance	8	6	6
74.	Finding one's way in unfamiliar suburban areas	3	11	6
75.	Finding one's way in familiar suburban areas	4	12	4
76.	Findin			
76.	Finding one's way in familiar shopping centers	12	5	3
77.	Finding one's way in unfamiliar shopping centers	4	11	5
78.	Finding one's way in familiar rural areas	5	8	6
79.	Finding one's way in unfamiliar rural areas	2	9	8
80.	Finding up-curbs	0	2	18
81.	Assessing the distance of stationary objects	14	6	0
82.	Assessing the distance of moving objects	3	14	3
83.	Squaring off to face objects and people	11	7	2
84.	Finding one's way in large open spaces	3	1	16
	Total	9	14	4

85. Do the sounds from the glasses seem to provide a sense of security for the trainees?
    a. no 2
    b. yes, for a few 7
    c. yes, for most 11

86. Has your experience in training people in the use of the glasses suggested any changes in the recommended training technique?
    a. yes 13
    b. no 7

87. If you answered "yes" to question 86, please outline briefly the training modifications you would suggest.

88. If you wish to add anything to this questionnaire about important areas not covered, or further explanations of your experiences, please do so below.

APPENDIX 2

SONIC GLASSES EVALUATION QUESTIONNAIRE

Replies From Trainees

The purpose of this questionnaire is to obtain information about your attitude and experiences with the sonic glasses. The questions are intended to gather information about a number of areas, ranging from the training period to the device's reliability.

If you have difficulty remembering a specific fact asked for, please try to answer as best you can. You are not required to put your name on the questionnaire and all data analyses will be performed upon groups, so that no individual respondent will be identified.

(The number following each choice indicates the response.)

1. What is your age?
   - a. Under 20 — 8
   - b. 21-30 — 15
   - c. 31-40 — 14
   - d. 41-50 — 13
   - e. over 50 — 6

2. What is your sex?
   - a. male — 41
   - b. female — 15

3. At what age were you blinded?
   - a. birth — 11
   - b. 1-10 — 6
   - c. 11-20 — 12
   - d. 21-30 — 12
   - e. 31-40 — 9
   - f. after 40 — 6

4. Which of the following best describes the cause of your blindness?
   - a. diabetes — 4
   - b. congenital — 12
   - c. injury — 15
   - d. other — 25

5. Which of the following statements best describes the extent of your blindness?
   - a. I can see objects — 2
   - b. I can see shadows — 3
   - c. I can see light — 17
   - d. I am totally blind — 34

6. Which of the following statements best describes your hearing ability?
   - a. I have no difficulty hearing — 48
   - b. I have slight difficulty hearing — 8
   - c. I have moderate difficulty hearing — 0

7. What is the highest level of education that you have *completed*?
   - a. elementary school — 4
   - b. high school — 24
   - c. college — 15
   - d. Masters degree — 7
   - e. beyond a Masters degree — 6

8. Are you employed?
   - a. Yes — 35
   - b. No — 21

9. If you are employed, do you work at home or do you travel to work?
   - a. I work at home — 0
   - b. I travel to work — 30

10. If you work and if you travel to work, how do you travel?
    - a. I walk — 8
    - b. I use public transportation — 8
    - c. Someone drives me in their car — 10
    - d. Other — 0

11. If you are employed and if you travel to work, what is the distance you travel?

a.	1-5 miles	21
b.	6-10 miles	7
c.	11-15 miles	3
d.	more than 15 miles	0

12. If you are employed, please describe below the nature of your work.

13. How long ago was your last mobility training prior to your training with the sonic glasses?

a.	less than 1 year	19
b.	1-3 years	19
c.	4-7 years	15
d.	8-11 years	2
e.	12-15 years	0
f.	more than 15 years	0

14. What mobility aids have you been trained with? Enter the letters of *all* aids you have been trained with.

a.	cane	33
b.	dog	6
c.	sonic torch	0
d.	path finder	0
e.	other	1

15. What mobility aids, in addition to the sonic glasses, do you use on a fairly regular basis?

a.	cane	41
b.	dog	11
c.	sonic torch	1
d.	path finder	0
e.	other	1

16. On the average, how much time per day did you spend in travel outside your home *prior* to training with the sonic glasses?

a.	less than 1 hour	15
b.	1-2 hours	18
c.	3-4 hours	12
d.	more than 4 hours	10

17. Prior to training with the sonic glasses, what percentage of your travel time was independent travel, that is, travel without the aid of another sighted person?

a.	0-25 percent	12
b.	26-50 percent	4
c.	51-75 percent	8
d.	76-100 percent	32

18. Prior to training with the sonic glasses, what percentage of your travel was devoted to travel in unfamiliar areas?

a.	0-25 percent	37
b.	26-50 percent	9
c.	51-75 percent	6
d.	76-100 percent	2

19. Prior to training with the sonic glasses, did you often travel alone in unfamiliar areas?

a.	Yes	25
b.	No	29

20. On the average, how much time per day do you now spend in travel outside your home?

a.	less than 1 hour	11
b.	1-2 hours	24
c.	3-4 hours	11
d.	more than 4 hours	9

21. At present, what percentage of your time is spent in independent travel, that is, travel without the aid of another sighted person?

a.	0-25 percent	12
b.	26-50 percent	10
c.	51-75 percent	7
d.	76-100 percent	27

22. At present what percentage of your travel time is devoted to travel in unfamiliar areas?

a.	0-25 percent	37
b.	26-50 percent	10
c.	51-75 percent	2
d.	76-100 percent	5

23. Do you often travel alone in unfamiliar areas?

a.	Yes	23
b.	No	32

The following series of 26 items list a number of situations you have likely encountered as you have travelled about. For each situation, indicate your answer by *circling* the appropriate letter.

A If the addition of sonic glasses provides better mobility than before you used glasses

B If your mobility prior to training with the sonic glasses was better than your mobility with the sonic glasses

N If there is no difference in mobility when using glasses

E If you have never encountered the situation

	A	B	N	E
24. Locating land marks	52	1	2	1
25. Avoiding other pedestrians in crowded areas	33	4	16	2
26. Avoiding obstacles in your path	45	2	9	0
27. Following sidewalks bordered by grass	14	5	33	3
28. Locating doorways	43	2	10	0
29. Guidelining (shore-lining)	38	2	12	2
30. Following paths with hedgerows	42	0	8	5
31. Following a path along store-fronts	42	2	11	1
32. Following a path in hallways	29	8	13	6
33. Locating a clerk in a store	18	1	18	19
34. Taking your place in a line	29	2	9	16
35. Locating a seat in a restaurant	9	4	14	29
36. Crossing a street in a downtown area	32	3	17	4
37. Traveling in moderate pedestrian traffic	38	2	13	2
38. Finding a specific store downtown	22	3	18	13
39. Seeking pedestrian assistance	23	2	19	11
40. Finding your way in unfamiliar suburban areas	30	4	9	13
41. Finding your way in familiar suburban areas	35	1	15	4
42. Finding your way in familiar shopping centers	37	1	10	8
43. Finding your way in unfamiliar shopping centers	29	3	5	18
44. Finding your way in unfamiliar rural areas	16	3	3	33
45. Finding your way in familiar rural areas	17	3	6	28
46. Finding up curbs	20	5	28	2
47. Assessing the distance of stationary objects	52	2	1	1
48. Assessing the distance of moving objects	30	5	19	1
49. Squaring off to face objects and people	37	2	13	4
50. Finding your way in large open spaces	17	2	30	7

Following is a series of 18 statements about the sonic glasses. For each statement circle

- SA if you *strongly agree* with the statement
- A if you *agree* with the statement
- N if you *neither agree nor disagree* with the statement
- D if you *disagree* with the statement
- SD if you *strongly disagree* with the statement

	SA	A	N	D	SD
51. Use of the sonic glasses has reduced my travel stress in familiar residential areas	19	14	9	8	6
52. Use of the sonic glasses has reduced my travel stress in unfamiliar residential areas	15	26	9	4	2

	SA	A	N	D	SD
53. I have a better understanding of my environment since I started using the sonic glasses	27	15	5	7	2
54. My mobility has improved since I started using the sonic glasses	13	23	8	9	3
55. I can locate and identify objects more accurately since I started using the glasses	23	27	4	2	0
56. Use of the glasses has reduced my travel stress in familiar shopping areas	13	21	12	7	3
57. Use of the glasses has reduced my travel stress in unfamiliar shopping areas	8	20	22	3	2
58. The glasses are useful indoors	4	19	16	10	7
59. Since I've used the glasses, I'm more likely to travel in unfamiliar areas	8	20	12	10	5
60. The glasses are more useful in heavy pedestrian traffic areas than in uncrowded areas	5	11	20	14	6
61. The glasses have made it easier for me to locate people on the sidewalk	15	29	4	8	0
62. The glasses are an aid in determining distance	16	36	3	1	0

	SA	A	N	D	SD
63. Since my initial training, I have continued to learn more about how to use the glasses	16	25	10	4	1
64. Since training with sonic glasses, my independent travel time has increased	4	11	22	16	2
65. I usually use the glasses when I am in unfamiliar areas	8	19	13	11	2
66. The glasses are more useful in familiar than in unfamiliar areas	2	18	17	14	4
67. Since using the glasses, I find it more enjoyable traveling away from my home	13	20	11	8	2
68. I would like the glasses to have greater range	22	12	9	10	3

69. Do you use the sonic glasses primarily for determining

a. distance of objects	0
b. direction of objects	1
c. recognition of objects	2
d. distance and direction	9
e. distance and recognition	2
f. direction and recognition	3
g. all three	34

Following is a series of questions concerning your experience when using the glasses. Answer each question "yes" or "no" by *circling* the appropriate answer, according to your personal experiences with the device.

	Yes	No
70. Are the audible signals of the device easily interpreted after training?	41	14

	Yes	No
71. Do the signals from the device enable you to discriminate fairly well between different types of objects (e.g., tree vs. poles, hedge vs. fence, etc.)?	51	4
72. Do your ears often become fatigued from the audible signals?	13	41
73. Is the range of objects which the device enables you to detect adequate?	37	17
74. Does the device provide more aid in orientation or in recognition of landmarks in familiar areas than the long cane?	42	9
75. Does the device provide more aid in orientation or in recognition of landmarks in unfamiliar areas than the long cane?	38	11
76. Do the signals from the device often create confusion in orientation?	20	35
77. Does the device give reliable direct path travel information?	48	6
78. Can you readily determine the direction of objects from the audible signals while traveling at your normal walking rate?	48	6
79. Can you readily determine the size of objects from the audible signals while traveling at your normal walking rate?	25	31
80. Has the device improved your line of travel in comparison with your line of travel prior to using the device?	34	21
81. Have you increased your walking speed since using the glasses?	16	39
82. Have you reduced your walking speed since using the glasses?	8	47
83. Is your walking speed important to you?	37	17
84. Are you relaxed and comfortable using the device?	40	14
85. Do you find yourself traveling more in a wider variety of areas now that you use the device?	15	41
86. Do you feel you've mastered the use of the device sufficiently to feel confident with the device?	40	15
87. Do you like the signals to be loud?	19	36

Now we should like to inquire about the training program you underwent to familiarize you with the sonic glasses and their use. First, we should like some general background information.

88. What agency provided you with your training?

89. In what city and state did your training take place?

90. Please give the approximate starting and concluding dates of your training.
Starting date ____________________
Concluding date ____________________

91. About how many hours per day did you have *supervised* training?

a. less than 1 hour	1
b. 1 hour	23
c. 2-3 hours	24
d. 4-5 hours	7
e. more than 5 hours	1

92. On how many days per week were you given training?
a. less than 2 days 2
b. 3-4 days 9
c. more than 4 days 45

93. Which of the following options best describes the period in training when you were first provided with your own personal device?
a. at the start of training 37
b. about 1/3 of the way through training 6
c. about 1/2 way through training 4
d. about 2/3 of the way through training 5
e. after training 3

94. How many hours per day did you devote to practicing, on your own, the training lessons?
a. less than one hour 18
b. one hour 18
c. two hours 15
d. three hours 3
e. more than three hours 2

95. What percentage of your training was devoted to indoor travel exercises?
a. 0-10 percent 24
b. 11-20 percent 15
c. 21-30 percent 5
d. more than 30 percent 12

96. At the time of training, did you feel the pole exercises were irrelevant?
a. yes 8
b. no 48

97. In retrospect, do you now see the value of the pole exercises?
a. yes 55
b. no 1

98. If you were to recommend procedures to train additional people in the use of the device, would you suggest that more time be devoted to pole exercises?
a. yes 13
b. no 42

99. How many days did you have to train and practice before you understood the pitch/distance relationship?
a. 1-2 days 35
b. 3-7 days 18
c. 8-14 days 3
d. 15-21 days 0
e. more than 21 days 0

100. How many days after you understood the pitch/distance relationship did you have to train and practice before you could use it in traveling?
a. 1-2 days 21
b. 3-7 days 28
c. 8-14 days 6
d. 15-21 days 1
e. more than 21 days 0

101. How many days did you have to train and practice before you understood the left-right direction cue?
a. 1-2 days 31
b. 3-7 days 21
c. 8-14 days 4
d. 15-21 days 0
e. more than 21 days 0

102. How many days after you understood the left-right direction cue did you have to train and practice before you could use it in traveling?
a. 1-2 days 27
b. 3-7 days 23
c. 8-14 days 4
d. 15-21 days 1
e. more than 21 days 1

103. How long after you learned to use the pitch/distance relationship and right-left cues did it take you to locate objects around you?
a. 1-2 days 30
b. 3-7 days 17
c. 8-14 days 6
d. 15-21 days 2
e. more than 21 days 0

104. Did you experience confusion from the sounds early in your training?
a. no, not at all 8
b. yes, a little 21
c. yes, a moderate amount 23
d. yes, a great deal 4

If you answered the previous item "yes," please answer the following 4 questions. If you answered "no" to the previous item, omit the following 4 questions.

105. Was the confusion from the sound disturbing?
a. yes, a little 26
b. yes, a great deal 6
c. no 17

106. Were steps taken by your instructor to explain the sounds in confusing situations?
a. always 41
b. sometimes 6
c. never 1

107. Did the instructor monitor the sounds?
a. always 12
b. sometimes 27
c. never 9

108. Did it help to have the instructor monitor the sounds you were hearing?
a. yes 36
b. no 5

109. When in training did you notice a reduction in your confusion at incoming signals?
a. within 2 days of the initial confusion 18
b. from 2 to 5 days of the initial confusion 17
c. from 6 to 9 days of the initial confusion 10
d. from 10 to 14 days of the initial confusion 4
e. more than 14 days after the initial confusion 1

110. Does the sound from the glasses give you a sense of security?
a. no 15
b. yes, a little 15
c. yes, a moderate amount 17
d. yes, a great deal 9

111. Did you feel you advanced through the lessons as quickly as it was possible for you?
a. yes 48
b. no 8

112. Did your training enable you to reach a level of proficiency at which you could continue to learn about the glasses on your own?
a. yes 54
b. no 2

113. Would you have liked to continue training for a longer period?
a. no 30
b. yes, for another week 10
c. yes, for another two weeks 6
d. yes, for another month 10

114. Do you feel you've regressed in your ability to use sonic glasses effectively since you concluded training?
a. no 40
b. yes, a little 8
c. yes, a moderate amount 6
d. yes, a great deal 2

115. At what stage in your training were you able to pay equal attention to your cane and the glasses?
a. at the start of training 8
b. about 1/3 of the way through training 14
c. about 1/2 way through training 16
d. about 2/3 of the way through training 6
e. never 2

116. At what stage in the travel lessons did you begin to experience benefit from the glasses?
a. at the start of training 23
b. about 1/3 of the way through training 16
c. about 1/2 way through training 9
d. about 2/3 of the way through training 5
e. never 3

117. Did training emphasize interpreting the "language" of the glasses?
a. yes 52
b. no 4

The following 10 questions ask for your overall impression of your training experience and your perceptions of the necessity for training in the use of the glasses. Answer each question by *circling* the appropriate choice, "yes" for agreement with the statement, "no" for disagreement.

	Yes	No
118. Generally speaking, was the training you received adequate?	52	4
119. Was the training period too long?	6	50
120. Should there have been more training?	25	31

	Yes	No
121. Did you benefit from the training?	52	3
122. Do you think that training is essential to being able to use the glasses effectively?	51	5
123. Do you think that many people could train themselves in the use of the sonic glasses without the aid of an instructor?	5	51
124. Did you find learning to use the glasses simple?	29	29
125. Did your glasses malfunction during training?	24	32
126. Did you have a spare set of glasses available to enable you to continue training if your initial device malfunctioned?	34	18
127. Would you recommend that spare glasses be available to all trainees?	48	7

If your initial set of glasses broke down during training *and* if you had a spare set available to continue training, please answer the following five questions. If your glasses did not break down or if you had no spare set available, omit the following five questions and go directly to question 133. *Circle* the choice which most accurately describes whether you found the spare glasses different or the same as your initial device with respect to:

	Same	Different
128. Frame size	8	11
129. Pulse rate	14	5
130. Quality of sound	11	8
131. Direction cue change	14	4
132. Distance cue change	16	3

133. Do you think additional training in your primary mobility aid (e.g., dog, cane), would have helped your mobility more, as much, or less than training with glasses?
- a. more 11
- b. as much 11
- c. less than 24

Below are some questions about the reliability and appearance of the sonic glasses.

134. In general, how satisfied are you with the glasses' reliability now?
- a. very satisfied 16
- b. satisfied 30
- c. unsatisfied 6
- d. very unsatisfied 3

135. Are the glasses reasonably maintenance-free now?
- a. yes 42
- b. no 11

Following is a list of difficulties and inconveniences one might experience while using the sonic glasses. Please *circle* for each statement, whether you have had no problem in that area, minor problems in that area, or major problems in that area.

	No	Minor	Major
136. Earmolds difficult to insert	39	13	4
137. Glasses awkward to put on and take off	28	23	5
138. Cable too long	32	17	7
139. Cable too stiff	27	18	11
140. Control box difficult to carry	26	17	12
141. Switches difficult to get at	40	10	5
142. Volume control range inadequate	45	9	1
143. Glasses too noisy	44	9	1
144. High-low gain switch ineffective	50	4	1

	No	Minor	Major
145. Battery catch difficult	47	6	1
146. Glasses too heavy on bridge of nose	19	24	12
147. Glasses hurt side of head	44	9	3
148. Glasses hurt behind ears	41	13	2
149. Device too bulky	14	20	22
150. Friends tell me glasses are ugly	35	11	10
151. Glasses interfere with mobility	44	8	4

152. In general, do you think the glasses are adequate in their present form?
   a. yes 34
   b. no 22

The final section of this questionnaire is concerned with your general attitudes about the sonic glasses. Below is a series of statements. For each statement circle
- SA if you *strongly agree* with the statement
- A if you *agree* with the statement
- N if you have *no opinion* about the statement
- D if you *disagree* with the statement
- SD if you *strongly disagree* with the statement

	SA	A	N	D	SD
153. After using the glasses, my attitude is favorable toward them	30	16	2	2	2
154. I would like to keep the glasses	35	13	3	3	1
155. The benefits of the glasses make it worth the trouble of training	33	10	5	6	1
156. I find the concept of using sound to aid mobility useful	28	21	2	3	1
157. The benefits of the glasses justify the inconvenience of training	27	18	2	6	2
158. In general, things seem better for me since I've used the glasses	17	14	12	8	4

	No	Minor	Major		
159. My friends and family are positive about my mobility using the glasses	16	19	12	6	2
160. I would recommend the glasses to another blind person	21	23	7	2	1
161. I was very motivated to learn how to use the sonic glasses	28	23	4	0	0
162. The glasses could be used to motivate mobility in blind persons where motivation is lacking	13	18	13	4	7

For the following five categories, indicate those characteristics of potential trainees which would make training successful. *Circle* your choice.

163.	young persons	9
	middle age persons	18
	old persons	1
	all equally	17
164.	highly motivated persons	18
	motivated persons	3
	unmotivated persons	0
	all equally	21
165.	smart persons	17
	average persons	19
	not-too-smart persons	0
	all equally	7
166.	males	6
	females	0
	both equally	50

167. Do you still have the glasses?
   a. No, I have returned them 5
   b. Yes, I plan to keep them 43
   c. Yes, but I have not yet decided whether to keep them 7

168. What improvements in the glasses would you most like to see? List 4.

169. Please feel free to add additional comments about the sonic glasses, your attitude towards the glasses, or your training experiences which you feel would better enable us to assess the adequacy of the glasses and the training period.

EVALUATION OF THE BINAURAL SENSORY AID

Peter W. Airasian*

INTRODUCTION

This report summarizes the results of an evaluation of the Binaural Sensory Aid (Sonic Glasses) training project. The evaluation was conducted in the Spring and early Summer of 1972. Data were gathered by means of questionnaires mailed to both trainers and trainees in the project. Information was gathered about the following areas: characteristics of the respondents, training practices and experiences, mobility skills before and after training, mechanical adequacy of the device, and attitudes toward training and the use of the device. This report treats the results of the trainer and trainee questionnaires separately and respectively.

Limitations of Survey Data

Before presenting the data, a brief note is in order concerning the limitations of survey data. The validity, generalizability, and accuracy of the data produced by a survey or mailed questionnaire is dependent upon the design of the measuring instrument. However even with the most carefully designed surveys, caveats are in order. There are, in other words, limitations and special characteristics to be kept in mind while reading survey results.

Surveys describe the values, attitudes, opinions and recollections of the respondents at the time of their completing the questionnaire. Responses are a result of the respondents' individual understanding of the questions and their direct or vicarious experiences with the issues involved. From one attitudinal survey one cannot assume how the same respondents would react to the same set of questions at a later point in time. Nor can one assume that they would react similarly to a question addressed to the same issue but worded slightly differently. In short, then, the findings must be tempered with a consideration of the point in time of the survey, the wording of the questions, and the knowledge and experience of the respondents.

Another caution is that statistical summaries of responses to various items or groups of items can be deceiving if they are thought of only in terms of a majority or plurality. "Only twenty percent. . ." may be a considerable number of people. More important, the characteristics of 20 percent might be such that their opinions should receive as much weight or more than the majority 80 percent in arriving at a policy decision. In other words, the responses to this type of survey are *not* meant to be treated as votes with the option receiving the largest percent "winning." The data presented should be taken as descriptions and not directions.

Further, there are certain specific limitations to the mailed questionnaire survey technique. Despite its relative economy (interviewing each trainer and trainee would have been prohibitively expensive) and the wide range of questions it permits, the technique is subject to a variety of inherent limitations. A primary difficulty is the problem of nonreturns. One can never be certain whether subjects fail to return questionnaires because they simply are not motivated to do so, because they are pessimistic about the device or program being evaluated,

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or for some other reason. Usually, after a two- to four-week time lapse, a follow-up letter is sent to all subjects urging them to respond if they have not already done so. While this procedure was not carried out in this evaluation (due to time and distance constraints), even when it is carried out, one rarely can expect to obtain complete instruments from 100 percent of the subjects and the problem of reasons for nonreturns, though somewhat alleviated, remains nonetheless. As a consequence, one is forced to assume that the responses of those who do return the instrument are representative of the nonreturnees. To encourage honesty to the responses and to assuage potential fears that responses might somehow be used against respondents, both trainers and trainees in this evaluation completed their questionnaires anonymously and returned the completed questionnaire to the author, not to the project officers. It should be noted that in this evaluation the rate of returns from both trainers and trainees exceeded the usual or expected return rate of 70 percent.

Finally, most surveys cannot provide answers to "why-type" questions. The results of this evaluation, for example, represent a description of trainer and trainee attitudes, opinions and recollections. Why trainees or trainers feel the way they do, why differences in perceptions exist between and within groups of respondents, or why various anomalies appear in reactions to specific items are questions beyond the scope of this evaluation. It is crucial in interpreting the data to be presented that the distinctions between description and explanation be kept in mind. Undoubtedly numerous reasons can be advanced to explain particular findings. However, to verify which explanation is accurate requires investigation beyond that contained in this evaluation.

TRAINER RESULTS

This section of the paper summarizes the results of a questionnaire mailed to instructors of the sonic glasses. The questionnaire was intended to gather data about the background characteristics of the instructors (number of years experience in mobility training, number of students trained, etc.), the attitudes of the instructors toward the glasses, the difficulties encountered during training, and the particular skills the glasses seemed best suited to developing in the mobile blind. Twenty-five questionnaires were mailed to instructors and twenty-one were returned. This report includes the responses of only twenty instructors, since the questionnaire of the twenty-first was received too late to be included in the data analysis. The data will be presented in four sections dealing with:

1. General attitudes toward the device and training;
2. Mechanical and design adequacy observations;
3. Ratings of skill for which the device is useful and not useful;
4. Observations on the training program.

Although the data were broken down by various strata (e.g., experience of trainers, location of training, and so on) in the report submitted to the project director, this paper will treat only the overall unstratified results.

General Trainer Attitudes

Throughout the questionnaire were a series of items which asked, in a general way, for responses about the usefulness of the glasses, the adequacy of the concept on which the glasses are based, and so on. A view of responses to these questions provides an index of the overall satisfaction of the instructors with the device. As will be seen in later sections, there were difficulties and problems with the device and the training program. However, this section is concerned only with items which can be taken as providing a general description of the trainers' satisfaction with the device.

Of the 20 respondents, 19 (95 percent) indicated that they wished to continue teaching the glasses. Seventeen of these 19 wished to do so on a part-time basis. Although the vast majority wished to continue teaching, there was some disagreement on the size of the totally-blind mobile population for whom the glasses would be beneficial. Ten of the respondents (50 percent) indicated the glasses would be beneficial to only a small segment of the totally blind mobile population, while seven (35 percent) indicated the glasses would benefit a medium sized segment. Only three trainers (15 percent) suggested the glasses would be useful for a large segment of the totally-blind mobile population. Respondents were afforded an opportunity to identify characteristics of people who learn best with the glasses. Those trainers who indicated that the glasses would be beneficial to a medium or small segment of the mobile-blind population most often mentioned high motivation to learn, good auditory capacity, well developed independent travelling skills and interest, and at least average intelligence as those characteristics which were required if training was to succeed. Motivation was the primary factor mentioned and the implication was that better than average motivation was a prime requisite to a trainee's success in mastering the glasses.

All 20 of the respondents (100 percent) agreed that based upon their experience thus far, the concept on which the glasses are based, that is, the form of coded sound, is useful. Thirteen (65 percent) of the trainers agreed that the number of blind persons being trained in the glasses should be increased, while six (30 percent) were neutral on this question, and one (5 percent) disagreed that more blind should be trained. Similarly, there was spread among the trainers concerning whether more Orientation and Mobility instructors should be trained to teach the glasses. Eleven (55 percent) agreed that more instructors should be trained, five (25 percent) were undecided, and three (15 percent) disagreed. It is likely that the relative newness of the training program and the short periods many instructors have worked with the glasses contributes to the sizable percentage in the "undecided" category of these questions. However, when asked whether their attitude towards the glasses was favorable, eighteen trainers (90 percent) agreed that it was, while two (10 percent) were undecided. No one was unfavorable towards the glasses. Eighteen of 20 respondents (90 percent) agreed that the benefits of the glasses justify the training period. The remaining two respondents were undecided on this item.

On the matter of the trainer's preparation for training the blind in the use of the glasses, twelve (60 percent) respondents agreed that their preparation was adequate. However, five trainers (25 percent) disagreed with the statement that their training was adequate and three (15 percent) were undecided regarding their preparation. The majority of respondents, fourteen (70 percent) indicated that they would have liked more preparation, while three respondents (15 percent) were undecided and three (15 percent) did not desire more training. It is interesting to note that while 60 percent of the respondents claimed to have had adequate preparation for training, 70 percent would have liked additional training.

If general trainee enthusiasm as perceived by the trainers is an index of general satisfaction, it is important to note that 13 of the 20 respondents (65 percent) agreed with the statement "Trainees comment enthusiastically about the glasses often." Four trainers (20 percent) neither agreed nor disagreed with this statement and three (15 percent) disagreed.

Two items asked the trainers to comment upon the usefulness of the glasses as an orienting aid as compared to the long cane in familiar settings and unfamiliar settings. Of the eighteen trainers who responded concerning familiar settings, seventeen (94 percent) indicated that the glasses provide more aid in orientation in familiar settings than the long cane. (On a few items, some respondents did not select any option. As a consequence, the total number of respondents does not always equal 20, and percentages change accordingly.) Fourteen of the seventeen (82 percent) who responded concerning unfamiliar settings stated that the glasses provided more aid in orientation than the long cane. In addition to perceived benefits over the long cane, instructors were unanimous in agreeing that toward the end of training most trainees are relaxed and comfortable using the glasses and that after training most trainees feel confident in using the glasses on their own.

In general, trainers believe that the glasses can be beneficial to the mobile-blind population, although there was some disagreement on the size of the segment of the blind population for whom the glasses would be beneficial. The vast majority felt that the glasses would be more useful to a small (50 percent) or medium (35 percent) segment of the mobile-blind population. Motivation, good auditory capacity, intelligence, and developed independent travelling skills and interest were most often mentioned as prerequisites for successful trainees. Most trainers would like additional training, but in spite of this felt need, 90 percent expressed favorable attitudes toward the glasses and 90 percent agreed that the benefits of the glasses justify the training period. Nineteen of the twenty respondents wished to continue teaching the use of the glasses. Overall, with a few misgivings, the trainers seemed to express positive attitudes toward the glasses, their benefits, and the training program.

Mechanical and Design Adequacy

Trainers were asked to rate a series of situations which might have occurred during training. For each item trainers were asked to respond in one of the following four categories:

1. The situation was not encountered during training
2. The situation was encountered but caused only minimal inconvenience
3. The situation was encountered and caused moderate inconvenience
4. The situation was encountered and caused severe inconvenience.

This section of the report outlines trainers' responses to items concerned with the device's mechanical and design adequacy.

Based upon the results shown in Table 1, it appears that trainers encountered some difficulties with the mechanical and design features of the glasses. The only difficulties which caused severe inconvenience during training related to the device breaking down (25 percent of the respondents) and the monitor cable being in the way (15 percent of the respondents). In general, between 60 percent and 90 percent of all trainers reported no or only slight inconvenience for all items except "monitoring caused static in client's aid" and "monitor cable got in the way"; where 50 percent and 35 percent respectively reported no or slight inconvenience. In the light of the findings presented in Table 1, it is interesting to note that twelve respondents (60 percent) agreed when asked whether trainees should be fitted with a backup set of glasses. Two trainers (10 percent) were undecided and six (30 percent) disagreed on the question.

Ratings of Skills for Which the Device is Useful

The trainers were given a list of skills blind persons might acquire in mobility training. For each skill the trainers were asked to indicate whether the sonic glasses could have a great, moderate, or small impact on helping the mobile blind person to acquire the skill. The items were intended to determine which skills the instructors thought could be taught well, moderately well, or not at all via the device. Table 2 summarizes the responses to these items.

The glasses were judged to have a moderate or great impact on training a wide variety of skills. For those skills or situations where auditory cues were likely to be lacking (following sidewalks bordered by grass, finding up curbs, finding one's way in large open spaces), the device can have little impact on learning new skills. This finding is, of course, expected given the nature of the device.

TABLE 1

Trainer Responses to Mechanical and Design Situations

Situation	Never Occurred	Minimal Inconvenience	Moderate Inconvenience	Severe Inconvenience
Cable caught on objects	10 (50%)	5 (25%)	5 (25%)	0 (0%)
Device broke down during lessons	6 (30%)	6 (30%)	3 (15%)	5 (25)
Ear fittings were uncomfortable	7 (37%)	7 (37%)	5 (26%)	0 (0%)
Ear tubes fell out	13 (68%)	4 (22%)	1 (5%)	1 (5%)
Ear fittings occluded ambient sounds	12 (63%)	5 (26%)	2 (11%)	0 (0%)
Lesson time spent checking device for malfunctions	7 (35%)	11 (55%)	2 (10%)	0 (0%)
Monitoring caused static in client's aid	4 (20%)	6 (30%)	9 (45%)	1 (5%)
Monitor cable got in the way	2 (10%)	5 (25%)	10 (50%)	3 (15%)

What is perhaps the most important, yet anomalous, finding from these series of questions is the wide variance among trainers in their perceptions of the usefulness of the device in training for a given skill. One does not expect unanimity across response categories in an instrument such as the questionnaire, but one does anticipate responses tending in one direction or the other. For numerous items (e.g., locating a clerk in a store, seeking pedestrian assistance, etc.) responses are split almost evenly among the response options. Even in cases where the majority of respondents indicate a given response or direction of response, there usually is a sizable minority who tend to respond in the opposite direction (e.g., guidelining, finding a specific store downtown, locating a seat in a restaurant, etc.).

One can only speculate regarding the reasons for the apparent variance in response across trainers. Perhaps many of the skills and situations had been encountered by only a portion of the instructors. Perhaps the newness of the training programs themselves have not permitted the full range of potential uses to emerge for all instructors. Perhaps also there is sizable variance in the training of trainers programs or the various training programs themselves--or both--which contributes to the disparity evidenced on these items. It is clear that some instructors perceive a wider range of usefulness for the glasses than others, despite the fact that most instructors claim the glasses can have a moderate or great impact on skill training in most of the areas examined.

Observations on the Training Program

The final area of the questionnaire concerned the perceptions and experiences of the trainers during training. As has been indicated in the section on General Attitudes, 95 percent of the trainers wish to

TABLE 2

Ratings of Usefulness of Device on Training in Various Skills

Skills	Small Impact	Moderate Impact	Great Impact
Locating landmarks	0(0%)	8(42.11%)	11(57.89%)
Avoiding pedestrians in crowded areas	1(5%)	13(65%)	6(30%)
Avoiding obstacles in one's path	0(0%)	8(40%)	12(60%)
Following sidewalks bordered by grass	20(100%)	0(0%)	0(0%)
Locating doorways	1(5.26%)	7(36.84%)	11(57.89%)
Guidelining (shorelining)	4(21.05%)	8(42.11%)	7(36.84%)
Following paths with hedgerows	2(10.53%)	10(52.63%)	7(36.84%)
Following a path along storefronts	1(5%)	8(40%)	11(55%)
Following a path in hallways	2(10%)	11(55%)	7(35%)
Locating a clerk in a store	7(35%)	7(35%)	6(30%)
Taking one's place in a line	3(15%)	8(40%)	9(45%)
Locating a seat in a restaurant	9(45%)	8(40%)	3(15%)
Crossing a street in a downtown area	15(75%)	3(15%)	2(10%)
Travelling in moderate pedestrian traffic	3(15.79%)	12(63.16%)	4(21.05%)
Finding a specific store downtown	3(15%)	12(60%)	5(25%)
Seeking pedestrian assistance	6(30%)	6(30%)	8(40%)
Finding one's way in unfamiliar suburban areas	6(30%)	11(55%)	3(15%)
Finding one's way in familiar suburban areas	4(20%)	12(60%)	4(20%)
Finding one's way in familiar shopping centers	3(15%)	5(25%)	12(60%)
Finding one's way in unfamiliar shopping centers	5(25%)	11(55%)	4(20%)
Finding one's way in familiar rural areas	6(31.58%)	8(42.11%)	5(26.32%)
Finding one's way in unfamiliar rural areas	8(42.11%)	9(47.37%)	2(10.53%)
Finding up-curbs	18(90%)	2(10%)	0(0%)
Assessing the distance of stationary objects	0(0%)	6(30%)	14(70%)
Assessing the distance of moving objects	3(15%)	14(70%)	3(15%)
Squaring off to face objects and people	2(10%)	7(35%)	11(55%)
Finding one's way in large open spaces	16(80%)	1(5%)	3(15%)

continue teaching the device. Of this percentage, the vast majority, 17 of 19, prefer to continue teaching the device on a part-time basis. The majority of the instructors felt that the training program requires between 41 and 60 hours for completion (12 respondents, 60 percent). Four respondents (20 percent) thought less time was required, and four (20 percent) thought more time was needed for adequate training).

A series of statements were provided and respondents asked to agree or disagree in terms of their training experiences. Twelve respondents (60 percent) agreed that each trainee should be fitted with a backup set of glasses, while six (30 percent) disagreed, and two (10 percent) were undecided. The majority of respondents agreed that the clients they had trained were highly motivated to learn the device (N = 15, Percent = 79). Only one trainer disagreed that his clients were highly motivated. It is perhaps this experience on the part of the vast majority of instructors which makes them suggest the importance of motivation as a prerequisite for successful training.

It appeared that instructors agreed that for training to be successful the student had to practice a great deal on his own (70 percent agreed, 30 percent undecided, 0 percent disagreed). There was sizable disagreement (N = 12, Percent = 63) that the blind person's mobility could have been increased as much by additional training in their primary mobility aid. Four instructors (21 percent) agreed with the statement and three (16 percent) were undecided. It appears from this item--taken with the data presented in the prior section--that the glasses do have a unique contribution to make to increasing the blind person's mobility. Further, the trainers were unanimous in their disagreement that the students could learn to use the glasses without formal training. In fact, 17 of the 20 respondents who disagree with this item expressed strong disagreement. About 85 percent of the trainers (16) indicated the need for more follow-up of students after training.

Fourteen of the twenty respondents (70 percent) indicated that their students had learned completely new skills as a result of training with the glasses. Among the most common new skills mentioned were: locating teller's window in a bank, finding empty restuarant seats, and taking place in a line. One trainer mentioned that a client used the glasses during jogging to follow a sighted jogger.

In the same manner that information about the mechanical and design suitability of the glasses was obtained, information about the training program was obtained. That is, a series of situations were presented and the instructors were asked to indicate whether the situation caused minimal, moderate, severe, or no inconvenience during training. Table 3 presents the results of these items.

Few of the situations outlined in Table 3 presented severe inconvenience to the instructor except the glasses not being ready on time and the glasses breaking down during lessons. In each case, five respondents (25 percent) indicated severe inconvenience arising from these difficulties. The other items in this table provide some insight into what parameters might be considered in establishing a training program to facilitate the convenience of the instructors.

An additional set of training items asked the instructors to respond "yes" or "no" to some questions according to their perceptions and experiences. Table 4 provides the results of these questions.

In viewing the data presented in Table 4, it seems clear that most instructors agree that the signals from the device are easily interpreted, help trainees discriminate between objects, have an adequate range to facilitate mobility, give reliable information, and provide better orientation than the long cane in both familiar and unfamiliar settings. Further, after training, most trainees are relaxed, comfortable and able to use the glasses on their own. If there

TABLE 3

Ratings of Inconvenience Associated with Various Situations in Training Program

Situation	Never Occurred	Minimal Inconvenience	Moderate Inconvenience	Severe Inconvenience
Other responsibilities made it difficult to organize the training program	4(20)	11(55%)	4(20%)	1(5%)
Exercise poles not ready on time	13(65%)	3(15%)	3(15%)	1(5%)
Transportation problems occurred	15(75%)	2(10%)	3(15%)	0(0%)
The glasses were not available on schedule	8(42%)	2(11%)	4(21%)	5(26%)
Too much organizational planning was left to the instructor	8(40%)	9(45%)	2(10%)	1(5%)
The device broke down during lessons	6(30%)	6(30%)	3(15%)	5(25%)

are any problems, they relate to fatigue related to the audible signals and some confusion in orientation associated with the signals.

Finally, instructors were asked whether they could suggest changes in the recommended training technique. Thirteen (65 percent) said they could, while seven (35 percent) said they could not. The most frequently mentioned suggested change concerned relating training and the pole exercises to the real environments more often than is currently done. Many of the instructors expressed the need for tying training and the pole exercises more closely to the real environment trainees will encounter. Other suggestions included: more indoor work, training for pitch/distance and azimuth, more independent exercises, and affording trainees a general familiarity with the device signals prior to training.

<u>Summary</u>

If one views the four areas outlined in this report seeking an overall general perception of the trainers to the device and the training program, one should be encouraged. Within the context of the limitations of survey research detailed at the start of this report and recognizing the relative newness of the training programs in numerous centers and the small number of trainees who have completed training under some of the instructors who responded to the questionnaire, it is clear that the concept on which the glasses are based is deemed beneficial by most instructors. Eighty-five percent thought the glasses would be beneficial to either a small (50 percent) or medium-sized (35 percent) segment of the mobile blind population. General attitudes were, on the whole, favorable and there is

TABLE 4

Responses to Questions Concerning Trainees' Attitudes Toward the Signals from the Glasses

Question	Yes	No
Are the audible signals easily interpreted by the trainees?	14(82.35%)	3(17.65%)
Do the signals enable the trainees to discriminate between different types of objects (e.g. tree vs. pole, hedge vs. fence, etc.)?	15(78.95%)	4(21.05%)
Do trainees often become fatigued from the audible signals?	12(63.16%)	7(36.84%)
Is the range of objects which the glasses enable trainees to detect adequate for mobility?	17(89.47%)	2(10.53%)
Do the glasses provide more aid in orientation than the long cane in familiar settings?	18(94.44%)	5(5.56%)
Do the glasses provide more aid in orientation than the long cane in unfamiliar settings?	14(82.35%)	3(17.65%)
Do the signals from the glasses often create confusion in orientation?	6(31.58%)	13(68.42%)
Do the glasses give reliable information on objects in the line of travel?	17(94.44%)	1(5.56%)
Can trainees determine direction of objects from audible signals while travelling at their normal rate after training?	18(100%)	0(0%)
Toward the end of training are most trainees relaxed and comfortable with the glasses?	19(100%)	0(0%)
After training, do most trainees indicate they have mastered the use of the glasses sufficiently to use the glasses on their own?	18(100%)	0(0%)

a desire on the part of the vast majority of instructors to continue training, at least on a part-time basis. Instructors do generally feel that, although their training was adequate, more training would be desirable.

Mechanically the device seemed adequate, although there was some inconvenience caused by malfunctions during training and by the monitor cable. Monitoring also caused static in clients' aids.

The device was judged to have moderate or great potential in training the mobile blind in the series of skills included on the questionnaire. In the eyes of the instructors, there appear to be unique skills and abilities which the device can foster. It must be noted, however, that there was sizable disagreement on the part of the instructors regarding the potential impact the device could have on training certain skills. This disagreement may be attributed to the newness of the training programs, the fact that some instructors had not encountered some of the skills mentioned, or differences in training locations and surrounding environs. The device was judged to provide more aid to mobility than the long cane in both familiar and unfamiliar settings.

Questions about the training program itself indicated that there might be a need for a set of backup glasses for each trainee. Training seemed to progress well, a fact which can be attributed both to the skill of the instructors and the indicated high motivation of the clients. Trainees seemed to acquire a series of new skills concomitant to their training (e.g., finding teller's window, lining up, etc.). Administratively, instructors seemed to be somewhat inconvenienced by the press of organizational duties. The signals from the glasses were judged easily interpretable by trainees, adequate to discriminate between objects, adequate in the range of objects they enabled trainees to detect, and reliable in the information they provided to the trainee. Aside from what were indicated to be relatively minor inconveniences by the group, the trainers suggest changes in training procedures which would tie training and/or the pole exercises more closely to the real environments the trainees would be likely to encounter.

TRAINEE RESULTS

Questionnaires were mailed to 94 trainees. Seventy-four of 94 questionnaires have been returned (38 from the United States, 15 from England, 15 from Australia, and 6 from New Zealand). These 74 questionnaires are included in the data analysis. Thus, about 79 percent of the questionnaires were returned at the time of writing.

The trainee questionnaire surveyed a number of characteristics including general trainee background information, travel habits before and after training with the glasses, mobility before and after training, uses of the glasses, adequacy of the glasses' range and signals, training experiences and attitudes, design difficulties and inconveniences, and overall attitudes toward the glasses. These sections will be treated respectively in the body of the evaluation report. The report itself treats the responses of all 74 respondents *not* broken down by various strata (e.g., country, prior mobility training, age, etc.). Although such analyses were performed, they are beyond the scope of this general discussion.

Trainee Background Characteristics

The trainees are of varying ages (13.51 percent under 20; 32.43 percent between 21 and 30; 24.32 percent between 31 and 40; 21.62 percent between 40 and 50; and 8.11 percent over 50). Over 70 percent of the trainees are male (74.32 percent) compared to 25.68 percent females. About three-quarters of the trainees were blinded before the age of 30, with approximately 20 percent of the total sample reporting being blind at birth. Regarding causes of blindness, the breakdown is 5.41 percent diabetes, 25.68 percent congenital causes, 27.03 percent injury, and 41.89 percent other. Over 90 percent of the sample is either totally blind

(57.53 percent) or can see only light (32.88 percent). Given the nature of the sonic glasses, hearing ability is an important variable among the trainees. Eighty-six percent report no hearing difficulty while 12 percent indicate only slight hearing problems.

Trainees were spread across levels of education. Broken down by the highest level of education attained, the trainees distributed thusly: elementary 5.48 percent, high school 39.73 percent, college 32.88 percent, masters degree 13.70 percent, and higher than masters degree 8.22 percent. Forty-nine of the trainees (66.22 percent) are employed).

Of the employed trainees, 43 report travelling to their place of employment. Thirty-eight percent of these have someone drive them to work, 35 percent take public transportation, and 27 percent walk. The majority (59.09 percent) travel a distance of from one to five miles to work. Twenty-three percent travel six to ten miles and the remainder of the employed trainees who travel to work travel eleven to fifteen miles.

The final questions in this section of the instrument asked about prior mobility training. About one-third of the trainees had their last mobility training less than a year before training with the sonic glasses. Slightly over another third (38.36 percent) had their last training one to three years prior. Twenty-three percent report their last training four to seven years prior to the sonic glasses training and about four percent indicate that their last mobility training was eight to eleven years prior. Seventy-four percent of the trainees use a cane as a mobility aid on a fairly regular basis, while 23 percent use a dog. The remaining three percent (two people) use either a sonic torch or some other aid.

Travel Habits Before and After Training

A series of questions regarding travel habits prior to and after completion of the sonic glasses training period were included on the questionnaire. Table 5 presents the results of the comparison. There is seen to be essentially no difference between travel habits before and after training with the device. The trainees do not tend to alter the time spent travelling outside their homes, their amount of independent travel, or their frequency of travel in unfamiliar areas. Given the sampling error associated with the questionnaire, the before and after training results presented in Table 5 can be considered virtually identical.

Glasses Aid to Mobility in Various Situations

While the data in the prior section reveal no differences in time of travel before and after the training period, the data in this section reveal that the glasses are rated very favorably as a mobility aid. Thus, while travel time is not increased by training, the glasses do appear to make mobility easier.

Trainees were presented with 27 situations and asked to respond to each by selecting one of four response categories:

1. If the sonic glasses provide better mobility than before the glasses were used,

2. If mobility prior to training is better than mobility after training,

3. If there is no difference in mobility before and after training,

4. If the situation has never been encountered.

Table 6 gives the results of the analysis. To a greater or lesser extent, mobility is judged the same or better after the glasses than before by the overwhelming proportion of the trainees. On most of the items mobility after the glasses is clearly perceived to be superior to mobility prior to use of the glasses.

Three-quarters or better of the respondents rate their mobility better with the glasses in such

TABLE 5

Comparison of Travel Habits Before and After Sonic Glasses Training

Item		
How much time per day did you spend travelling outside your home?		
4 hours	16.44%(12)	16.44%(12)
3-4 hours	20.55%(15)	21.92%(16)
1-2 hours	39.73%(29)	45.21%(33)
1 hour	23.29%(17)	16.44%(12)
What percentage of your travel time is occupied in independent travel?		
76-100%	54.79%(40)	50.00%(37)
51-75%	16.44%(12)	14.86%(11)
26-50%	6.85%(5)	16.22%(12)
0-25%	21.92%(16)	18.92%(14)
What percentage of your time do you devote to travel in unfamiliar areas?		
76-100%	2.82%(2)	8.33%(6)
51-75%	8.45%(6)	4.17%(3)
26-50%	19.72%(14)	22.22%(16)
0-25%	69.01%(49)	65.28%(47)
Do you often travel alone in unfamiliar areas?		
Yes	45.83%(33)	45.21%(33)
No	54.17%(39)	54.79%(40)

situations as: locating landmarks (94.44 percent) indicate better mobility with the glasses; avoiding obstacles in their path (81.69 percent); locating doorways (78.87 percent); following a path along storefronts (73.61 percent); following a path with hedgerows (77.46 percent); and assessing the distance of stationary objects (91.67 percent). In no situation was mobility judged to be better before the glasses than after. In fact, on only two items (following a path with hedgerows and a path in hallways) did more than 10 percent of the trainees indicate better mobility before using the glasses. Table 6 also reveals that in a few situations such as following sidewalks bordered by grass, locating a clerk in a store, finding a seat in a restaurant, finding up-curbs, and finding one's way in large open spaces, the plurality of respondents indicate no difference before and after training. However, it should be noted that in those situations not obviously limiting because of the lack of feedback from the glasses, a sizable proportion of the respondents specify never having encountered the situation. Overall, then, the trainees indicate strongly improved mobility in a wide variety of situations after training with the sonic glasses.

General Uses of the Sonic Glasses

Sixty percent of the trainees agree, either strongly (35.62 percent) or moderately (24.66 percent) with the statement that the glasses have reduced their travel stress in

TABLE 6

Trainees Ratings of Mobility Before and After Sonic Glasses Training

Situation	Greater Mobility After Training	Less Mobility After Training	Same Mobility Before and After	Never Encountered Situation
Locating landmarks	94.44%	1.39%	2.78%	1.39%
Avoiding other pedestrians in crowded areas	66.20%	7.04%	23.94%	2.82%
Avoiding obstacles in your path	81.69%	2.82%	15.49%	0.00%
Following sidewalks bordered by grass	29.58%	8.45%	57.75%	4.23%
Locating doorways	78.87%	4.23%	16.90%	0.00%
Guidelining (shorelining)	68.57%	2.86%	24.29%	4.29%
Following paths with hedgerows	77.46%	0.00%	14.08%	8.45%
Following path along storefronts	73.61%	4.17%	19.44%	2.78%
Following path in hallways	52.11%	12.68%	25.35%	9.86%
Locating a clerk in a store	34.72%	4.17%	33.33%	27.78%
Taking your place in a line	52.78%	4.17%	13.89%	29.17%
Locating a seat in a restaurant	16.67%	5.56%	25.00%	52.78%
Crossing a street in a downtown area	61.11%	5.56%	27.78%	5.56%
Travelling in moderate pedestrian traffic	70.42%	5.63%	21.13%	2.82%
Finding a specific store downtown	44.44%	4.17%	33.33%	18.06%
Seeking pedestrian assistance	43.66%	4.23%	30.99%	21.13%
Finding your way in unfamiliar suburban areas	52.78%	5.56%	16.67%	25.00%
Finding your way in familiar suburban areas	63.38%	2.82%	28.17%	5.63%
Finding your way in familiar shopping centers	69.44%	2.78%	16.67%	11.11%
Finding your way in unfamiliar shopping centers	56.34%	5.63%	8.45%	29.58%
Finding your way in unfamiliar rural areas	29.58%	4.23%	4.23%	61.97%
Finding your way in familiar rural areas	31.43%	4.29%	8.57%	55.71%
Finding up-curbs	38.03%	9.86%	49.30%	2.82%
Assessing the distance of stationary objects	91.67%	2.78%	4.17%	1.39%
Assessing the distance of moving objects	59.15%	7.04%	32.39%	1.41%
Squaring off to face objects and people	68.06%	2.78%	23.61%	5.56%
Finding your way in large open spaces	31.94%	2.78%	50.00%	15.28%

familiar residential areas. Sixteen percent of the respondents neither agree nor disagree with the statement, while 23 percent disagree, 15.07 percent moderately and 8.22 percent strongly. *Vis-a-vis* travel in unfamiliar residential areas, the glasses appear to be more powerful stress reducers. About 74 percent of the trainees claim a stress reduction in unfamiliar residential areas with the use of the glasses compared to 10 percent who claim no such reduction. Seventy-eight percent agree (46.58 percent strongly; 31.51 percent moderately) that they have a better understanding of the environment since using the glasses. Fourteen percent disagree and 8 percent are neutral.

In response to the statement "My mobility has improved since I started using the sonic glasses" the breakdown was strongly agree 21.92 percent; agree 43.84 percent; neutral 13.70 percent; disagree 13.70 percent; and strongly disagree 6.85 percent. Ninety percent respond that they can locate and identify objects more accurately since using the glasses, while 5.48 percent are undecided and only 4.11 percent disagree.

Travel stress in both familiar and unfamiliar shopping areas has been reduced for 66 percent and 54 percent of the respondents, respectively. Nineteen percent are neutral regarding familiar shopping areas and 37.50 percent are neutral regarding unfamiliar shopping areas. Only 15 percent and 8 percent respectively disagree that their travel stress has been reduced.

Only 47 percent agree that the glasses are useful indoors, while 26 percent are undecided and 27 percent disagree. Fifty percent of the trainees indicate a greater likelihood to travel in unfamiliar areas since using the glasses. Responses to the item "The glasses are more useful in heavy pedestrian traffic areas than in uncrowded areas," produced an almost even split among the respondents. Thirty-seven percent disagreed, 29 percent were neutral, and 35 percent agreed. There was little disagreement, however, that the glasses make it easier to locate people on the sidewalk (approximately 93% agree), and are an aid in determining distance (82 percent agreed). Similarly, 74 percent of the trainees indicated that they have continued to learn more about the glasses since training ended.

Trainees split on whether their independent travel time has increased since they were trained in the use of the glasses. Thirty-one percent indicate no increase, 40 percent are undecided, and 29.16 percent indicate an increase. About 53 percent state that they usually use the glasses when they're in unfamiliar areas, compared to 20 percent undecided and 27 percent disagree. Regarding the usefulness of the glasses in familiar versus unfamiliar settings, 42 percent opt for more usefulness in familiar settings, 28 percent are undecided and 30 percent state that the glasses are not more useful in familiar settings. Sixty-five percent find it more enjoyable travelling away from home since they have been using the glasses. Eighteen percent disagree and 17 percent are neutral. Fifty-nine percent also would like the glasses to have greater range. When asked whether they used the glasses primarily to assess distance or direction of objects or to recognize objects, 71.21 percent indicated using the glasses to fulfill all three functions. Another 15.15 percent indicated primary use in determining distance and direction of objects.

Overall, viewing the responses of "agrees" versus "disagrees" and omitting neutral or undecided responses, the large majority of the trainees claimed a better understanding of the environment, improved mobility, more accurate identification and location of objects, reduced travel stress, better distance determination, and increased travel in unfamiliar areas with the glasses. The majority would, despite these advantages, prefer the sonic glasses to have a greater range.

Adequacy of the Glasses' Range and Signals

Trainees were asked a series of questions concerned with the signals which emanate from the device and the range of the device. Trainees responded "yes" or "no" to each question. Table 7 gives the results of this series of items.

TABLE 7

Responses to Questions Regarding Signal and Range

Question	Yes	No
Are the audible signals of the device easily interpreted after training?	74.65%	25.35%
Do the signals from the device enable you to discriminate fairly well between different types of objects (e.g., trees vs. poles, hedge vs. fence, etc.)?	91.55%	8.45%
Do your ears often become fatigued from the audible signals?	25.35%	74.65%
Is the range of objects which the device enables you to detect adequate?	68.57%	31.43%
Does the device provide more aid in orientation or in recognition of landmarks in familiar areas than the long cane?	86.36%	13.64%
Does the device provide more aid in orientation or in recognition of landmarks in unfamiliar areas than the long cane?	80.00%	20.00%
Do the signals from the device often create confusion in orientation?	34.29%	65.71%
Does the device give reliable direct path travel information?	88.73%	11.27%
Can you readily determine the direction of objects from your audible signals while traveling at your normal walking rate?	87.32%	12.68%
Can you readily determine the size of objects from the audible signals while traveling at your normal walking rate?	48.61%	51.39%
Has the device improved your line of travel in comparison to your line of travel prior to using the device?	66.20%	33.80%
Have you increased your walking speed since using the glasses?	30.43%	69.57%
Have you reduced your walking speed since using the glasses?	12.68%	87.32%
Are you relaxed and comfortable using the device?	73.91%	26.09%
Have you mastered the use of the device sufficiently to feel confident with the device?	75.71%	24.29%
Do you like the signals to be loud?	32.39%	67.61%

The signals and range of the device are easily interpreted, enable discrimination between objects, provide more aid than the long cane in both familiar and unfamiliar settings, afford reliable direct path travel information, and enable ready determination of the distance of objects. For most of these items, however, there is a group of trainees, varying in size from 8 percent to 25 percent, who respond negatively about the device. However, on the skills mentioned above, three-quarters or more of the respondents are pleased with the device. Although two-thirds respond that the range of objects which the device can detect is adequate, one-third indicate that range is one of the device limitations. Also, one-third of the trainees indicate frequent confusion in orientation from the signals. The device seems better able to identify direction of objects than size. Walking speed does not seem to be affected greatly by the device. Finally, about 70 percent of the trainees indicate that they are traveling in a wider variety of areas than before training and about 75 percent indicate that they are relaxed and comfortable using the device.

Training Experiences and Attitudes

Trainees reported being supervised during training to varying degrees. While the majority were supervised either one hour per day (40.54 percent) or two to three hours per day (37.84 percent), two respondents indicated less than one hour per day of supervised training and 14 indicated more than four hours per day. Seventy-seven percent were given training more than four days per week. 20.27 percent from three to four days per week, and 2.70 percent less than two days a week. The majority (64.38 percent) of the trainees received their personal set of sonic glasses at the start of training, while another 21.92 percent received a device by half way through the training. Five trainees (6.85 percent) did not receive their own personal device until after training was completed.

When asked how many hours per day they practiced on their own, 30.14 percent indicated less than one hour, 34.25 percent indicated an hour, 24.66 percent two hours, and the remaining 10.96 percent three hours or more. Regarding the percent of training time devoted to outdoor travel exercises, the training sessions were indicated to be different from location to location. While 39.19 percent reported training in outdoor travel situations from zero to ten percent of the time, 29.73 percent indicated 11 to 20 percent of the time, 10.81 percent 21 to 30 percent of the time, and 20.27 percent greater than 30 percent of the time. While 85 percent of the trainees felt the pole exercises were relevant during training, 97 percent thought they were relevant after training. However, 77.78 percent indicated that no additional training time should be devoted to the pole exercises.

Judging from the responses to items concerning the number of training days required to master the use and pitch/distance and right-left direction cue relationships, it appears these relationships were readily mastered by the majority of trainees. At the end of seven days, 95.95 percent of the trainees reported that they understood the pitch/distance relationship. Eighty-nine percent could use this relationship for traveling within a week after understanding it. Similarly, 94.50 percent could understand the right-left direction cue within seven days. Ninety-two percent could use it in traveling within seven days of understanding it. Another 5.41 percent could use it in traveling within an additional week. After mastering both relationships independently, the majority of trainees (87.67 percent) could use these in combination to locate objects within seven days. Within 21 days, all trainees could locate objects. It appears, therefore, that understanding and being able to use these relationships in travel is relatively easy and rapid.

Given the nature of the device, the use of a form of coded sound to aid mobility, it is reasonable to expect that some confusion arises among trainees from the audible signals. A series of questions concerning the nature and extent of confusion were asked. Only 14.86 percent of the trainees reported experiencing no confusion from the sounds early in training, while 41.89 percent reported little confusion, 36.49 percent reported moderate confusion, and 6.76 percent reported a great deal. Half of the respondents (53.13 percent) found the confusion a little disturbing, and a third (35.94 percent) reported not being disturbed. In 84.13 percent of the cases, trainees reported that instructors always took steps to explain the sounds in confusing situations. Only one person reported that his instructor *never* explained the sounds in confusing situations. Over 80 percent of the instructors monitored the sounds during training (28.13 percent always and 53.13 percent sometimes). Such monitoring was reported helpful by 87.50 percent of the trainees. For the majority of trainees, within nine days, a reduction in confusion at incoming signals occurred. The breakdown of the length of time for confusion to be reduced was: less than two days 40.00 percent; two to five days 32.31 percent; six to nine days 18.46 percent; 10 to 14 days 6.15 percent; and greater than 14 days 3.08 percent. Lastly, 16.44 percent of the trainees report that the sounds from the glasses give them a great sense of security, 32.88 percent report a moderate sense of security; 26.03 percent little security, and 24.66 percent no security.

Eighty-nine percent of the respondents reported that they advanced through the lessons as quickly as was possible for them. Over 95 percent stated that training enabled them to reach a level of proficiency where they could continue to learn on their own. However, 45 percent of the trainees would have liked to continue for another week (16.22 percent), two weeks (8.11 percent) or a month (20.27 percent). Perhaps the responses to this last item shed some insight into the item which asked whether trainees felt they had regressed in their ability to use the glasses since they concluded training. While 65.75 percent responded "no," 15.07 percent indicated little regression, 12.33 percent moderate regression and 6.85 percent a great deal of regression.

By the time they were half way through training 80.95 percent of the trainees (17.46 percent at the start of training; 28.57 percent one-third of the way into training; and 34.92 percent half way through training) responded that they were able to pay equal attention to their cane and glasses. Ninety-five percent of the respondents indicated benefitting from the glasses. The period during training when the benefits first manifested themselves varied, however. Forty-one percent indicated benefit at the start of training; 33.78 percent by the time training was one-third over; 13.51 percent by the time training was half over; and 6.76 percent by the time training was two-thirds over. Four people (5.41 percent) indicate never benefitting from the glasses.

To obtain the trainees' overall impression of the training period, trainees were asked to respond to ten questions by answering "yes" or "no." Table 8 gives the percentage of responses to each option on each item.

Overall, training was judged adequate and beneficial, if not particularly easy. About half the trainees had the glasses malfunction during training. This fact perhaps accounts for 89.04 percent recommending the availability of spare glasses during training.

Those trainees who had malfunctions and who had spare glasses available (23 in all) were polled regarding differences between the two pair of glasses in the frame size, pulse rate, quality of sound, direction cue change and distance cue change. For each characteristic, the percentage reporting similarity between the two sets of glasses were: frame size 39.13 percent, pulse rate 69.57 percent, quality of sound 52.17 percent, direction cue change 77.27 percent, and distance cue change 81.82 percent. Frame size and quality of sound appear to be the major differences.

When asked whether additional training in their primary mobility aid (dog, cane, etc.) would have helped their mobility more than, less than, or the same as the sonic glasses training, 55.56 percent said additional training in their primary aid would have helped less

TABLE 8

Trainees' Overall Impressions of the Training Period

Question	Yes	No
Generally speaking, was the training you received adequate?	91.89%	8.11%
Was the training period too long?	10.81%	89.19%
Should there have been more training?	41.89%	58.11%
Did you benefit from the training?	94.52%	5.48%
Do you think that training is essential to being able to use the glasses effectively?	91.89%	8.11%
Do you think that many people could train themselves in the use of the sonic glasses without the aid of an instructor?	9.46%	90.54%
Did you find learning to use the glasses simple?	52.70%	47.30%
Did your glasses malfunction during training?	44.59%	55.41%
Did you have a spare set of glasses available to you to continue training if your initial device malfunctioned?	62.86%	37.14%
Would you recommend that spare glasses be available to all trainees?	89.04%	10.96%

than the sonic glasses training, 22.22 percent said it would have helped more, and 22.22 percent said the benefit would have been the same.

Design Difficulties and Inconveniences

Trainees were presented with a series of 16 possible mechanical, design, and cosmetic difficulties which they might have experienced while using the sonic glasses. For each difficulty, trainees responded regarding whether that problem

a. had never occurred,

b. had occurred but was only a minor inconvenience, or

c. had occurred and was a major inconvenience.

Table 9 indicates the percentages of trainees responding to each option for each difficulty.

From Table 9 it is evident that there are a few design difficulties with the glasses, at least as perceived by trainees. The primary difficulties relate to the size or bulkiness of the device. On the items "cable too stiff," "control box difficult to carry," "glasses heavy on bridge of nose," and "device too

TABLE 9

Trainees Ratings of Design Difficulties and Inconveniences

Difficulty	No Problem	Minor Problem	Major Problem
Earmolds difficult to insert	69.86%	23.29%	6.85%
Glasses awkward to put on and take off	50.68%	41.10%	8.22%
Cable too long	54.79%	30.14%	15.07%
Cable too stiff	39.73%	39.73%	20.55%
Control box difficult to carry	50.00%	29.17%	20.83%
Switches difficult to get at	75.00%	18.06%	6.94%
Volume control range inadequate	77.78%	16.67%	5.56%
Glasses too noisy	80.28%	16.90%	2.82%
High-low gain switch ineffective	86.11%	9.72%	4.17%
Battery catch difficult	87.32%	11.27%	1.41%
Glasses too heavy on bridge of nose	35.62%	39.73%	24.66%
Glasses hurt side of head	76.71%	17.81%	5.48%
Glasses hurt behind ears	71.23%	24.66%	4.11%
Device too bulky	23.29%	38.36%	38.36%
Friends tell me glasses are ugly	57.53%	26.03%	16.44%
Glasses interfere with mobility	80.82%	12.33%	6.85%

bulky," over 20 percent of the trainees (almost 40 percent on the last item) cited these as major problems. Other problems related to the cosmetics of the glasses.

When asked whether the glasses were adequate in their present form, 57.53 percent responded "yes" and 42.47 percent "no." However, the problems trainees perceived with the glasses seem largely ones of size, convenience and appearance, since in response to the item "Are the glasses reasonably maintenance-free now?" 82.35 percent responded "yes" and 17.65 percent responded "no." There is thus a group of about 18 percent of the trainees who are still having maintenance difficulties with the glasses. Overall, when polled on their general satisfaction with the glasses, 27.14 percent indicated being very satisfied, 58.57 percent indicated being satisfied, 8.57 percent indicated being unsatisfied, and 5.71 percent indicated being very unsatisfied. Eighty-six percent of the trainees state satisfaction with the glasses.

Overall Attitudes Toward the Glasses

Ten statements, designed to assess attitudes toward the glasses and the training period were included in the questionnaire. Trainees responded to each item on a five-point scale ranging from strong agreement with the statement to strong disagreement. Table 10 presents the statements and trainees' responses.

TABLE 10

Trainees Responses to General Attitudinal Statements

Statement	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
After using the glasses, my attitude is favorable towards them.	56.16%	34.25%	2.74%	2.74%	4.11%
I would like to keep the glasses.	63.89%	25.00%	4.17%	4.17%	2.78%
The benefits of the glasses make it worth the trouble of training.	61.11%	20.83%	6.94%	8.33%	2.78%
I find the concept of using sound to aid mobility useful.	51.39%	40.28%	2.78%	4.17%	1.39%
The benefits of the glasses justify the inconvenience of training.	47.22%	34.72%	4.17%	11.11%	2.78%
In general, things seem better for me since I've used the glasses.	26.39%	31.94%	22.22%	12.50%	6.94%
My friends and family are positive about my mobility using the glasses.	27.78%	34.72%	25.00%	9.72%	2.78%
I would recommend the glasses to another blind person.	36.11%	45.83%	12.50%	4.17%	1.39%
I was very motivated to learn how to use the sonic glasses.	54.79%	38.36%	6.85%	0.00%	0.00%
The glasses could be used to motivate mobility in blind persons where motivation is lacking.	23.61%	34.72%	19.44%	12.50%	9.72%

While there is a small percentage of trainees, usually below 15 percent of the total, who express negative attitudes, and while on some items there is a group of about 20 percent who are neutral, the overall impression conveyed by the reponses to the attitudinal items is positive. Eighty percent or better of the trainees indicated agreement or strong agreement concerning their favorable attitudes towards the glasses, their desire to keep the glasses, the benefits of the glasses justifying the training period, the use of sound to aid mobility, their motivation to learn how to use the glasses, and their willingness to recommend the glasses to another blind person. On every item in this section, the majority of respondents expressed agreement. The trainees were asked whether, now that they had completed training, they still had the glasses. Over nine percent indicated that they did not; 11 percent still have the glasses but have not yet decided whether to keep or return them; 79 percent still have the glasses and plan to keep them.

The last few items on the questionnaire asked trainees to cite characteristics of potential trainees which would help make training successful. Sex was not judged to make a difference in training success. Twenty-three percent indicated that the level of motivation did not make a difference, while 36.84 percent said a person should be highly motivated to make training successful. Sixty percent of the respondents suggested that training would be more successful with young (20 percent) or middle aged persons (40.44 percent) than with old persons (2 percent). About 38 percent indicated that all ages could equally be successful. Regarding intelligence, 17.24 percent suggested better success for smart people, 41.38 percent selected average smartness, and 39.93 percent said intelligence did not make a difference in training success.

Summary

For the majority of the trainees, the questionnaire results indicate that the training period and the glasses themselves were favorably received. Given the limitations in the data collection technique utilized in this evaluation and the number of questionnaires returned in relation to the number sent out, the evaluation identifies a number of assets associated with the glasses. A few liabilities are also identified.

While use of the glasses does not appear to increase independent travel time or travel patterns, the glasses are rated quite favorably as a mobility aid. Although travel time is not increased after training in the use of the glasses, mobility is made easier. Trainees rated mobility better after training than before on a wide range of travel skills. In no instance was mobility with the primary aid before training judged better than mobility with the glasses after training, though in some cases, trainees judged before and after mobility equivalent. The glasses reduce travel stress for a sizable proportion of the respondents, although many were neutral or undecided regarding a stress reduction. Trainees report traveling in a wider variety of areas than before training and being relaxed and comfortable using the device.

Trainees claimed a better understanding of the environment, improved mobility, more accurate location and identification of objects and better distance determination. However, the majority of trainees would like the glasses to have a greater range. Except for a portion of the respondents ranging from 8 percent to 25 percent, there seem to be few problems regarding the signal and range adequacy of the glasses. However, the device is judged to be too bulky, to hurt the bridge of the nose, to have too stiff a cable and to be cosmetically unappealing by a sizable proportion of the trainees. Other than these problems, there are no other major perceived design difficulties or inadequacies.

Training experiences and attitudes are well rated generally except that the majority of trainees recommended a spare device be available in case the principal device malfunctions--which it did for about 45 percent of the trainees. Learning was judged satisfactory. However, many trainees, about 45 percent, indicated that they would have liked to have had training continue for a longer period. Usually, by the time training was half-way completed, the trainees could pay equal attention to the glasses and their cane. Learning to use the pitch/distance and right-left cue relationships in traveling took on the average about two to three weeks.

General attitudes were also favorable, although there was a relatively small percentage of trainees who expressed negative attitudes. Over 80 percent of the trainees cite that the glasses are reasonably maintenance free now. Eighty-six percent of the trainees indicate satisfaction with the glasses. Finally, 79 percent still have the glasses and plan to keep them, 11 percent still have the glasses but have not yet decided whether to keep them permanently, and only 10 percent have returned the glasses.

THE EVALUATION OF BLIND MOBILITY*

J. Alfred Leonard**

This essay is primarily addressed to those who attended the recent Conference on the Evaluation of Mobility Aids for the Blind, held at Airlie House, Warrenton, Virginia, June 21st-23rd, 1970. At that Conference we had a good many discussions on the topic of evaluation and a wide range of views were expressed. These views in turn are a reflection of the attitudes held towards the whole field of blind mobility. The main thesis of this essay is that blind mobility should be a serious matter of scientific and professional concern, a subject matter in its own right, achieved by effective collaboration between users, practitioners, inventors, designers, and researchers. That is the thesis, though this is not the place or the time to spell out its administrative implications.

Those of us who are taking the matter of blind mobility as a problem to be solved rather than as a hobby played out on a more or less elaborate scene, have a simply defined aim: blind people should be able to walk about just like sighted people, and should be indistinguishable from them, whichever way you care to make the comparison. Of course this aim is not attainable within the next week or so, and maybe it is not attainable for some decades: but let there be no mistake and no avoiding of the issue about this point, that here and now as well as ultimately, this is the standard which we are working to. Thus the first and most obvious way of tackling any problem of evaluation is to say how close the present state of blind mobility comes to sighted mobility.

The second issue arises directly from the first: having established the extent to which blind mobility does not come up to sighted mobility along any given number of dimensions, we want to know the reasons why. For it must be obvious to the meanest intelligence that there are at least two reasons for carrying out any evaluation worth the name. First we want to know whether a new device or a new training method is an advance on what we already have, again along a number of different dimensions or in terms of a multiplicity of criteria. This is simply in order to see whether it is worth while implementing the new device or training scheme on a large scale. Secondly, we want to understand the reasons why the new solution succeeds or fails to get us closer to our ultimate aim.

The third point is rather more a matter of substance: can we in fact say how close we are at present to sighted mobility? The answer to that must be an emphatic Yes! if we accept that the practitioners (those who teach mobility in one way or another) know what they are talking about and that blind users, particularly those who knew what sighted mobility is like are in a very good position to assess the size and nature of the remaining gap. Those of us who carry out research in the area of blind mobility owe an enormous debt to users and practitioners, for it is with them that almost all the worthwhile knowledge resides at this point in time. It is verging on the criminally negligent that we are not taking more intelligent steps to make better use of that knowledge--but then there is hardly a calendar of social or scientific crimes.

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*Ed's Note: First distributed on a limited basis during the Fall of 1970.

**Dr. Leonard died in late 1971. At the time of his death he was director of the Blind Mobility Research Unit, Department of Psychology, University of Nottingham.

The fourth point concerns the bread and butter, the nuts and bolts, of evaluation. Of course, it is understood that there are different kinds of evaluation, and of course it is understood that you do not, and would not want to, evaluate along one dimension or by one criterion alone, except in a sort of portmanteau sense mentioned in the second paragraph, that we are aiming at sighted achievement. But in the end, there must come the kind of evaluation which does say quite specifically what a device or a training scheme adds, if anything, to the present state of the art. It may do any one or none of these: it may please the user; it may add to the extent of his mobility in terms of the routes he will cover; it may increase the number of occasions when he goes out by himself, or the length of time for which he goes out; it may improve the cost-effectiveness of the training; it may enable previously immobile sections of the user population to become a bit more mobile; it may reduce the "stress" presently experienced when moving about unguided; it may improve the quality of his current performance; it may do a good many other things. Now I want to be quite emphatic about this: however crudely, all of these achievements can be quantified and made use of if we really put our minds to it. They are well understood aspects of human conduct and performance.

Thus we come to the fifth point: is it worth doing any of this? Would it not be far better to let things go on as they are and hope that somehow something will emerge, while we create a valuable impression that we are really trying to solve the problems of blind mobility and in the process satisfy all sorts of personal needs? Put in this underhand way I do not suppose anybody would answer the question in the affirmative. And yet, broadly speaking we are apparently and quite cheerfully prepared to let things go on as they are, using as excuses that we do not really know what blind mobility is all about, that it is some mysterious craft at best, and that almost anything is worth trying regardless of rationale, cost, raising of false hopes, and the rest. All this would just about be all right if there were unlimited resources in manpower and finance, if there were not urgent problems crying out to be solved to make life just a little bit more tolerable for all or some of our users rather than provide a haven for just one or two. From the problems of looking at the cost-effectiveness of current training methods via the increased flexibility of existing training programs and the pitiful failure to produce a sensible foldable or collapsible cane, and making a better job of users with additional handicaps or residual sight, to a concentrated attempt at consolidating the accumulated knowledge of practitioners and users, there is lots which could be done here and now with relatively little money. Nor does one want to inhibit the creativity or the enthusiasm of inventors and designers of devices, or the justifiable claims of scientists to satisfy their intellectual curiosity. But, ye Gods, I will help to produce a list of the ten most highly mobile blind people and will ask them to let you watch them, and then you will see the size of the gap between what they can do now and what we ought to be able to help them to achieve. And these will be the best; our current moving standards towards which we aim to bring the bulk of the user population and do not know how. There is neither enough manpower in quality and quantity nor enough money to do what, I submit, needs to be done both on a short-term and a long-term basis.

The sixth point is easy enough to make, but I do not know how many people would agree with me. It would be good to know. The present state of the art in blind mobility is that for a relatively small number of the potential user population existing training methods and devices can provide almost complete body protection against collisions, a small degree of distant sensing, and a fair amount of overall orientation skills. Thus travellers can, if they want to, at the very least, make their own way to their place of employment in safety and with a measure of comfort. Some can do more and are not only willing to, but enjoy exploring new routes and territory by themselves. Of the quality of their performance it can said that it approaches very closely to the core of sighted performance. But, all this is achieved at all sorts of costs in terms of training time, or painful experience if self-taught; it is carried out within a relatively narrow vocabulary of routes; in general it is only done when there is strong motivation; and when it is done there is greater "stress" than in sighted mobility.

Finally then, what of new devices and training schemes? A hard one and often a problem of chicken and egg, admittedly. I would have thought that it should be incumbent on anyone who nowadays wants to try out something new in this field to have a reasonable idea of how the new thing will alter the present state of affairs in any one of the senses mentioned under point four above. I would also have thought that as a consequence he should be able to build into his evaluation, tests which seek to demonstrate and confirm his claim. But I do recognize that this assumes an acceptance of an untenable proposition, that our knowledge about the problem is indeed complete--which it can never be. So there must be room for people to try out ideas which are external to our present body of knowledge. There must be room for a "suck it and see" approach. But coming back to point five, there must be a sense of proportion about all this given on the one hand that there are identifiable needs and on the other limited resources both for research and for implementation. I would submit that the time is past, or should be past, where the identification of needs, and the allocations of resources is left in its present haphazard state. By all means let us have some flexibility in the system, but let us put the emphasis on coordination and organization for a change.

TECHNICAL POSTSCRIPT

Perhaps it might help to point out that we do have a background of experience of the problems involved in evaluation, and that I am not just talking from the armchair.

1. I initiated two surveys: the first was carried out on behalf of the Ministry of Health and was a random sample of the whole of the blind population of England and Wales age 16 to 64 and 65 to 79, a total of 1,500 cases. This was essentially a type of market-survey, state-of-the-art affair (Gray and Todd, 1967). The second was the work just about to be submitted as a Ph.D. thesis, and most likely to come out as a book, by Mrs. Heather Wood. She applied Newson type of techniques to the parents of 75 blind infants zero to five years old to find out about patterns of development.

2. Mobility evaluations have been carried out by us ever since 1962. There was the first Sonic Aid Evaluation at Worcester College in 1962 (Leonard and Carpenter, 1964) and then a long gap. In 1966/67 we did our map work and that was evaluated in Leonard and Newman, 1967, and 1970. In 1967 too we carried out a fairly large-scale evaluation at Royal Normal College and published it together with a general statement about evaluation problems (Leonard and Wycherley, 1967). 1969 saw the evaluation of the non-residential client training at Midlands Mobility Centre, Birmingham (Crouse, Leonard, et al., 1970), and two Sonic Aid Evaluations (Leonard, Armstrong, and Sharpe, 1969; Sharpe 1969). And the summer of 1970 found us evaluating a modified long-cane/orientation course at Worcester College, the results of which are still being processed.

3. In most of these cases we did ask some quite specific questions and found answers of a sort to them. In 1962 we wanted to know how boys trained with the Sonic Aid compared with boys trained without. In the map work we wanted to know whether blind people could walk over completely unfamiliar routes with the aid of maps. At Royal Normal we wanted to test how well the youngsters who had been taught by local

staff could cope with a route they had been taken over once before. In Birmingham we wanted to assess the effectiveness of the program in terms of levels of achievement reached by our clients and the number of hours spent over successive units of the training course. In the second round of Sonic Aid work we wanted to know how well self-trained blind people performed and how well we could teach Sonic Aid use with a manual to a group of sighted subjects under the blindfold. Finally at Worcester we again wanted to see how far and how well one could get in 30 hours of training.

4. In all these cases we obviously tried to find ways and means of answering the questions put as specifically as possible. In the case of the map work, this was by far easier than in other cases because we were concerned with solving a specific problem rather than with assessing the quality of performance. The same applies to Sharpe's work.

5. Evaluation is neither trivial nor easy. But it is certainly neither impossible nor meaningless.

REFERENCES

Crouse, R. J. and J. A. Leonard *Client Output Evaluation of the Midlands Mobility Centre*, Department of Psychology, University of Nottingham, 1970.

Gray, P. G. and J. E. Todd. *Mobility and Reading Habits of the Blind.* (SS.386) Her Majesty's Stationery Office, London, 1967.

Leonard, J. A., J. D. Armstrong, and R. Sharpe. "The Sonic Aid: Two Evaluations." *New Beacon*, 1969, Vol. 53, pp. 317-9.

Leonard, J. A., and A. Carpenter. "Trial of an Acoustic Aid." *American Foundation for the Blind Research Bulletin*, 1964, No. 4, pp. 70-119.

Leonard, J. A., and R. Newman. "Spatial Orientation in the Blind." *Nature*, 1967, Vol. 215, pp. 1413-4.

Leonard, J. A., and R. Newman. "Three Types of 'Maps' for Blind Travel." *Ergonomics*, 1970, Vol. 13, pp. 165-79.

Leonard, J. A., and R. J. Wycherley. *Towards the Measurement of Performance of Travel Skill.* Department of Psychology, University of Nottingham, 1967.

Sharpe, R. *The Evaluation of the St. Dunstan's Manual of Instruction for the Kay Sonic Aid*, 1969.

REDUCTION OF THE EFFECTS OF CATARACTS ON VISION BY THE USE OF CONTACT LENSES

Douglas McQueen*
Jaroslaw Pekar**

INTRODUCTION

Recently it has been pointed out that some of the adverse effects of lens cataracts or corneal scatterers on vision can be reduced by the use of diaphragmed or tinted contact lenses.[1,2] The idea of blocking out some of the light incident on the eye in order to obtain better vision is quite old, and rather successful. Here we present the results of a recent experiment concerning contact lenses designed especially for blocking light impinging on a lens cataract, as well as a more complete theory of the effect of unwanted scattering on vision.

The procedure is to block light from impinging on the cataract by the use of a light-absorbing shield. The proposed methods of blocking are most effective if the cataract has well defined, smooth boundaries, and does not cover the entire area of the pupil. Congenital cataracts can fulfill these conditions, but often old-age cataracts, for example, cover the whole pupil area and are not amenable to our procedure.

THEORY OF THE EFFECT OF CATARACTS ON VISION

Common to both epithelial oedemae and lens cataracts is that the light scattering is predominantly in the forward direction.[3,4] Scattering is probably many times stronger than absorption, a fact not widely appreciated by eye specialists. In fact, scattering from these structures can easily be motivated quantitatively on the basis of their microscopic structure.[5] Thus, almost all of the light incident on such structures is scattered in the forward direction. In the eyeball this scattered light impinges primarily on the central part of the retina. It is this part of the retina which is most important for normal vision.

Let us suppose that a cataract of fairly well-defined, smooth boundaries covers only part of the lens. The remaining clear part functions correctly and focuses an image of the viewed object on the retina. The intensity of the image is proportional to the exposed clear area of the lens. However, the light which impinges on the cataract is scattered toward the retina with an intensity proportional to the illuminated area of the cataract. Since this light was scattered in the cataract, it carries no useful information about the viewed object; no image is formed by this light. Instead it causes a loss of contrast in the image made by the clear part of the lens. This results in a reduction of the effective visual acuity of the subject.

It is probably this sort of difficulty that cataract or oedema-afflicted persons suffer. One could obtain increased image contrast by blocking out this scattered light. This is exactly what is attempted with the contact lens.

For an epithelial oedema all that is necessary is to hold a light-absorbing shield in front of the

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oedema. A contact lens with a black dot in the shape of the oedema would do the job. For a cataract one would ideally put the black dot on the crystalline lens itself, but as this would involve a somewhat delicate operation into the eyeball, a contact lens with a black dot has been used instead, as described below.

RESULTS OF A TRIAL FITTING

One of us (J. Pekar) has congenital cataracts in both eyes. In the better left eye, the cataract covers most, but not all, of the normally illuminated lens area. The remaining small, clear, portion forms an image on the retina, while the larger cataractous portion reduces contrast in the image. Under optimum conditions of lighting, visual acuity has been measured to be at best 20/80. (The subject sees at 20 ft. what he should see at 80 ft.)

The cataract is not centered on the lens, and this together with an extraordinarily strong corneal curvature and strong nystagmus means that an orientable contact lens which can follow the quick eye movements practically instantaneously is required. The usual corneal contact lenses do not fulfill these conditions. However, the larger scleral contact lenses provide a promising method for holding light-absorbing shields (black dots imbedded in the lens) in front of the cataract.

When testing such a lens in the cataractous eye an increased visual acuity was obtained: 20/60 as compared to 20/80 previously. This improvement was registered in spite of a double image seen by the subject (due to an air gap between the contact lens and the cornea) and in spite of probable poor alignment of the black dot with respect to the cataract (due to orientation fluctuations of the lens). These errors are due to poor fitting of the lens, and not to the technique itself. When a better fit is obtained, an even better result is expected.

Absolutely no awareness of the black dot on the part of the subject is either expected or found. This is because the dot is in the plane of the lens, far inside the focal plane.

CONCLUSIONS

This increase in visual acuity is probably due primarily to two effects: (1) Removal of a large portion of the undesirable scattered light, and (2) Slight increase in the pupil diameter (due to the fact that there is less total light impinging on the retina), exposing a greater amount of clear lens.

It should be pointed out that after insertion of the contact lens the eye can be refracted for geometrical defects and eyeglasses fitted. (Previously Mr. Pekar has not used eyeglasses.)

It is not expected that 20/20 vision can ever be obtained with this procedure because the intensity of the image on the retina will always be relatively lower than in a normal eye. Moreover, it is not possible to block off all light impinging on the cataract without also blocking the clear-lens area. An unsolved problem is the optimum size of the black dot compared to the cataract. We have used a dot just slightly smaller than the cataract. The optimum size probably depends on psychological as well as physiological factors.

Our report is incomplete and lacks accurate, professional medical support. Both authors would be extremely thankful for any such assistance that might be offered.

REFERENCES

1. Haas, *Contacto*, September 1967, p. 23.
2. Haas, *Contacto*, June 1968, p. 45.
3. Bo Philipson, "Light Scattering in Lenses with Experimental Cataract," *Acta Ophthalmologica*, 1969, Vol. 47, p. 1089.
4. Tore Feuk and Douglas McQueen, "The Angular Dependence of Light Scattered from Rabbit Corneas," *Investigative Ophthalmology*, 1971, Vol. 10, p. 294.
5. McQueen, Douglas H. Ph.D. Thesis, University of North Carolina, 1971.

ADAPTATION TO THE FUNCTIONAL LOSS OF PINNAE IN SOUND LOCALIZATION ABILITY*

Marvin R. Navarro**

Abstract

This study reviewed the role of the pinnae (the external ears) in sound localization, and investigated adaptation to the functional loss of pinnae. Pulses of white noise were presented to six subjects individually under two conditions: control condition--with pinnae; experimental condition--pinnae covered by a modified earphone for a period of one hour per day for five days. In both conditions, the testing was done at the beginning of an hour and again at the end of an hour. The subjects were asked to identify the source of sound from one of six speakers in the absence of head movement.

A statistical analysis of the data indicated that the subjects could localize better in the control condition than in the experimental condition, thereby lending support to the contention that the pinnae is a definite aid to sound localization. There was not sufficient improvement of localization ability to indicate the presence of adaptation.

PURPOSE OF THE STUDY

The phenomenon known as sound localization has been researched extensively for many years. Such noted scholars as Venturi (Rosenweig, 1961), Weber and Strutt (Stevens and Warshofsky, 1970) and Stevens and Davis (1938) have tried to explain this phenomenon on the basis of phase, time, or intensity cues. Most researchers tend to overlook the role of the pinnae in sound localization ability. This is so in spite of Bekesy and Rosenblith's (1951) report of research which states that localization suffers when the pinnae is altered. As recently as 1966, O'Neill and Oyer stated that the pinnae served only as ornamentation. Contrary to this statement, Batteau (1967) and Fisher and Freedman (1968) have begun to demonstrate that the pinnae is a definite aid to localization. Since Fisher and Freedman concluded that in the absence of head movement, the pinnae are crucial to auditory localization, this study was designed to verify their findings, and to investigate the ability of humans to adapt to an absent or deformed pinnae.

The literature which explains localization on the basis of interaural phase, time, and intensity cues; under careful scrutiny cannot explain either accurate monaural localization (Angell and Fite, 1901; Bauer, *et al.*, 1966) or localization of elevated sources (Batteau, 1967; Bauer and Blockmer, 1965). Because of these inadequacies in accepted theories, it seemed reasonable to assume that the pinnae serve to process the sound stimuli as an aid to localization.

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METHOD

To test this assumption, eight normal hearing (15 dB or better re: ISO, 1964) subjects (Ss) (mean age 22.7 years) were asked to localize a series of pulses of white noise presented under two conditions. One condition tested localization with pinnae unaltered and served as the control condition (CC). The second condition tested localization with the pinnae covered by a specially designed earpiece. This condition served as the experimental condition (EC). Each subject was tested at the beginning of an hour (CC_A and EC_A, respectively) and at the end of an hour (CC_B and EC_B, respectively) for a period of five days for each condition. Listening experience for the EC condition was provided during the hour interim between each of the two daily tests by a standard AM radio. This experience was provided to maintain the functioning of the auditory scanning mechanism (Myklebust, 1964). Subjects were randomly assigned to one of two groups. Originally, there were an equal number of Ss in each group but two Ss dropped out of the study. Consequently, there were two Ss in Group I and four Ss in Group II. Group I received the control condition first and Group II received the experimental condition first.

Stimuli consisted of tape-recorded trains of three consecutive pulses of white noise at the rate of one pulse-per-second. Each pulse was 40 msec in duration with a five-msec rise/fall time. After each train of three pulses, there was a five-second interval during which no pulses occurred. During this interval, the examiner scored the S's response.

The stimuli were presented to the Ss by playing the tape on a tape recorder (Sony Model TC5600) which was connected to a speech audiometer (Grason-Stadler, Model 162). The input of a six-position switch was plugged into the speech audiometer. Each of the six output leads of the switch led tc one of six identical speakers located 45 inches from the floor of a sound-treated room (Industrial Acoustics Company, Model No. 1203A). Each of the six 5" x 4" speakers were housed in separate plastic boxes lined with foam rubber. Each speaker was 40 inches from the approximate midpoint of the S's head. The speakers on each side formed two arcs of 100 degrees with unilateral adjacent speakers 50 degrees apart. No speakers were placed in zero azimuth as several researchers (Rosenweig, 1961; Hochberg, 1966) have shown a high percentage of front back reversals which would only confound the present study. Figure 1 illustrates this equipment.

Since the noise pulses were too short in duration to allow accurate intensity measurements with the equipment used, a 1000-Hz 60-second tone was recorded on the stimulus tape. This tone was calibrated so

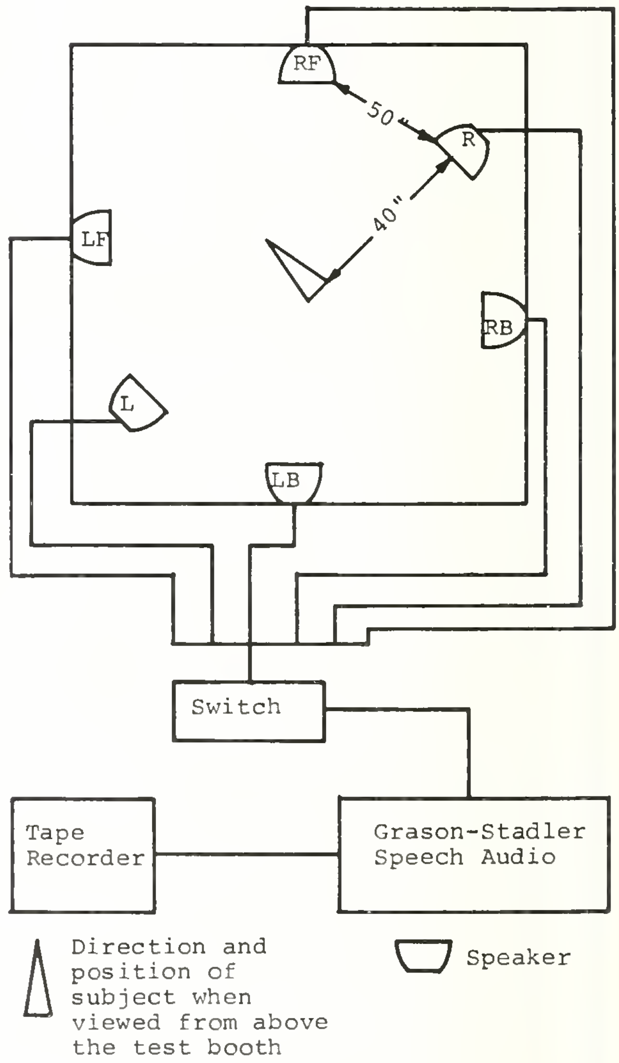

Figure 1. Equipment Schematic.

that it registered at zero Vu on the speech audiometer. The intensity of this tone was measured daily on the linear scale of a Bruel and Kjaer Sound Level Meter (Model 2203 with a Type 4132 microphone) and maintained at 60.3-dB sound pressure level (re: 0.0002 dyne/cm^2). During the daily calibration measurements, the sound level meter was positioned where the S's head would normally be during the experiment.

For the EC condition, the Ss wore one of four pairs of specially constructed headsets which limited the use of the pinnae by routing the signal directly to the ear canal. Each headset consisted of a headband, two circumaural cushions (Grason-Stadler, Type 001), and two wooden blocks inserted into the cushions in place of the usual earphone transducers. A 1/4-inch (O.D.) glass tube 3 inches long was inserted through a hole in the wooden block. Through each glass tube, a 3/16-inch polyethylene tube was positioned with a size 50 cotton thread inserted through the polyethylene tube to reduce standing waves. Rubber ear inserts were then attached to one end of the polyethylene tube and inserted into the S's ear canal. The outside of the earphone was covered with foam rubber to minimize reflecting surfaces (Figure 2).

Figure 2. Specially Constructed Headset Used in Experimental Condition.

Figure 3. Chair Used to Restrict Head Movement During Testing.

Figures 3 and 4 illustrate the head restraining chair which was used to restrict rotational head movement during all testing. The S's head was braced at the back of the head and at the bridge of the nose. Individual brace settings for each S were recorded and maintained throughout the study. After the S's head was braced, he was asked to point to and to verbally identify the speaker which emitted a train of noise pulses. He was not to respond until he heard all three pulses for each train. Each response was recorded on the randomized order of testing set forth on the score sheet (Appendix A).

RESULTS

Four total raw scores were obtained for each of the six subjects--two (A and B) for the normal pinnae condition and two (A' and B') for the altered pinnae condition (Table 1). The scores under test session $CC_{A'}$ ranged from 28 to 30 with an $\overline{X}$ of 29.5. All Ss obtained

Figure 4. Subject in Test Chair.

scores of 30 under test session CC_B. For the normal pinnae condition, the combined scores (A + B) ranged from 58 to 60 with an $\overline{X}$ of 59.5. The scores obtained under $EC_{A'}$ ranged from 11 to 19 with an $\overline{X}$ of 13.83. Under $EC_{B'}$, the obtained scores ranged from 13 to 18 with an $\overline{X}$ of 14.83. $EC_{A'}$ + $EC_{B'}$ combined scores ranged from 25 to 37 with an $\overline{X}$ of 28.67.

The difference between the mean A score and the mean B score clearly was of inconsequential magnitude, hence these means were treated together as a CC score. The difference of the six judgments between A' and B' was tested statistically through the use of a t test (Pophams, 1966). The resultant t of 0.975 (df 5) did not approach the value of 2.015 required for significance at the 0.05 level of confidence. This nonsignificant t indicates that subjects did not adapt demonstrably to the altered pinnae condition and permitted the grouping of A' and B' scores together for purposes of analyzing the difference between CC and EC.

TABLE 1

Summary of Total Number Correct Judgments for Each Condition Over the Entire Test Period

Subject	CC			EC		
Number	A	B	A + B	A'	B'	A' + B'
1**	30	30	60	12	13	25
2**	29	30	59	16	13	29
3**	30	30	60	12	15	27
4**	30	30	60	11	14	25
5*	28	30	58	19	18	37
6*	30	30	60	13	16	29
Total	117	180	357	83	89	172
Mean	29.5	30.0	59.5	13.83	14.83	28.67

*Group I received CC first.

**Group II received EC first.

The difference of 30.83 between the $\bar{X}$ of CC and the $\bar{X}$ of EC scores gave rise to a t of 20.36. This far exceeds the value of 6.859 required for significance at the 0.001 level of confidence. The accuracy with which Ss performed the localization task was seen to have been significantly reduced when pinnae alteration occurred.

It is of interest to note that a relatively direct relationship existed between scores under CC and those under EC for these Ss. A raw score r correlation coefficient of 0.912 was obtained (using A + B scores). This r exceeds the value of 0.874 required for significance at the 0.01 level of confidence and indicates strongly the existence of more than a chance relationship between the two sets of scores. Whatever the effects of pinnae alteration, there would appear to be factors unaltered by this experimental condition which play a significant--but not exclusive--role in sound localization.

Inspection of the data (Figure 5) shows that the two Ss of Group I did perform better than most of the Ss of Group II in the EC. This analysis suggests that task familiarity or lack of it may have influenced the results. During the testing several Ss complained about having something in their ears while others reported that it helped to move their eyes toward the stimulated side. Weerts and Thurlow (1971) seem to support the impression that eye movement may influence the results. Most Ss felt uncertain about the accuracy of their localization judgments under the altered condition but did not feel this uncertainty in the normal pinnae condition. In fact, two Ss had difficulty determining if the sound came from the left or right side. However, Hochberg (1966) and Rosenweig (1961) reported that their Ss had no such right/left confusions.

In its final analysis, the pinnae theory seems to have increasing validity and should be considered

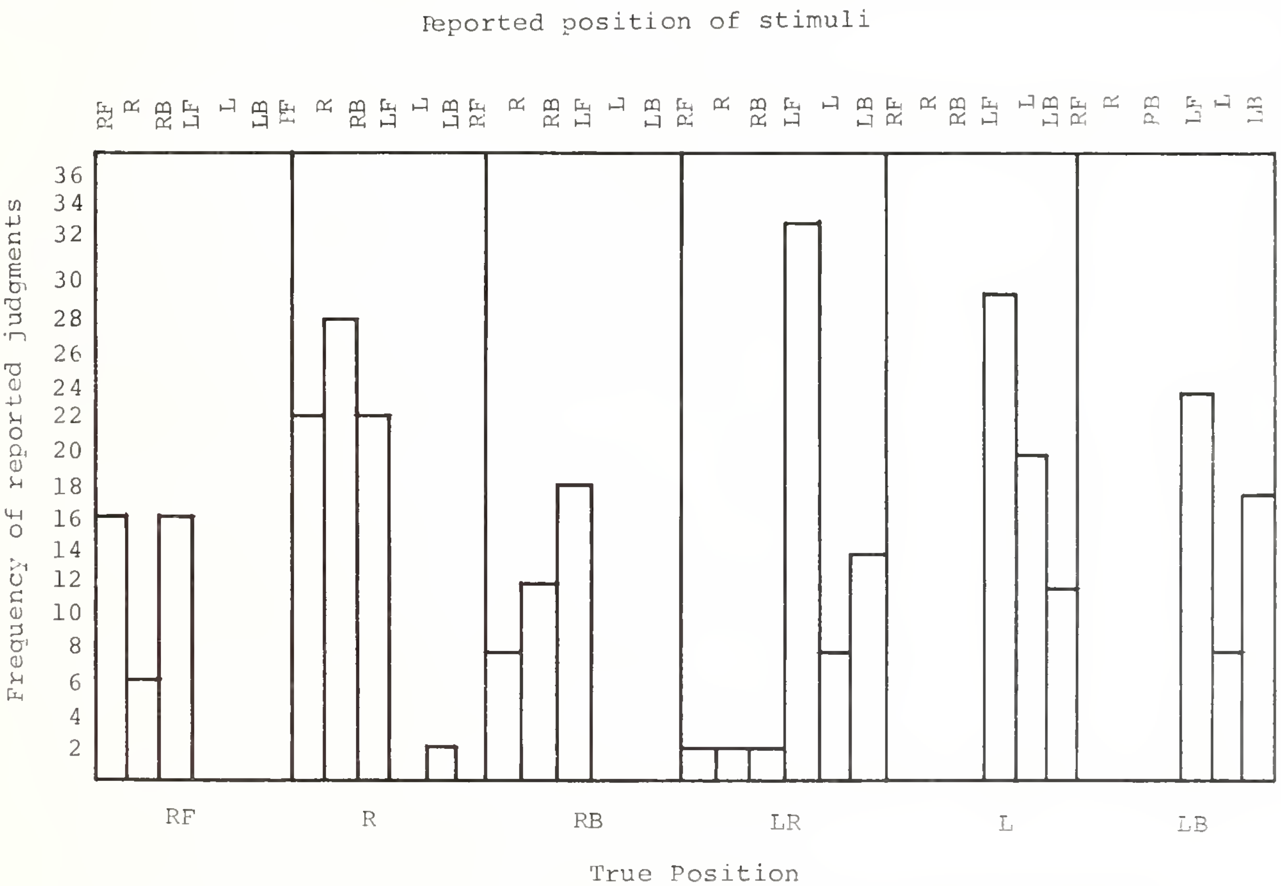

Figure 5. Histogram Illustrating Frequency of Reported Judgments of Sound Position, and Their Relationship to the True Sound Position.

whenever sound localization is discussed. Frequently, improved localization is used as an argument for the binaural fitting of ear-level hearing aids (Carhart, 1958; Kodman, 1961; Dirks and Wilson, 1969). However, a realistic look at sound localization theory raises serious questions about this assumption. Whereas binaural hearing aids may provide gross cues to identify the side from which a sound emanates, they cannot provide the discrete information provided by the pinnae. If one considers that phase cues, intensity cues, time cues, and the pinnae may all play a role in providing maximum information for sound localization, one must also consider that all of these prerequisites are disrupted by hearing aid circuitry and earmold. This entire area of sound localization and hearing aids deserves serious exploration.

In our fast moving society, rapid and successful localization is frequently paramount to staying alive. This is true for the normal sighted person but is of even more significance for the blind or partially sighted individual who is dependent upon his hearing to maintain environmental contact (Conkey and Schneiderman, 1968). The implications of the pinnae theory should henceforth be considered whenever mobility skills of the visually impaired are discussed. Such implications are even more critical for the hard-of-hearing blind.

It is interesting to note that there was no evidence of a statistically significant amount of adaptation to the functional loss of pinnae. This may be due to the lack of a sufficiently discrete task which might better detect adaptation or to the lack of sufficient opportunity for adaptation to occur. It is also possible that the human organism cannot adapt to the functional loss of pinnae in sound localization.

SUMMARY

This study reviewed the role of the pinnae in the phenomenon of sound localization and investigated the ability to adapt to the functional loss of pinnae. A train of pulses of white noise were presented to six normal-hearing Ss individually. The Ss were asked to identify the source of sound from one of six speakers in the absence of head movements under two conditions. The control condition (CC) tested sound localization with the pinnae unaltered. The experimental condition tested localization with the pinnae covered by a modified earphone for a period of one hour per day for five days. In both conditions, the testing was done at the beginning of an hour and again at the end of an hour.

Statistical analysis of the data indicated that under the conditions of this study, Ss could localize significantly better with the pinnae uncovered than with the pinnae covered by a modified earphone. There was not sufficient evidence to conclude, though, that these subjects adapted to the functional loss of pinnae by regaining their ability to localize as well as they did with the pinnae uncovered.

Acknowledgments

Rarely is one able to successfully complete a task such as this entirely on his own. I would like to take this opportunity to thank those who facilitated the completion of this work: Dr. Robert Erickson, Dr. Courtney Stromsta, Mr. William Dawson, and Dr. Harold Bate.

Special acknowledgment must go to Dr. Harold Bate whose patience, prodding, and critical consideration of all aspects of this project guided its completion.

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Acknowledgment must also be extended to my wife, Diane, for her patience during the most crucial periods of this endeavor.

APPENDIX A

Score Sheet

Pretest--to assure that subject understands task

	RB	LF	L	R	LB	RF	Correct	Incorrect
First Daily Test								
Test Day One	R	LF	LB	RB	RF	LF		
Test Day Two	RB	L	R	RB	LF	RF		
Test Day Three	L	LB	R	RB	LF	RB		
Test Day Four	L	RF	RB	RF	R	LF		
Test Day Five	RF	LF	L	LF	R	RB		
					Total			
Second Daily Test								
Test Day One	LF	LB	R	L	RF	LF		
Test Day Two	RB	LB	L	LF	R	RB		
Test Day Three	LB	RB	LB	R	LF	LF		
Test Day Four	L	LF	R	LF	RB	LB		
Test Day Five	LF	RF	L	RB	LF	LB		
					Total			

CC

EC

Group I/Group II

RF--Right Front
R--Right
RB--Right Back

LF--Left Front
L--Left
LB--Left Back

Name

Brace Setting

1) Back
2) Top
3) Nose

REFERENCES

Angell, J. R., and W. Fite. "The Monaural Localization of Sound." *Psychological Review*, 1901, Vol. 8, pp. 225-46; 449-58.

Arkins, Herbert, and Raymond R. Colton. *Tables for Statisticians.* New York: Barnes & Noble, Inc., 1963.

Batteau, D. W. "The Role of the Pinnae in Human Localization," *Proceedings of the Royal Society*, London, CLXVIII No. 1011 Series B, 1967, pp. 158-80.

Bauer, R. W., and R. F. Blackmer. "Auditory Localization of Noises," U.S. Army Human Engineering Laboratory Technological Memo 4-65. Aberdeen, Maryland, January, 1965.

Bauer, R. W., J. L. Matuzsa, R. F. Blackmer, and S. Glucksburg. "Noise Localization After Unilateral Attenuation," *Journal of Acoustical Society of America*, 1966, Vol. XL, pp. 441-4.

Bekesy, G. von, and W. A. Rosenblith. "The Mechanical Properties of the Ear," *Handbook of Experimental Psychology*. Edited by S. S. Stevens. New York: John Wiley & Sons, Inc., 1951.

Carhart, Raymond. "The Usefulness of the Binaural Hearing Aid," *Journal of Speech and Hearing Disorders*, 1958, Vol. XXII, pp. 42-51.

Carroll, Reverend Thomas J., and Leo H. Riley. "Human Communication and Its Disorders: An Overview." U.S. Department of Health, Education, and Welfare Monograph No. 10. Bethesda, Maryland: National Institute of Neurological Diseases and Stroke, 1970.

Conkey, H. O., and C. R. Schneidermann. "The Effect of CROS on Auditory Localization and Mobility of a Blind Person," *Exceptional Child*, 1968, Vol. XXXIV, pp. 705-6.

Dirks, D., and R. Wilson. "Binaural Hearing of Speech for Aided and Unaided Conditions," *Journal of Speech and Hearing Research*, 1969, Vol. XII, pp. 650-64.

Fisher, H. Geoffrey, and Sanford J. Freedman. "Role of the Pinna in Auditory Localization," *Journal of Auditory Research*, January 1968, Vol. VIII No. 1, pp. 15-26.

Hochberg, Irving. "Median Plane Localization of Speech," *Journal of Auditory Research*, July 1966, Vol. VI No. 3, pp. 277-81.

Kodman, Frank, Jr. "Successful Binaural Hearing Aid Users," *Archives of Otolaryngology*, 1961, Vol. LXXIV, pp. 302-4.

Myklebust, Helmer. "Sensory Deprivation and Behavior," *Psychology of Deafness.* New York: Grune and Stratton, Inc., 1964.

O.Neill, John J., and Herbert J. Oyer. *Applied Audiometry.* New York: Dodd, Mead & Company, 1966.

Pophams, W. James. *Educational Statistics.* Evanston: Harper & Row, 1966.

Rintelmann, William, E. Harford, and S. Burchfield. "A Special Case of Auditory Localization: CROS for Blind Persons with Unilateral Loss," *Archives of Otolaryngology*, March 1970, Vol. LXLI No. 3, pp. 284-8.

Rosenweig, Mark R. "Auditory Localization," *Scientific American*, Vol. CCV No. 4. San Francisco: W. H. Freeman Company, October 1961, pp. 132-42.

Stevens, S. S., and H. Davis. *Hearing.* New York: John Wiley & Son, Inc., 1938.

Stevens, S. S., and Fred Warshofsky. *Sound and Hearing.* Editors anonymous. Time-Life Books. New York, 1970.

Weerts, Theodore C., and Willard R. Thurlow. "The Effects of Eye Position and Expectation on Sound Localization," *Perception and Psychophysics*, January 1971, Vol. IX, pp. 35-9.

TRANSPOSITION IN MENTAL SPATIAL MANIPULATION

A THEORETICAL ANALYSIS

Jyrki Juurmaa*

This survey is exclusively concerned with the phenomena related to the transposition of *spatial relationships* from one modality sphere to another. The research results gained so far in this field are fragmentary. Yet the more systematic the form in which the observations and research findings related to a problem area are put, the easier it will be to see the gaps and weak points in our knowledge of this area. A systematic exposition may also create a frame of reference indicating the directions in which research efforts should be concentrated, and may reveal how problems in the field are interrelated.

It is hoped that a survey of this kind will pave the way to a comprehensive theory. The most profound sort of satisfaction a researcher can feel springs from the discovery of how any individual phenomenon forms part of a more extensive structural whole.

THE CONCEPT AND ITS ORIGIN

Primacy of Vision

The concept of transposition in mental spatial manipulation is rooted in the view that vision always occupies a position of primacy relative to the other senses. This view has guided concept formation and influenced the choice of problems in many fields of psychology, especially in the psychology of perception and in gestalt psychology but also--and this will prove relevant in this paper--in the differential psychological investigation of mental abilities.

In the analysis of the structure of intelligence, attention has been focused exclusively on a single aspect of spatial ability, the so-called visual or visualization ability. This has been analyzed extensively, and its relationships with a variety of other mental abilities have been explored, *but no attempt has been made to discover how it is related to mental manipulation in space on the basis of sense modalities other than vision.*

The Proposition of Révész and Its Generalization

The basic idea underlying the transposition concept here in question is apparent from the following words of Révész:** "The tendency towards perfecting and supplementing the haptic impression of form is achieved *by a transposition of the contents of our haptic perceptions into visual images.*"

The literature dealing with this phenomenon, which is far from extensive, suggests that Révész's assertion can be expressed in a more general form: Where operations with spatial relationships based on senses other than vision are called

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**If not otherwise indicated, all assertions of Révész referred to in this paper are contained in his *Psychology and Art of the Blind* (1950).

for, they are performed by transposing the relevant sense-data or images peculiar to these other senses into visual images and by carrying out the task ideationally within the field of the sense of vision.

"Transposition" in the Literature

The term *transposition* is employed in this sense neither generally nor uniformly in psychological literature. This is simply because there is no general psychological theory concerning the "replacement" of spatial images peculiar to one sense department by those peculiar to another, and thus there has also been no corresponding "theory of transposition in mental spatial manipulation." The phenomena subsumed here under the transposition concept have previously been named variously by various authors in various contexts; not only the term transposition but also terms such as "translation," "transformation," "transfer," "perception across modalities," "association," have been used to denote them.

It is also worth mentioning that the *Dictionary of Psychology* (Drewer, 1956), does not include the term transposition (Révész's work appeared in English translation in 1950). Nor does the dictionary contain references to the displacement of sense data from one modality to another under the other possible terms (transformation, translation or transfer) in mental spatial manipulation. This may be taken as a further indication of how undifferentiated the analysis of the phenomena of spatial transposition is.

"Transposition" in This Paper

In the present paper the term *transposition* will be used in the broadest sense possible, *to denote the displacement of sense data, sensory images, and mental pictures associated with spatial functioning from one modality sphere to another* (or the replacement of such sense data peculiar to one modality by others peculiar to another modality), no matter how this displacement (or replacement) takes place.

Transposition may take place in such a way, for instance, that spatial relationships patterned by means of one sense modality are transposed into another sense department to be manipulated or to be operated upon. For example, tactually patterned relationships are to be transposed into an equivalent, larger "walking locomotion pattern." Such transposition may be in principle either direct or indirect. The latter meaning for instance that visual imagery serves ideationally as a mediating modality.

In consequence, Révész's hypothesis concerning the so-called optification tendency in tactual spatial manipulation is a special case of transposition as defined here.

Thus, the term transposition is employed here to denote a generic concept embracing all thinkable kinds of displacement of sense data in spatial functioning, and only future research will reveal what kind of conceptual framework should be subordinated to this generic concept.

An attempt will be made in this paper to demonstrate that transposition in any meaning of the word is in itself a very complex phenomenon. For the present we do not even possess a conceptual framework adequate for the description of the nature of the various phenomena and activities subsumed here under the transposition concept. An effort will be made to sketch such a framework and, moreover, to form a picture of the various psychic functions and performances distinguishable in the transposition phenomena.

PRELIMINARY CONCEPTUAL CLARIFICATIONS

Transposition and Apprehension of Space

The apprehension of space should be distinguished conceptually from spatial sense data, impressions, images, and mental pictures. Even if any sense data whatever could be transposed from one modality into another, in one way or another, this would not imply that we would be able to perform a corresponding transposition within the sphere of the apprehension of space. The concept of apprehension of space is very problematic and indefinite in itself. From the standpoint of the present paper the meaning to be given to this concept will be highly relevant.

Senses Considered as Perceptual Systems

Before proceeding to consider the transposition phenomena, the level of description on which the discussion will move should be specified, by making clear what is meant when we speak about senses. Especially within the sphere of the kinestetico-proprioceptive sensory functions it is, in practice, anything but clear what is actually meant by senses.

The traditional physiological-psychological classification of specific receptors and senses will not be applied in this paper. Instead, the level of description and classification will mainly follow lines similar to those adopted by Gibson (1966), and we will consider senses as perceptual systems. To put it briefly, we might say that a perceptual system is a kind of hypothetical spatial modality.

This view is consistent with those previously presented by Katz (1925) and Révész. According to Révész "the hand is a kind of *sense organ* as distinguished from the skin of hand." In reference to this assertion of Révész, Gibson (1962) stresses that the *active touch* is not a sum of the kinesthesis of finger movements and the touch sense of the skin; instead, the perception based on the active touch has to be dealt with as an independent modality on its own. This integration of modality spheres is of such a great bearing on thorough analysis of the spatial transposition phenomena that a somewhat longer quotation of Gibson's views on what the senses really are is called for.

> "There are two different levels of sensitivity. It will be evident that the so-called sense organs are of at least two different sorts: the passive receptors that respond each to its appropriate form of energy, and *the active perceptual organs*, better called systems, that can search out the information in stimulus energy. The receptors have measurable thresholds below which they are not excited: the organs and systems do not have fixed thresholds except as they depend on receptors.
>
> "Similarly, there are different levels of stimulation. The stimulus energy of optics, mechanics, and chemistry is coordinate with receptors, but the *stimulus information to be described is coordinate with perceptual systems*. Stimulus energy varies along simple dimensions like intensity and frequency, but stimulus information varies along innumerable complex dimensions, not all amenable to physical measurement.
>
> "Instead of supposing that the brain constructs or computes the objective information from a kaleidoscopic inflow of sensations, we may suppose that the orienting of the organs of perception is governed by the brain so that the whole system of input and output resonates to the external information.
>
> "The question, then, is how the senses work? Since the senses are being considered as perceptual systems, the question is not how the receptors work, or how the nerve cells work, or where the impulses go, but how the system works as a whole. We are interested in the useful senses, the organs by which an organism can take account of its environment and cope with objective facts."

Views of the above kind mean the adoption of an entirely new attitude towards the fundamentals of the theory of perception, which differs particularly sharply from the one that has previously been typical of Anglo-Saxon researchers. *According to these views, the* *"modalities" come into being more in the central than in the peripheral parts of the nervous system.* How exactly this takes place is a point concerning which Gibson presents no assumptions. At least for the present his description is wholly pragmatic; it, in fact, merely amounts to the observation, in various practical contexts, that perception must be something else other than the sum of various sense-specific functions or activities.

The term *kinesthesis* is used in a very wide sense in psychological literature. The regulation of all movements in any part of the body is said to be based on the kinesthetic sense. Nevertheless, no such specific sense exists. Gibson (1966) states that kinesthesis is "one of the best examples of detection without a special modality of sensations."

What hypothetical modalities or perceptual systems suitable for the description of spatial functioning, and transposition phenomena in particular, can be distinguished in the sphere of kinesthesis and haptics?

The following classification and terminology should be regarded as tentative and is created for pragmatic purposes. The empirical studies carried out so far have also been taken into consideration, in order to facilitate the description of the results and functions in uniform terminology.

Cutaneous-perceptual systems. These are involved in perceptions by means of the skin in cases where the perceiving subject is completely passive. (The situation could be characterized by saying that "something happens on the skin" and the person concerned seeks to pattern it.)

It is important to make a distinction between two kinds of cutaneous perceptual systems: (a) *simultaneous systems*--a wire bent into the shape of a triangle is pressed against the skin and (b) *successive systems*--a figure is drawn on the palm of the hand successively.

Stereoplastic-perceptual systems (resting touch). Here a perception of form comes into existence when an object remains in the grasping grip between the fingers, for example, or between the fingers and the palm of the hand. What is essential here is that the surface of the skin is not moved along the surface of the object.

Tactile-perceptual systems (active touch). This is a typical sort of form perception in the haptic sphere. An attempt is made to obtain a picture of the object by moving the fingers and the palm of the hand along its surface. A good example of this kind of perceptual activity is given by the following quotation from Gibson (1962), who employs the term "active touch."

> "When a person touches something with his fingers he produces the stimulation as it were. More exactly, variations in skin stimulation are caused by variations in his motor activity. What happens at his fingers depends on the movements that he makes--and also, of course, on the object that he touches. Such movements are not the ordinary kind usually thought of as responses. They do not modify the environment but only the stimuli coming from the environment. Presumably they enhance some features of the potential stimulation and reduce others. They are exploratory instead of performatory. In this respect these touching movements of fingers are like the movements of the eyes. In fact, active touch can be termed *tactile scanning*, by analogy with ocular scanning."

Brachial-perceptual systems. This is involved when the perception of form takes place by means of the arms. Brachial form perception, in its purest form, would be in question if a person tried to draw given figures in the air purposefully (so that the tactile component would be eliminated). Yet it can be maintained to be involved also where a blind person, for example, tries to detect the shape of a piece of furniture by means of the cane.

Ambulatory-perceptual systems. These are involved in the mastery of locomotion patterns. For example, the subject has to walk in a straight line, to repeat a closed walking path.

These terms of reference in mind, we shall later discuss what possibilities there are, within what is traditionally called *haptics*, to apprehend spatial relations and to transpose these--in one way or another--from system to system.

The most important question, which also has points of contact with the theory of cerebral (cortical) localization is: to what extent can mutually-independent spatial-ability factors be distinguished within (traditional) haptics? In other words, how are spatial performances based on various perceptual systems or hypothetical modalities intercorrelated?

TRANSPOSITION AND PREVIOUS VIEWS ON SPACE-GENERATING SENSES

Philosophico-psychological tradition contains few explicit assertions about transposition of spatial relationships. Nevertheless, various conceptions previously advanced and held concerning "space-generating" senses do have certain implications regarding the transposition phenomenon.

At this point it is sufficient to mention the following five, which have implications concerning sensory spatial transposition:

1. The apprehension of space is based primarily on haptics,* and optic space is something that must be learned, in a sense, by means of transposed images.
2. The apprehension of space is learned primarily on the basis of optic images. This view has the consequence, for instance, that the congenitally blind do not primarily possess a conception of space.
3. The apprehension of space has its primary basis in both the optic and haptic spheres.
4. Whichever of the above views is adopted, there can be no independent acoustic space. In other words, auditory perceptions may only be transposed in some way or other into the optic or haptic sphere.
5. Vision is the dominant sense in the apprehension of space.

These assertions will be discussed in relation to the following questions:

1. On which sense modalities is the apprehension of space based primarily?
2. On the basis of which modalities is the apprehension of space possible in principle?
3. What is the relation between spatial dominance and ontogenetic development?

Only some of the most representative opinions will be described here briefly, disregarding all the numerous variants of these main propositions.

Vision as Primary Spatial System

After analyzing practically all the known documents concerning the blind who had recovered from blindness through operation, von Senden arrived at the conclusion that those born blind do not possess any primary awareness of space. This maintains that the apprehension of space is based exclusively on vision.

> "Von Senden (1960) goes so far as to maintain that, for the congenitally blind, ordinary straightforward movement only means a kind of. . . 'dynamic state of equilibrium,

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*In this instance the term haptics will merely be used to introduce the transposition conceptions implicit in philosophico-psychological tradition.

in which both sides of body are equally in tension, but in which the whole bodily tone is displaced forwards. The legs, indeed, are in rhythmic motion, but even under this tension the upper part of the body seems to them to remain as it were stationary and persistent.' It is 'unnecessary to assume that they [the blind] have any adequate consciousness of the objective change of location they effect by means of this walking motion. What a sighted person regards as his line of advance is for them a knowledge that after a certain number of steps they will reach the object sought, provided they continue in this characteristic bodily posture."

Thus, in von Senden's opinion, what the congenitally blind possess are merely locomotion schemata of a kind constituted by the ratios of successive muscular tensions or the time periods requisite for various movements. Regarding tactual spatial manipulation, again, von Senden maintains that the blind seek to discover the relevant identifying qualitative characteristics, rather than to collect material for actual form perception. For example, a blind person, rather than experiencing angles as changes in spatial relationships, experiences them as qualitative differences in dynamic motion. In the congenitally blind the apprehension of geometric figures also rests on successive kinesthetic rhythmicity.*

What, then, is the transposition like that occurs in the early blind, for example, in the direction "tactual-perceptual systems"--"ambulatory-perceptual systems" or in the opposite direction? As will be seen later the congenitally blind are able to transpose forms in both of these directions. How is "a certain number of steps" transposed into "a certain number of finger movements?" Granting that this is possible, as it actually is, what can be meant by asserting that it is unnecessary to assume that the congenitally blind possess an apprehension of space? What do we mean by the apprehension of space in this context? This point will be discussed more thoroughly later on.

The conclusions drawn by von Senden from the spatial performances of the operated blind are erroneous in several respects. For a discussion of this point see Juurmaa (1965). As will also be demonstrated later in this paper, there are no grounds for assuming that those born blind are in principle devoid of a mastery of space. Quite the contrary, they are able to master it at least in the functional sense of the word. What is meant by an "awareness of space," for example, from the phenomenological point of view, is another epistemological question.

It seems likely that investigation of the transposition phenomena in the congenitally blind (within various perceptual systems) will open up entirely new vistas concerning the apprehension of space in the absence of vision.

Haptics as Primary Spatial System

Berkeley, the philosopher, was first to advance the view that visual impressions of space are primarily derived from haptic spatial impressions. The visual space is learned through associating haptic impressions with their corresponding visual impressions. Yet is is by no means clear exactly what Berkeley meant by his statement. Apparently, however, it had to do with two kinds of phenomena:

1. The apprehension of optic space comes into being by associating visual impressions with (or transposing them into) primarily

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*However, von Senden was not the first to advocate such views. According to Révész (1950), Platner, in his *Philosophische Aphorismen* (1793) stated: ". . . to those born blind time serves instead of space." According to Lotze (1852) again, the space conception of the blind was an artificial system of conceptions of movement, time, and effort.

three-dimensional haptic impressions. (According to Berkeley, the three-dimensional impressions that an infant has belong initiallv to the haptic sphere. He thus seems to hold, in a sense, that a transposition of the apprehension of space from one modality sphere into another is possible.)

2. The impressions received of similar figures through different senses are completely different qualitatively. This also means that it is impossible to know that the same figures are in question, except through associating them with each other. (For example, the generic modality-unspecific concept of triangle has been learned by associating visually-perceived and tactually-perceived triangles with one another. Generally speaking, we do not know which forms in different sensory spheres correspond to each other except by way of association.)

Thus, Berkeley actually posited two modes of spatial transposition: *Transposition of the apprehension of space* and *transposition of meaning.*

The first of these points will be discussed later. The transposition (association) of meaning will be shown in connection with Révész's propositions and Worchel's studies, that *what is concerned in the so-called optification tendency is actually association or "transposition" of the meaning of a form familiar from past experience.* This is an entirely different thing from what Berkeley meant.

Berkeley would have been surprised to find that a bottle can be recognized immediately by touching or scanning it with a toe, even without seeing it and in the absence of previous experience. Here we assume that he knew that the nervous pathways connecting the toes to the cerebral cortex are different from those connecting the fingers to the cerebral cortex. The above two transposition concepts are implied by Berkeley's propositions, and each of them can and will be given a reasonable content; nevertheless, both propositions formulated by Berkeley were incorrect or only partly correct.

> "Certain child-psychological conceptions have points of contact with the view that haptics is the primary spatial system. According to Jean Piaget's ontogenetic spatial theory, the first spatial operations a child comes to understand involve primitive notions of proximity, enclosure and boundary, which are non-metric in character and obviously based on haptic sensations. From Piaget's (1956) account it is not completely clear what is, in his opinion, the bearing of this primary position of haptics on the later phases of ontogenetic development. Also, the Russian school of learning theory has something in common with the conception that haptics is the primary spatial sense, e.g., Sechenov thought that the representation of spatial relationships of objects is based on the indications of the sensory instruments located in the muscles." (Semyakin, 1959)

Haptics-Vision as Primary Spatial System

It is impossible to say which perceptual system is primary in an absolute developmental-psychological sense when the apprehension of space begins to evolve in the infant. It is fully justifiable to speak of a primary space to the development of which all sense modalities have made a contribution. It is wholly impossible to distinguish one from the other the parts played by the kinesthesis of arms and legs, tactual and visual perceptions, the kinesthesis of the eye movements, the vestibular functions, and, perhaps, acoustic stimuli.

According to Révész, we have to assume that both vision and haptics are primary senses (perceptual systems) with respect to spatiality. He cannot see any well-founded reason why the one but not the other would be primarily spatial. "Only very special reasons could justify such an assumption, which from the point of view of theory formation is definitely superfluous." His views concerning primary spatiality are based on his experience with the congenitally blind. He had observed that, in principle, Euclidean geometry did not present difficulties to the congenitally blind. (This does not contradict Révész's transposition theory, maintaining that, despite everything, spatial operations are carried out by means of visual images, whenever possible.)

Commenting on the view that the apprehension of space rests primarily either on haptics or on optics alone, Révész makes another important observation, "It can hardly be assumed that the representatives of such an 'empiristic' nativism have pictured what such a *secondary world of space* would be like compared with the primary one."

The concept of a secondary world of space and the problem dealt with by Révész are crucial to our considerations of the transposition phenomena. The terminology suggested by Révész is very appropriate, but he does not succeed in giving reasonable content to it. This is due mainly to his further propositions. Révész definitely holds first that the apprehension of space cannot be transposed from one modality sphere to another. Secondly, he feels that the apprehension of space is possible only on the basis of haptics and vision. Hence an independent acoustic space, for instance, cannot exist. Arguments presented by Révész in support of this view will be dealt with later.

These propositions confront us with the crucial question which Révész does not consider: to what extent can the apprehension of space and the transposition of the apprehension of space be regarded as something absolute or as something relative? This point will be discussed under the heading "Analysis of Révész's Conception of Transposition."

The Question of Autonomous Spatiality

A distinction should be made between primary and autonomous spatiality. Révész's propositions imply that vision and haptics are both primarily and autonomously spatial modalities. On the other hand audition ("acoustics") is neither primarily nor autonomously spatial (1937 and 1946). Neither Révész nor anybody else has used the term "autonomous" in this sense. A distinction is made here between primary and autonomous spatiality for the sake of convenience, in order to facilitate further discussion.

What, then, do we mean by saying that a perceptual system is autonomously spatial?

The most important criterion suggested by Révész is that for a sensory space to have a true spatial character, measurement of distance must be possible, as it is in the case of vision and haptics. As Révész sees it, acoustic space does not satisfy this criterion. He refers to haptics and vision as the *space-and-object-perceiving senses*, feeling that the space-forming function of experience is characteristic of these two modalities alone.

Yet a dichotomous classification is hardly more appropriate here than in the case of primary spatiality; rather than asking whether or not a sense modality is autonomously spatial we should seek to determine the extent to which it is autonomous in this respect. Thus it is interesting to consider various sense modalities in the light of the following criteria, which are also relevant to the question of transposition. In the case of any one sense modality we may ask:

1. Does the fact that some other sense modality is non-functional prevent or render difficult spatial operations and manipulations based on this modality?

2. Are spatial operations and manipulations based on this sense modality possible only in such a way that the sense data in question are transposed, in one way or another, into some other modality sphere or spheres? If this is the case, the following question arises: What are the functions like on the basis of which the spatial patterning actually takes place?

3. Are operations with spatial relationships possible at all on the basis of this modality?

4. How does the estimation of spatial directions and distances take place on the basis of this modality?

Let us briefly consider how the above questions should be answered in the case of vision, haptics, audition and the vestibular-postural-proprioceptive sphere.

Vision

The figures in parentheses refer to the above questions.

(1) We cannot know how the elimination of haptics would affect the spatial functioning resting on vision, since haptics cannot be eliminated. (By investigating the deaf it is possible to gain knowledge of the influence of audition via language upon visual patterning.)

(2,3) There is nothing to suggest that vision would not be both primarily and autonomously spatial. *Vision presumably forms the sphere from which spontaneous transposition to other modalities takes place less frequently than from any other sphere--if ever.*

(4) Révész's criterion of "true spatiality" was obtained from vision: distances should be measurable, or capable of apprehension, as in the case of vision. Yet he did not pay sufficient attention to the fact that measurability has its limitation in the sphere of vision too. When distances are long enough or short enough, they cannot be mastered visually. Thus, measurability within the visual sphere is a relative concept rather than an absolute concept. This actually holds true for all modalities.

Haptics

(1) The performances of the congenitally blind demonstrate that, even where vision is absolutely absent (i.e., where it is not present even in the form of images), does not prevent haptic patterning. The way in which the absence of vision renders haptic patterning difficult will be considered later in connection with the discussion of Révész's transposition theory and in the survey of experimental studies. It is obvious *a priori* that haptics is less autonomous than vision. Or more correctly, *haptics is autonomous within narrower limits than vision.*

(2) The origin of the concept of transposition is related to this point, as was indicated earlier. What is meant by the so-called optification tendency is a general inclination for an individual to visualize any haptically-perceived spatial relationships, which visualization is assumed to facilitate performance. In the section on experimental studies it will be indicated that at least the latter assertion is tenable only as far as the patterns concerned are familiar from past visual experience.

(3) Within certain limits, spatial functioning is entirely possible on the basis of haptics alone, without any need for transposition into other modalities. (We do not yet know how broad or how narrow these limits actually are.)

(4) Révész's measurement-of-distances criterion may best be satisfied in the sphere of haptics. It should be pointed out that, where small differences in perception are concerned, haptics is usually relied upon to check visual perceptions.

Audition

(1) It is impossible to find out whether the first criterion is or is not satisfied, as it is virtually impossible to picture a person in whom both vision and haptics are nonfunctional.

(2) Audition is the sphere which has generally been regarded as non-spatial in the sense that auditory-spatial apprehension has been considered impossible except insofar as auditory sense data can be transposed into the field of vision, haptics or both.

In the case of audition, what is meant by autonomous spatiality depends critically on the answer we will find to the second question. Within our terminology we also ask whether there is a relationship between auditory spatial functioning and autonomous auditory spatiality. Because the possibility of auditory spatial performances has generally been denied, it is obviously not meaningful to introduce audition as a separate spatial modality in the present discussion unless arguments speaking against this current conception can be found. Therefore, it is necessary to consider this point rather thoroughly.

Von Senden argues: to ask whether an auditory space exists or not is tantamount to asking whether the perception of a sound, heard in complete separation from all other sounds, leads not only to a perception of the quality and intensity of the sound but also to a *spatial awareness* of the direction of the sound source and its distance from the observer. This kind of inference concerning the nature of auditory space is accepted by many others but, in a sense, it is peculiar. It would be equally justifiable to ask whether a point seen in complete separation (against a blue sky, for example) leads to an estimation of its distance from the observer--to which the answer would obviously be negative.

How far a purely auditory space could exist independently of vision and haptics is a question to which no answer based on empirical evidence can be given. *It is obvious, however, that auditory as well as visual, spatial patterning presupposes the existence of more than a single point.* The question of an auditory space is summarized: *How far can various points perceived through audition organize into spatial patterns and to what extent are these patterns independent of the sensory contents of other sense modalities.*

Fleishman et al. (1958) in their studies obtained a factor constituted mainly of two tests involving the apprehension of rhythms and melodies respectively--or as Guilford put it, "two clear cases of auditory systems." Rhythm Discrimination was an adaptation of Seashore's test. In Hidden Tunes, pairs of short melodies were presented, the second member of each pair being slightly longer, and the subject had to say whether the second included the first.

Guilford terms this factor obtained by Fleishman a Cognitive-Figural-Systems-Auditory (CFS-A) factor. He refers to his SI-model (Structure of Intelligence). And he seems to consider this factor, curiously enough, analogous to the visual-spatial factor, "The inference might be that auditory space involves a secondary CFS-A factor (as he feels that the factor mentioned above involved too large an evaluation component), which is not likely. It is probable that sound localizations are within the visual reference frame. *This hypothesis implies that there should be substantial positive correlation between accuracy of auditory localization and performance on tests of visual-spatial orientation. This problem needs investigation."*

There is reason to mention in this connection that Witkin et al. (1968) employed a test which they called "The auditory embedded-figures test." This test developed by White (1953) is an auditory translation of the visual embedded-figures test. A short three-, four-, or five-note tune is played followed by a longer, more complex tune, which may or may not contain the simple tune. Four findings are relevant to our considerations and merit further discussion. First, White (1953) reported a significant correlation of 0.63 between scores for the auditory embedded-figures test and scores for the Thurstone Gottschald T figures test. Second, Witkin et al. obtained with the congenitally blind a correlation of -0.30 between "tactile embedded figures" and "auditory embedded figures." Third, the congenitally blind (12-18 years of age) did significantly worse than the sighted in "tactile embedded figures." Fourth, in auditory embedded figures the outcome was diametrically opposed to the tactual performances. The blind did significantly better than the sighted control group. The differences were clear in both cases.

Guilford (1967), whose views are important in that he is one of the few investigators who have at least paid some systematic attention to the possibility of auditory patterning, apparently does not regard spatial patterning based on audition as impossible, since he writes in another context: "One implication is that if auditory tests were analyzed more extensively, we should find still other factors having auditory affiliation. It is not unreasonable to hypothesize a complete set of six auditory-figural abilities. (Guilford refers here to his Structure of Intelligence Model.) It is not so reasonable to expect to find six auditory-spatial factors."

The question of auditory spatiality is a highly problematic one, and therefore there is reason to make a few comments on Guilford's views. Let us first pay attention to some fallacies implicit in Guilford's line of thought.

First, it is far from easy to realize what the cognitive systems component is that Guilford sees in the factor obtained by Fleishman. For example, in my studies (1965 and 1967), Seashore's tests of rhythm and memory for melodies obtained appreciable loadings exclusively on a sensory-discrimination factor. This factor is not in any case analogous to the visual spatial factor. As to the auditory-embedded figures test, which Witkin did not regard as cognitive, he interpreted the superiority of the blind in terms of perceptual learning: "With their greater alertness to auditory cues, the blind *seem to have greater ability to maintain prolonged attention to auditory material.*"

Second, the sound localization test probably does not measure in itself spatial ability at all. As was pointed out above, this ability can only be measured by tests involving the spatial patterning of a number of sound points. In my study (1965) with blind persons the sound localization tests fell on a factor on which two tests of obstacle sense and a test measuring the ability to maintain the direction of locomotion also obtained high loadings. These tests involved only the localization of a sound source, and action in accordance with this localization. On the other hand, sound localization did not correlate with tactual spatial ability. Nor was it expected to correlate with it. In other words, *sound localization was not regarded as associated with cognitive systems*. According to our assumption, Guilford is obviously mistaken if he believes that sound localization and visualization correlate. Moreover, Gomulicki (1961) found that the congenitally blind did at least as well as the sighted on sound source localization.

Thus it seems obvious that the above two approaches to the study of auditory spatiality are misleading. The correlation obtained by White between "auditory and visual embedded figures" has not found subsequent support (Fleishman, 1958). In investigating intermodal relationships of spatial performances, the embedded-figures-type tests are not very suitable because there are too many intervening variables. The inferiority of the blind to the sighted in tactile embedded figures, for instance, can be accounted for by visual familiarity of the component figures. As already mentioned, auditory modification measures perceptual learning, rather than pure mental manipulation in space.

Is it possible, then, to construct tests for the measurement of such ability? As we have seen, Guilford's stand in the matter is ambivalent; but is also obviously not aware of all relevant facts, including the observations made on the blind.

Differential-psychological auditory test methods similar in structure to well-known visualization tests, have not yet been developed. Whether such methods can be developed at all cannot be known without experimental investigation. In any case, I am designing a series of experiments for the study of spatial performances related to various modality spheres. Following is an example of an auditory method, planned to be used in our project.

The apparatus, a "buzzing cube," will consist of a cubic frame to be constructed of wooden laths with sides measuring 6m x 6m and to be divided into 27 smaller cubic frames with sides measuring 2m x 2m. Each of the points where two laths cross will be equipped with a buzzer. The buzzers will be sounded so as to trace three-dimensional "auditory curves" in space, and the subject is required to recognize the curves by identifying their tactual and/or visual equivalents from among a number of alternatives.

Regarding the autonomy of auditory spatiality we might argue as follows. The more a person has received training and practice in relating auditory perceptions to one another spatially, the better he will learn to operate with auditory spatial relationships alone and the less will be his need to transpose auditory perceptions to the fields of haptics, vision, or haptics-vision. We may postulate, by way of a working hypothesis, that an auditory space exists if we are able to perform auditory tasks analogous to visual and tactual spatial tasks.

We may also accept the view that, initially, audition is neither primarily nor autonomously space-generating. As already pointed out, there is no way of knowing anything about this matter. Yet we may assume, on the other hand, that it becomes increasingly autonomous as a function of ontogenetic development and practice. It can also be said that vision and haptics span an auditory space, as it were, and that it is possible for this space to attain relative autonomy. In other words, it can be assumed that the central nervous system gradually learns through experience to pattern the spatial relationships inherent in auditory perceptions, to an increasing extent, independent of the sensory contents of the other senses. We might call this kind of space secondary space. Thus, Révész's concept of "secondary world of space" seems reasonable.

Granting that such a secondary auditory space can exist, the following problem, for instance, becomes interesting from the point of view of transposition: How are purely auditory spatial performances of the congenitally blind and the seeing related to one another? In other words, how is the transposition of auditory sense data into the pure haptic sphere related to the transposition of such data to the visual and haptic-visual spheres? Is the "secondary" auditory space more autonomous in the congenitally blind than in the sighted because of perceptual learning, or is it less autonomous in consequence of the total deprivation of vision?

It will be interesting to investigate how the hypothetical auditory-spatial ability is related to spatial abilities associated with various senses, especially in the blind as compared with the sighted. The auditory area will assume a very crucial position in the theory of spatial transposition.

Our working hypothesis will be that a secondary autonomous auditory spatiality is at least possible.

As already mentioned, Révész feels that there can be no genuine auditory space, because distances cannot be measured within the auditory sphere the way they can be measured within visual and haptic spheres. But what do we mean by the measurement of distances? Their measurement on the basis of vision differs from their measurement on the basis of haptics. First, the accuracy attainable in purely optic measurement may depend upon past haptic experience. (Teuber and Rudel's experiments with Mueller-Lyer figures are considered later in light of this.) Second, an optic measurement of distances in the absence of an adequate visual and/or haptic frame of reference is difficult, if not impossible (estimation of distances at sea). In this respect, the estimation does not differ in principle from that met within the auditory sphere. If Révész considers that an accurate estimation of distances is impossible on the basis of auditory cues, he is definitely mistaken. This is shown by the experiments conducted at the Institute of Occupational Health (Juurmaa and Järvilehto, 1969), where the best blind subjects were able to estimate the distances of movable targets on the basis of their natural hearing functions practically as well as the sighted subjects on the basis of vision. (The distances involved were a few meters.)

Phenomenologically, of course, distances differ depending on the sensory route through which they are perceived, and in this respect Révész's criterion is arbitrary. We may reasonably ask what estimation of distances and directions is possible and within what limits? The estimation of both distances and directions is possible on the basis of audition, within certain limits. The crucial question is to what extent is it possible to investigate performances related to auditory spatial ability within these limits?

Vestibular-Postural-Proprioceptive Sphere

The theories of perception infrequently take the vestibular area into consideration. Yet is is inseparably involved in all perceptual activities (visual, auditory, etc.) associated with movements of the head and body. Gibson (1966) writes: "During active locomotion the animal controls the distance of the displacement and the amount of his turning. During passive locomotion he perceives the distance and the turn. Vestibular kinesthesis is useful for both behavior and perception."

What was said above about auditory space and the criteria of spatial autonomy also applies, by and large, to vestibular space. For example, the experiments of Witkin et al. (1954) show that vestibular-proprioceptive cues associated with postures of the body can be highly accurate.

Experiments were conducted at the Institute of Occupational Health (Juurmaa and Suonio) with the object of discovering how far spatial patterning is possible on the basis of vestibular-proprioceptive cues when vision, audition, and the "kinesthetico-locomotor" senses are eliminated. (The subject was pushed in a vehicle like a wheelchair along paths that formed certain figures, and he had to reproduce these afterwards by walking them out.) These experiments revealed that, at least, certain kinds of vestibular spatial performances are possible and it follows from our operational definition that we are justified in speaking of a vestibular space.

Gibson (1966) feels that, phylogenetically, the most primitive and, in this sense, the most primary form of space perception is the one based on vestibular functions.

It should be pointed out that interesting questions concerning the comparison of spatial performances of blind and sighted subjects similar to those related to auditory functions, can be posed in the case of "vestibular sense."

A Working Hypothesis

An operational definition of the apprehension of space was presented above. We felt that there was no reason to define apprehension of space in phenomenological terms. The main problems concerning the primacy or autonomy of a perceptual space arise from a confusion of functional with phenomenological concepts. Let us now introduce the following working hypothesis:

> The spatial functioning of the central nervous system seems to be independent, in principle, of the sensory-input line concerned. "In principle" means here that there is a tendency for any set of sensations (sense data) to organize into spatial patterns, irrespective of the sense modality involved. The strategies employed by the central nervous system in spatial performances

differ, however, from one sense modality to another. This organization may take place either directly, in such a way that the original sense data organize or are organized into spatial patterns, or indirectly, through transposition.

On Integration and Mastery of Spatial Relations as Functions of Ontogenetic Development

The following sections will call attention to certain points that may prove relevant to the development of longitudinal hypotheses relating to the transposition phenomena.

An evolutionary view relevant to our subject matter was expressed by Birch and Lefford (1964), "In large part the understanding of the mechanism underlying phylogenetic differences in the plasticity and modifiability of behavior has been based upon recognition that as one ascends in the vertebrate series from fish to man *the unimodal sensory control of behavior comes to be superseded by multimodal and intersensory control mechanism*."

The analogy established between phylogenetic and ontogenetic development is self-evident. As to the mastery of spatial relationships, the interaction and the integration of functions related to various modalities have been assumed to increase with the age of the child. Birch and Lefford have also carried out experiments concerning sensory interaction in spatial performances as a function of age (1963). As these experiments are important in many respects they, and the conclusion derived from them, are subsequently described rather extensively. Only the following quotation from another study (1964) by the same investigators is of relevance at this point: "The evidence for normal children strongly confirms the view *that the elaboration of intersensory relations represents a set of developmental functions showing age-specific characteristics and markedly regular curves of growth*."

Birch and Lefford in fact put forward the following developmental hypotheses:

1. *The integration of functions related to certain different senses is age specific.*

2. *The hierarchy of this age-specificity is regular.*

The above hypotheses evidently have important implications concerning the development of transposition phenomena. But, in the words of Birch and Lefford, "Despite the potential importance of the establishment of interrelations among separate sense modalities for behavioral maturation, little evidence is available on the development of the functioning of sensory interactions and interrelationships.

With these wide evolutionary perspectives as a background, let us consider more specific questions.

The Integrative Function of Vision. Gomulicki (1961) investigated the growth curves of various kinds of performances (dexterity, sound localization, tactual discrimination, spatial ability and spatial orientation, etc.) with 5- to 16-year-old congenitally-blind and seeing subjects. At the age of five, the seeing were superior to the blind in every respect. The curves for the blind and those for the seeing approached each other, at first slowly but later at an accelerating rate. The seeing were still slightly superior to the blind in certain kinds of performances at the age of 16 but in spatial orientation, for example, the blind were already a bit superior to the seeing. These spatial experiments are considered in greater detail later. At this point we are interested in the following question: How can it be accounted for that young blind children, mainly those between ages 5 and 10, are so definitely inferior to their seeing age-mates?

The following answer, suggested by Gomulicki, would have far-reaching consequences provided it proved to be correct: "When the missing sense is vision, the loss of its integrative function makes the task of developing effective use of the other senses a particularly difficult one. The child blind from birth starts with a handicap not only in vision, but in other senses as well."

In another context Gomulicki writes: "A very important function of vision is to integrate the perceptions of the senses; without vision these perceptions tend to remain discrete and unorganized. The child who has never benefitted from the integrative function of vision has a tremendous task to develop the use of his remaining senses even to the point where they are as effective as those of the sighted."

What does Gomulicki mean by the "integrative function" of vision? He does not elaborate his thesis. Apparently, however, the following main alternatives can be distinguished.

1. Had Gomulicki only meant that many times more material can be mastered simultaneously on the basis of vision compared with other senses, he would have been surprised to find that the congenitally blind do reach the level of the seeing in later years. He seems to take this as self-evident and is interested almost exclusively in the cause of retardation of the younger blind.

2. It is obvious, however, that vision accelerates the establishment of a general perceptual frame of reference in the infant. In other words, the seeing initially have a large field to which they can relate or transpose new perceptions. As far as figures or spatial relationships familiar from past experience are concerned, the so-called optification tendency no doubt comes into play. In this sense the seeing children undoubtedly have a decisive advantage.

3. The most problematic, are these words of Gomulicki: "The blind child has a tremendous task to develop the use of his remaining senses." What does this mean? Does it, for instance, mean that there is a kind of transfer from the more advanced visual spatial strategies to the spatial strategies peculiar to other senses? This leads to the question: To what extent are the spatial strategies of the central nervous system related to the various senses specific, and to what extent are they general? On the other hand, is transfer of learning from one spatial strategy to another possible in principle? Practically no evidence is available permitting us to answer these questions. (I have discussed the problem of "intermodal spatiality" in other contexts (Juurmaa, 1965; 1967.) Another possible interpretation of Gomulicki's view is that vision guides the movements of the hand to find relevant objects easily, and thus simply accelerates the feedback processes associated with the learning of tactual strategies.

Birch and Lefford have presented the view that the integration of functions related to different systems or modalities is age-specific. This raises the following additional question: How long does it take to learn a special strategy adequate to a particular sense modality? And this question has, of course, to do with the question of the interdependence of various modality-specific strategies. Both questions are crucial to the hypotheses to be formulated for a longitudinal description of the transformation phenomena.

Gomulicki's results show, however, that vision is not irreplaceable. In the present writer's opinion, the most plausible explanation for the retardation of the blind in the younger years is the interdependence of various modality-specific strategies, but the guiding role of vision in speeding up the feedback processes related to all other senses must also be taken into consideration.

Gomulicki's result concerning sound localization is highly interesting. Initially the blind were definitely inferior to the seeing, then the curves approached each other, and at age 16 or so they coincided. It was not the slow rate of development of auditory perception in itself, as Gomulicki seems to think, but the slow development of a haptic frame of reference. If we accept the view that auditory space is only "secondary" it is obvious that initially the blind lack a system into which auditory sense data could be related. But by the age of 16 such a system had obviously been developed, since the congenitally blind were slightly better than the sighted in sound localization. In this sense, it is highly interesting and relevant to note that it is apparently as easy to relate or transpose a certain sound source to a purely haptic as it is to a haptic-visual or visual frame of reference. (It should be recalled that according to Guilford [1967] the sound-localization ability belongs to the domain of visualization.)

Sense Dominance and Age. Schachtel (1959) maintains that when the child develops, the dominance of the proximal senses (haptics--in the broad sense) is replaced by a dominance of the distal senses (vision and audition). Such a shift has generally been considered characteristic of phylogenetic evolution also. Schopler (1966) discovered that up to the age of three, children clearly preferred tactual to visual play stimuli.

The question of sense dominance in spatial patterning and manipulation is also very important in considering educational methods. The results thus far obtained are rather ambiguous. For example, Wilson and Halvarson (1947) found that a two-year old congenitally-blind child did not seem to be interested in gaining detailed information about objects by means of the tactual and kinesthetic senses. Like Gomulicki they maintained that early blind childrens' retardation is greatest in the motor and adaptive forms of behavior.

According to Zaporezhets' (1961) observations, 3-year-old children manipulate tactual spatial patterns more quickly than visual ones. He also put forward the noteworthy view that vision does not become the dominant sense until about the age of six or seven. It should be pointed out, however, that often when the dominance of a particular sense in very young children has been spoken of, "preference" and "ability" have been confused. It would be interesting to investigate how these two are interrelated. (The studies of Rudel and Teuber are discussed later.)

Rock and Harris (1967) carried out a wide variety of experiments in which adult subjects had simultaneously to look at and feel with the hand the same object (a square measuring 3 x 3 cm). Yet the subject had to view the object through a prism that made it seem, for instance, half its true size. In this situation of intersensory discordance or conflict, the visual and tactual impressions were, of course, not mutually compatible. It was found that visual impression invariably affected the tactual impression, but that tactual impression never influenced the visual one. The control group which did not view through the prism at all, made correct judgments.

The investigators coined the excellent term *visual capture* for this effect of vision, but their theoretical conclusions were both mistaken and misleading. The writers failed to make a distinction between the primary character and dominance (in the seeing adults) of visual space. In consequence, they argued that vision formed the primary basis for our space conception.

It should be borne in mind that, in the famous prism experiments of Stratton and, later those of Kohler, in which the subjects wore spectacles for several days that made the world seem upside-down, the haptics-vestibular system eventually returned the view of the world to its normal appearance.

Over (1966), again, has shown that the extent of visual dominance over the proprioceptive system of the arm is a function of the degree of discordance between the two systems. For example, transforming the visual input so that the retinal projection of a physically horizontal bar is slanted 15° from the horizontal, will lead to a proprioceptive response, which is almost completely in accordance with this visual transformation. As the transformation of the visual input is changed so that the discordance between vision and proprioception is increased, the extent of visual dominance is reduced and with a 90° discordance the proprioceptive response seems unaffected by visual transformation.

The above results seem to suggest that particular perceptions invariably tend to be transposed in the direction of the dominant intermodal perceptual whole. The question concerning the nature of this "whole" in various cases is a very interesting developmental problem from the point of view of transposition phenomena. Are different "perceptual systems" dominant at different ages and in different sensorily defective groups? These are questions which must be taken into consideration systematically when the transposition phenomena are being mapped out.

Age of Onset of Blindness and Visual Images. As already mentioned, the concept of transposition has its roots essentially in the view that visual imagery also plays a rather decisive role in spatial performances based on other senses than vision. When the part played by visual images has been studied, the blind are the most important group of subjects. In this respect the age of onset of blindness naturally also has an important meaning.

Lowenfeld (1945) feels that useful visual imagery does not persist if blindness sets in before the fifth year of age. Schlaegel (1953) summarizes his findings by stating that "our results indicate a transition zone from five to eight years of age, when blindness had occurred during this period some did and some did not possess visual imagery." (He also put forward the surprising view that visual imagery is stronger in the partially sighted than in the seeing or in the blind.) These are, however, only opinions rather than views based on systematic research. Most investigators seem to share Schlaegel's conception. Juurmaa (1965) set the limits at one year in selecting subjects for the study of spatial functioning based exclusively on haptics. It would seem that a reliable answer can only be found through extensive longitudinal investigations.

ANALYSIS OF REVESZ'S CONCEPTION OF TRANSPOSITION

The best introduction to a detailed analysis of transposition phenomena is to consider what is meant when we assert with Révész that "*the haptic impressions of form is achieved by transposition of the contents of our haptic perceptions into visual images.*" Even in this special case, the concept of transposition, rather than providing a key to the solution of the problem of "non-visual spatial abilities," proves problematic and complex in itself. This analysis is illustrative in that the "epistemological" problems encountered here are largely similar to those met in other transposition phenomena also.

Révész's Terminology

In Révész's terminology, *haptomorphic forms* are forms that cannot be transposed, even in principle, to the field of the sense of vision. In a strict sense, such forms are only possible in the case of those born blind.

By *optomorphic* forms, again, he means forms comprehended at least in part by means of visual images, or forms that people seek to comprehend by means of visual images. It is important to realize that these are not visual forms, but instead forms perceived through haptics that are only apprehended in such a way that an attempt is made to transpose sense data concerned into the visual sphere. Révész's term for this tendency toward transposition into visual field is *optification.*

In themselves, the terms haptomorphic form, optomorphic form and optification tendency are very useful in the description of spatial functioning.

Révész makes a distinction between two types of optomorphic patterns, active and passive. Since Révész's classification is of interest from the point of view of intermodal relationships in general, a further quotation is in order: "There are two types of visual transposition: one of them is a *genuine one*--namely, when kinetic and tactile impressions are directly translated into visual ones--the other is met when haptic impressions arouse in a *productive way, by means of the abstract fixation* of the formal data, corresponding ideas of form."

What is concerned in "genuine passive" forms is obviously a kind of partial *unconscious association* from past experience.

In this paper we will concern ourselves only with active optomorphic patterns. According to Révész, such patterns are always involved where a seeing person has to operate with haptic forms in such a way that vision is eliminated. In similar situations a blind person who has lost sight later in life is also confronted with active optomorphic patterns.

The term *tactual perceptual system*, covers both haptomorphic and optomorphic forms, and we shall be especially interested in the extent to which tactual perceptual systems are actually "optomorphic" in the late blind and in the sighted.

Limits for Pure Haptomorphic Forms

Révész feels that a primary haptic space is possible, and thus he does not deny the possibility of operations with accurate haptomorphic patterns, within certain limits. He considers it completely possible that those born blind may be able to operate with geometric relationships. Révész writes:

> "We do not doubt that the blind are able to get haptically clear impressions of the form of objects when these are of simple structure. Nor do we wish to deny the blind the ability to unite simple forms or elements of form into higher entities by active synthesis. What we do deny is the assertion, which is decisive for the psychology of the blind, that it should be possible, by purely haptic perception, to get a homogeneous idea of the form of objects which differ from well-known or less complicated spatial figures."

What is Actually Transposed?

Thus according to Révész, there are very narrow limits for the coming into existence of pure haptomorphic forms. Only structurally simple relationships can be mastered in that way. In the case of optomorphic forms, an attempt is made to broaden these limits through optification or visualization. "We may ask why visualization takes place at all and why the haptic form, gradually apprehended through tactile investigation does not suffice." The tendency toward optification derives from the need for "exhaustive apprehension of form in the haptic sphere." Révész then proceeds to describe what it is, in the last analysis, that one seeks to transpose.

> "The answer to the question what it is that actually becomes visualized as a result of the purposive attitude, directed towards the recognition of a tactile object, is that it is a schematic form and not at all the total visual image. What is aimed at is not a visualized image of haptically perceived object corresponding to the visual impression, but merely a schematic visual concept of form. In that respect the visual transposition not only comprehends the form of the whole object, but is mostly limited to single successively touched parts. A synthesis in the visual sense is not achieved for the simple reason that the three-dimensional tactile image obtained through haptic examination of all sides cannot be grasped visually as a unitary body."

What is actually transposed, to summarize the views of Révész, is a kind of crude "schema" and successive sporadic perceptions of the parts of the whole. In other words optomorphic forms also have rather narrow limits.

To provide an example, the image obtained of a vase, say, by means of *optomorphic* patterns does not possess the accuracy of visual perception. Révész maintains that *form governs optics, whereas structure governs haptics*. In other words, haptic apprehension--optomorphic as well as haptomorphic--aims primarily at a successive patterning of a structural scheme devoid of accuracy in detail characteristic of visual perception. Juurmaa has previously (1959) pointed out that in this respect the difference between vision and haptics is one of degree rather than one of kind, and practical rather than theoretical. For instance, if we stand in front of a huge building, we "construct" a visual image of it successively, just as we construct a picture of a hammer haptically. Moreover, any visual pattern is successive to a greater extent than we are inclined to believe. The time intervals between the successive perceptions are extremely small, so that we are not generally aware of them. Attention is paid to successive-character, typical, simple, optic patterns, by A. R. Luria (1966), who points out that they are revealed in certain cases of brain lesion.

Conceptual Analysis of the Process of Transposition

Let us consider how transposition to the visual sphere takes place and how spatial manipulation in this sphere proceeds.

After realizing that the accuracy typical of visual perception cannot be attained haptically, the "observer tries to fix the idea abstractly and thereby to transpose the haptically apprehended figure into visual sphere." This passage seems to suggest that ultimately the transposition of tactual (haptic) sense data into visual images takes place by means of an abstract idea of some kind. Révész now comes to the most crucial point:

> *"We are therefore no longer dealing with optification, with the transposition of haptic impressions, but with a fixation by means of words and abstract ideas of tactile and kinetic contents, a fixation which tries, by means of abstract character, to bridge the gap between the two sensory spheres. The concept is the link by means of which the haptic form is brought into relation with the visual figures."*

Révész's views thus amount to a three-stage theory: haptic sense data--abstract idea--visual image.

At this point we cannot avoid meeting epistemological difficulties when we have to operate with terms such as *link*, *abstract idea* or *concept*, *to fix*, and in particular, *fixation by means of words*. Regarding the last-mentioned expression, Révész puts forward a peculiar but interesting view:

> "Finally I should like to remark that the *visualization of haptic data is also required for expressing in words what has been observed haptically*. Whenever we want to make a statement on the form or structure of an object *we have almost exclusively visual terms at our disposal*. The whole set of terms required for the presentation of spatial structures has its origin in the optics of form. We are therefore compelled, so to speak, to make the haptic impressions of visual forms."

In a generalized form, this idea would amount to the assertion that language affects perception and vice versa. As regards the tendency to optification, in particular, two kinds of situation can be pictured.

1. We are seeking to apprehend the form of an object haptically, and are simultaneously required to report what spatial relationships are involved. Then the language at our disposal obliges us to try to identify particular kinds of component patterns in the object, namely, patterns which have "names." And these names are incontestably something obtained from the visual world.

2. Even when not required to do so, we are inclined to discover component patterns for which we have names, and this inclination perhaps tends to lead the patterning astray. If all of us were congenitally blind, our body of spatial concepts as well as our "patterning norms" would of course be completely different. Nevertheless, the view that language favors the

transposition from haptics to the visual sphere is merely a hypothesis for the present.

The following is a simple summation of Révész's theory of transposition:

1. There is a tendency for the seeing and the late blind to transpose, whenever possible, haptic sense data into visual sphere.

2. Only very simple forms can be apprehended haptically without such transposition.

3. In haptic patterning, an attempt is made to form a scheme on the basis of the perceptions of single successively touched parts of the object.

4. What is actually, or ultimately, visualized (through transposition) is such a schematic form.

5. Transposition takes place in such a way that the observer first tries to fix an idea abstractly.

6. This fixation is not the same as transposition.

7. The idea thus fixed forms a bridge between two sensory spheres.

8. From this we have to infer, although Révész does not state it expressly, that it is this idea which generates, in one way or another, the visual images concerned.

9. Obviously, words and language in general greatly contribute to the coming into existence of this fixed idea, and language thus affects the entire process of transposition.

It should be pointed out that the fact that Révész speaks of transposition in general causes confusion because he does not specify the various kinds of performance in which it may be involved. As we will try to demonstrate later the role played by transposed visual images essentially depends on the nature of the task in question. In this respect the nine theses listed above raise a number of questions, to be discussed below.

The first thesis confronts us with the following three groups of questions:

1. Does the tendency toward optification present itself in any kind of (haptic or tactual) spatial patterning? And, if not, what kinds of patterning form exceptions to the rule.

2. Are attempts at optification likely to be successful, irrespective of the type of spatial patterning concerned? And if they are not, what kinds of patterning provide exceptions? Here we call an attempt at optification or transposition successful if visual images corresponding to the original sense data actually come into being.

3. Are the visual images helpful or perhaps harmful to the spatial patterning process? How does their helpfulness (harmfulness) depend on the type of patterning concerned?

The answers to these questions are less self-evident and unambiguous than could be expected. It will be shown later that they are largely dependent on the experimental designs used.

Regarding the second thesis we have to ask what can be meant by "structurally simple" relationships. It is undoubtedly true that we cannot obtain through touch as accurate a picture of the form of a curved vase, for instance, as through vision. Let us consider a slightly different kind of tactual spatial patterning. A congenitally-blind person and a (blindfolded) seeing person are required to build a cube out of parts which stick together, and none of which is optically familiar to the seeing. Experimental studies have shown that the early blind and the blindfolded seeing do equally well on such tasks. In Révész's terminology, relatively complex haptomorphic patterning may turn out as successfully as the corresponding optomorphic patterning process. Thus, the generalizations concerning the limits of the complexity of pure haptomorphic patterning are bound to the type of the tasks.

We can accept the third thesis in the sense that in haptic patterning when the aim is to form a simultaneous total picture, nuances and details are disregarded in an attempt to master the relationships inherent in the total structure. It would seem, therefore, that a kind of relational scheme is actually aimed at.

Yet a tendency opposite, in a sense, to this schematization tendency is also likely to be present in haptic patterning: a search for qualitatively familiar details, by means of which the total pattern could be recognized instantaneously. However, this point will not be discussed at greater length in this context.

As was already pointed out, the fourth thesis may be understood to mean simply that if some visual total image comes into being, it is obviously a kind of "skeleton pattern" of the shape of the object (a cubistic vase).

The remaining theses have been separated here from the contexts in which Révész himself did not elaborate his views in greater detail. None of the theses listed were based on empirical evidence, nor were they anchored in specific types of performance. But vague and even wholly erroneous assertions have often proved fruitful in that they have compelled other investigators to penetrate more deeply into the matters concerned.

Actual difficulties begin with the fifth thesis. Where does the abstract idea or concept which is supposed to be fixed come from? "We are no longer dealing with optification, but with a fixation by means of words and abstract ideas."

What is the origin and nature of this idea, thus fixed, that is asserted to be abstract in character? Is it sensory material? Obviously it cannot possibly have a visual content since, according to Révész, we are not, at this stage, dealing with optification. On the other hand, if it had a tactile content it could not be called abstract except in the sense that any perception of relationships based on concrete sense data is called abstract.

Here we in fact arrive at the logical conclusion concerning the nature of this abstract "link." A great many questions arise. Is an abstract idea the same as the apprehension (comprehension, recognition) of spatial relationships? How is this kind of abstract idea related to the degree of awareness? In other words, must this "idea" necessarily be conscious? If an idea serving as a "link" really emerges, does it in every case lead in itself to the creation of a visual image of the relationships concerned?

On the other hand, are some kinds of relationships inherent in the abstract idea in such a position of preference so as to excite the corresponding transposed visual image?

In its most general form the question reads: how and to what extent are the emergence of the "link idea" and that of the transposed (sensory material) visual image dependent on the structure of relationships of the stimulus (tactual, haptic) pattern?

No headway can be made unless the type or nature of the spatial (haptic, tactual) patterning in question is specified.

The task facing us is to formulate hypotheses by starting from certain "mental experiments." To this end we have to consider a few concrete examples. Imagine that we are blindfolded and required to perform a variety of tasks, at first comparatively simple and then increasingly difficult.

1. A glass is handed to us. We immediately "see" a glass before us. What is involved is an intense association of ideas based on simultaneous tactual and visual perceptions. Experiments with blindfolded subjects have shown that the recognition of such a concept as a glass is

almost completely independent, in principle, of the sensory-input line concerned.

As was mentioned earlier Berkeley would have been surprised to observe that he was able to recognize a glass immediately with his toe, without previous experience. What makes recognition possible here? The fact that visual and tactual perceptions have become strongly associated when we have seen a coffee cup in our hand is not a sufficient explanation. It is almost equally as easy to recognize a cup by touching it with a toe, the tongue, or the nose as it is to recognize it with the hand.

To find sufficient explanation, a further working hypothesis must be introduced. Provided that a given pattern has been sufficiently established (in principle, without a "name") in the central nervous system, its associative recognition is rather independent of the sensory-input line concerned. No one has been able to define "association" in this context, and it is used for lack of a batter term.

The difference between man and monkey is relevant and interesting in this context. We will see, when empirical experiments are described, cross-modal transfer of form discrimination occurring in man. The human being is able to conceptualize in some way or other, tactually-perceived unfamiliar patterns which he is able to relate to corresponding optic figures. Thus, he is capable of conceptualizing that which is not modality-specific. In contrast, Ettlinger (1969) suggests that monkeys are incapable of cross-modal form transposition of this kind.

To return to Révész, optification evidently and incontestably takes place in situations similar to our imaged "glass experiment."

2. We are given a cardboard square. Comparative tactual measurement tells us that what is involved is actually a square. Following this we are given an equilateral triangle measuring 5 cm. Both figures are familiar from visual experience and will command the corresponding visual images, just as the glass or coffee cup in the preceding example. The figures are removed, and we are required to draw a figure that would result if one of the sides of the triangle coincided with one side of the square. We will, no doubt, first draw a square depending on the visual image we have of it, and then, also depending on the relevant visual figure, an equilateral triangle which has one side in common with the square. *What is concerned here is recognition of optically-familiar figures and manipulation of such figures on the basis of the visual images we have of them.*

The important point is that we need not hypothesize here, or in the case of the glass, any additional "new mediating abstract link." In fact, the whole field of the frame of reference within which visualization and mental-spatial manipulation will take place is "associated" with these familiar forms to be employed.

3. We are given a rake and we take hold of it in such a way that the handle rests between the fingers and the palm. The shape of the handle is easy to recognize and we will shortly discover that the object in question is T-shaped. Moreover, as soon as we discover the row of teeth, an association of a rake almost immediately comes into being. Révész obviously has this kind of patterning in mind when he gives the following description, in which he scarcely employs his above-mentioned terminology at all.

> "Hand in hand with the recognition of the structure of the tactile image or the tactile object the visual forms emerge by *way of association.* By reason of the association with structure the transformation of the haptically-perceived image leads to schematic visual images."

Association can only be involved in cases where there is a pattern recorded by the central nervous system. In other words, there must be a corresponding representation of the pattern in the central nervous system which can be associated. The above quotation is wholly in accord with Révész's other propositions, provided that we are right in assuming that, when Révész considers transposition, he invariably has reference to visually-familiar patterns, with which the perceived images can be associated, consciously or unconsciously.

The doubt in fact arises that, when Révész speaks of an "abstract" idea or concept, he simply means that a visual image is preceded by its linguistic conceptual name.

4. Assume that an irregular, pentagonal figure is handed to us. We are required to determine its form and then, without the help of the figure, to traverse a path similar to it on the largest scale possible within a square measuring some 10 m x 10 m. In other words, our task is to transfer a tactual pattern into an extensive ambulatory pattern.

What will happen here? According to Révész, we would first try a visual image of the small tactual figure. In other words, we would be likely to rely upon "optification." Yet, since none of the relationships inherent in the figure are favorable for visual association, optification would be difficult. What could the abstract idea serving as a link be here?

We would be likely to realize soon that it is rather difficult for us to form any *stable* visual figure. One possibility would be to try to memorize "verbal-conceptual sequences" such as "first a short side, then an angle of 80°, then a somewhat longer side, etc." It might be possible for someone to master the figure more or less successfully and within certain limits by such methods. An average person would probably seek to memorize a succession of less well-defined relationships and partly visualized segments of the whole figure. It should be noted that in the present case associative recollecting and keeping in mind a familiar visual pattern--at least a complete whole--is unlikely. The retention in the mind of a simultaneous picture constructed from successive visual images lacks stability. For each individual, there is a limit beyond which the mastery of a simultaneous visual image of the whole pattern becomes impossible.

A question concerning the strategy of patterning may be raised at this point. Suppose that we have two groups of people, equal both in visual and in tactual-spatial abilities. One group is urged to perform the above task by purposely seeking to form as vivid a visual image as possible of the geometrical figure and to operate by relying in this image. The second group is only required to pay attention to the relationships between the sides and angles as such, and as far as possible, to avoid employing any vivid sensory images. Which of the two groups is likely to do better? If Révész's views are to be generalized, this would be the group resorting to optification, but this is by no means self-evident. For example, in experiments carried out at the Institute of Occupational Health a group of congenitally-blind subjects did as well as, if not better than a group of blindfolded seeing subjects on comparable tasks (Juurmaa, 1965). Gomulicki's maze experiments (1961), to be discussed later, yielded similar results. Thus it would appear, that transposition in a tactual-ambulatory sense may be, in principle, equally successful, irrespective of whether vision is or is not resorted to.

In types of task considered here, the vague and unstable visual images, images that are less stable than associatively familiar images, may be harmful rather than helpful. They may render the, perhaps unconscious, mastery of this scheme more difficult.

5. Let us finally consider tasks in which a single two- or three-dimensional figure has to be constructed from a number of visually unfamiliar parts. (The resulting total figure may also be visually unfamiliar.) The performance of congenitally blind and of blindfolded seeing subjects on such tasks represented the same level as experiments conducted at the Institute of Occupational Health (Juurmaa, 1967; Juurmaa and Suonio, 1969).

Thus, where the process involved has been complicated, multiphasic, haptomorphic performance has not compared unfavorably with an optomorphic one.

Let us make some further remarks on Révész's view that language is, as a mediating factor, helpful in tactual spatial manipulation. Révész seems to consider that language is of aid in discovering the relevant abstract ideas, which then generate the corresponding visual images. As already mentioned, he perhaps unconsciously identifies the "abstract link idea" with the corresponding verbal concept. Evidently, the misconception underlying the general assumption that spatial patterning invariably takes place on the basis of visual images is also involved here. This misconception implies that the patterns to be manipulated are always visually familiar and can be described in terms of normal language.

The above examples suggest that there are various types of transposition and that only future research can reveal how far these various types are governed by common laws. We will return to the general analysis of transposition, in a broad sense of the word, in the later sections of this article. At this point we only propose to summarize the questions raised by Révész's theses.

1. Is the view advanced by Révész that there is a general tendency toward optomorphic patterns or optification also correct in cases where the forms and patterns involved are not visually familiar?

2. Provided that such a general tendency actually prevails, to what extent are the attempts to transpose the relevant sense data into visual images likely to prove successful with various kinds of pattern complexes.

3. Provided that operations with transposed visual images can be and actually are resorted to, with what kinds of pattern complexes are such operations likely to be (a) helpful, (b) harmful, respectively?

4. Does Révész's "abstract idea" amount to anything else other than the apprehension of a relationship?

5. If it is not visually familiar, does such a relationship, inherent in an abstract idea serving as a "link," have a tendency to generate a visual image?

6. How is the abstract idea related to (a) verbal concepts, (b) non-verbal concepts?

7. Is it possible for the abstract idea serving as a link between two modalities to be sensory material at all? And provided it can be, how should its sensory material character be described?

8. To what extent can the entire process of spatial patterning proceed at the level of abstract relationships without any conscious sensory contents?

9. Is the tendency toward transposition identical, in general, with an inclination to seek and discover visually (and perhaps verbally) familiar relationships? And if it is not, what is its nature?

10. Is it probable that, psychologically, a particular ability for transposition independent, in principle of the various modality-specific spatial abilities can be identified? If such an ability is identifiable, to what extent is it general and to what extent is it specific for various performance combinations; tactual-ambulatory, etc.? This question has been neither raised nor investigated previously.

EXPERIMENTAL STUDIES RELEVANT TO THE PROBLEMS OF TRANSPOSITION

The main experimental designs used, and results obtained in the study of the phenomena of transposition will be surveyed and analyzed briefly in this section. The "perceptual systems" mentioned previously will provide a frame of reference for the description.

Ideational Transposition of Sense Data to Visual Images "Within Tactual Perceptual Systems" (Optification Tendency I)

Worchel (1951). Worchel's results have been referred to most frequently in the literature when the role of transposed visual images within "tactual perceptual systems" has been discussed and when generalizations concerning it have been made. Worchel employed the usual method of comparing the performances of the early blind, the late blind, and the seeing (16 early blind and 17 late blind and a matched group of 33 blindfolded seeing subjects). The following two of Worchel's experiments are of relevance here.

Form perception. Nine forms were used in the experiments: square, circle, triangle, semicircle, rectangle, quarter-circle, parallelogram, crescent, and ellipse. Three response techniques were used: (a) reproduction by drawing, (b) verbal description, and (c) recognition (the subjects were required to identify the stimulus from among choice forms).

The main results were as follows:

1. In drawing and verbal description the order of the groups from the best to worst was the seeing, the late blind, and the early blind.

2. All three groups did equally well in recognition.

Comments: All the forms employed were visually very familiar, and each had a particular name in everyday language. It is a trivial truth that it is relatively easy for a seeing person to draw a figure associatively familiar to him and to know its name. It should be emphasized, moreover, that the technical helplessness in drawing by the blind, and the early blind in particular, makes this type of response technique worthless. As for recognition-type tasks, they were obviously too easy. It was difficult for the blind to describe a quarter-circle, parallelogram and crescent, since these hardly occur in their perceptual world. However, from the fact that the verbal description of these particular figures was difficult for the blind, Worchel draws the following conclusion: "It may be that visual imagery is particularly important in synthesis of individual tactile impressions of more complex forms."

Tactual space relations. The problem consisted of presenting one part of a form to one hand and the second part to the other hand, and asking the subject what form would result if the parts were placed together. The response blocks included the following shapes: circle, equilateral triangle, semicircle, rectangle, trapezoid, ellipse, and square.

The main results were as follows:

1. The sighted made significantly fewer errors than the blind.

2. The late blind were significantly superior to the early blind.

3. The easiest forms for both the blind and the sighted to recognize were the ellipse and the circle. The most difficult form was the semicircle when the stimulus forms were the two quarter-circles.

Comments: Both the stimulus figures and the response figures were visually familiar in one way or another. It should be observed that in the most difficult variant, where two quarter-circles were presented to the subject, there was no difference between the seeing and the blind. Worchel paid no attention to this finding.

Worchel felt that his results justified the following generalization: "The present test shows that the tactual advantage is actually on the side of those who could see or translate impressions into visual imagery." (This statement was intended to refute the lay opinion that the blind are superior to the seeing in tactual-form perception and that this superiority is due to a "compensatory" ability.)

Each of the tasks has a similarity to the one we presented in connection with our analysis of Révész's transposition theses, in which a square and an equilateral triangle had to be put together. What is concerned in these experimental series, too, is a kind of associative recognition. As will be shown later, the following generalization by Worchel is misleading: "The use of visual imagery is of definite aid to the sighted and to the accidentally blinded in imaginally manipulating tactual perceptions." It is not tenable without qualification.

Drewer (1955). Drewer repeated the latter variant of Worchel's experiments in unchanged form and obtained completely similar results.

Ewart and Carp (1963) again repeated the former (form perception) variant in essentially unchanged form employing only the recognition-response technique. The blind and the sighted did equally well, and the authors concluded that visual imagery was not a critical factor in this kind of form recognition. The results do not, however, justify any conclusions since the experiments were obviously too easy.

Drewer, however, carried out two further experiments which did not support the above-mentioned results. The blind and the seeing did equally well in the mastery of shifts in spatial position of haptic forms. He did not attempt to reason why this was the case. From the point of view of our main hypothesis it is crucial that the spatial forms employed in Worchel's latter variants were visually unfamiliar.

Juurmaa (1965, 1967). In these two studies tactual-spatial performances of the blind and the sighted were compared. The first study was concerned with the orientation ability and the second with the mental-ability structure of the blind. The relationships of tactual-spatial ability with a number of other ability traits were explored.

It should be pointed out that the tests for tactual-spatial ability employed in these studies were such that the subject had to proceed to the final total solution via phases involving spatial relationships which were not of a visually-familiar type. In one test, for example, the subject was required to assemble a cube out of small (visually unfamiliar) wooden parts; in another he had to fill in square-shaped holes with pieces of metal plate.

The main results were as follows:

1. According to one study (1965) the blind were significantly superior to the blindfolded sighted. According to the other study (1967) there were no significant differences between the blind and the sighted. From these results, it can be maintained that the groups compared are at least on the same level.

2. With the congenitally blind, the tests measuring tactual-spatial ability formed a factor on their own, independent of both dexterity and reasoning. Is this factor comparable in some sense to the visual-ability factor of the seeing?

3. However, the experiments with blindfolded sighted subjects showed that tactual tests formed a factor completely independent of the visual-ability factor. This, in turn, raises the following question: Can either of the spatial-ability factors of the seeing be identified with the tactual-spatial factor obtained for the blind? In any case, some factor other than visual ability is involved in these tactual-spatial performances.

Juurmaa's results suggest that optification is not of aid in non-visual spatial performances involving spatial patterns that are not visually familiar.

Juurmaa and Suonio (1969). This study was intended to explore the validity of the following hypotheses advanced above. Insofar as tactual-spatial performance is based on visually-familiar patterns, optification improves the performance. On the other hand, insofar as tactual-spatial performance is based on forms and relationships that are not visually familiar, optification is of no help, and it is doubtful whether a tendency toward optification occurs at all.

To render the results comparable with those of Worchel, the study was based on experiments similar to Worchel's "tactual-space relations" and on modifications of these experiments, designed with a view to testing the above hypothesis. The experiment consisted of three phases:

1. Both the parts and the wholes were visually familiar forms. This was a repetition of Worchel's original experiments in unchanged form; the experiments on which the assertions advanced concerning the optification tendency have been based to a large extent.

2. The parts were visually unfamiliar, whereas the wholes were visually familiar. (The wholes were the same as in the experiments of the first phase, but they had been divided into two parts in such a way that neither of the parts represented a visual "ideal" form.)

3. Both the parts and the resultant wholes were optically unfamiliar.

Results and comments: The results yielded by phase 1, which was identical with the variant used by Worchel, were wholly consistent with Worchel's results. It is interesting that even in phase 2, where the resulting wholes were familiar but the parts unfamiliar, the early blind and the sighted did equally well. Obviously when the sighted were placing together the two parts ideationally, no associative links helped them.

In phase 3, again, the early blind did slightly better than the sighted. To remain on the safe side, we may say that both did at least equally well. The experiments reported here are sufficient to demonstrate that Worchel's thesis, in a generalized form, is not tenable.

General Considerations. The experimental results thus far indicate unambiguously that:

1. The optification tendency within the "tactual-perceptual system" seems to appear only in manipulating figures that are familiar from past experience.

2. There was no evidence for an optification tendency in those tactual-spatial tasks where the subject was required to operate with visually-unfamiliar forms.

The answer to the first question on page 110 concerning the analysis of Révész's generalizations is thus negative.

The second question is very difficult to answer. In any case, the answer will obviously depend on the experimental design used. It should also be pointed out that in order to discover how far the possible attempted transposition of sense data into visual images is likely to prove successful in various cases, a phenomenological approach must be used.

As to the third question the following quotation from Juurmaa and Suonio (1969) is of relevance: "If a person seeks to have recourse to a visual strategy in a tactual-spatial task to which this strategy is inappropriate, this 'tendency toward optification' may be definitely harmful rather than helpful. We may ask, therefore: To what extent should we simply guide blinded persons in avoiding irrelevant optification in tactual patterning? This is a point about which very little is known for the present, but there is reason to raise the question."

It should be mentioned at this point that erroneous generalizations concerning the role of visual imagery in tactual spatial manipulation have been made by many investigators. For example in tactual modifications of embedded-figures-type tasks the forms have largely been visually and geometrically familiar. Without paying attention to this point, Witkin et al. (1968) drew wholly misleading conclusions regarding the cognitive level of the early blind.

Thus, the theory of a general tendency toward optification within "tactual perceptual systems" can be regarded as convincingly falsified.

Transposition of Sense Data into Visual Images within "Ambulatory Perceptual Systems" (Optification Tendency II)

Worchel (1951). In order to put the role of imagery to a test in a wider setting Worchel also conducted a series of experiments concerning the mastery of kinesthetic locomotion patterns. Worchel describes these experiments as follows:

> "To determine the cues involved and the ability of the blind to orient themselves spatially two tests of orientation were administrated to the blindfolded blind and blindfolded sighted Ss in an outdoor experimental area relatively free from objects in the near vicinity. In the first test, S was led by E along two legs of a right triangle. The S was instructed to return in a straight path to the starting position, that is, along the hypotenuse. In the second test, S was led along a hypotenuse path by E, and had then to return to the starting position in a right-angle path. Seven different distances were used in each test."

The hypotenuse varied from 8 to 22 feet in length.

The main results were as follows:

1. The sighted were significantly better than the blind, that is, they returned closer to the starting point.

2. There was no difference between the early blind and the late blind.

3. The error in missing the starting position increased both with the blind and the sighted as the hypotenuse distance increased.

Comments: What was visually involved was a highly familiar figure, a right triangle, and the distances involved were comparatively short. In view of the above propositions concerning the optification tendency within "tactual-perceptual systems" these locomotion results appear self-evident. What is again in question is obviously a kind of associative recognition of the visually familiar field or frame of reference.

The following quotation from Worchel is of interest: "These results lead to the conclusion that in the absence of auditory cues, the blind rely primarily on time for distance estimation. Kinesthetic cues without the aid of visual imagery resulted in poor directional orientation." Worchel's reference to the time scheme in the blind is especially interesting. It is not clear, however, whether Worchel feels like von Senden, that the early blind do not have any apprehension of space.

Juurmaa (1965). This was concerned with the orientation ability of the blind. The blind and the sighted were compared with respect to the mastery of locomotion patterns. Almost all the patterns employed were of a visually-unfamiliar type.

There were three main types of spatial-locomotion pattern tests:

1. The subject was requested to walk in a straight line and estimate distances.

2. The subject had to traverse a complicated path and to return straight to the starting point.

3. The subject was aided to traverse a closed path which he then had to repeat unaided. The reliabilities of the locomotion variables ranged from 0.70 to 0.85. (There were 52 congenitally totally-blind male subjects.)

The main results concerning spatial locomotion performances were:

1. The blind were significantly superior to the blindfolded sighted in all spatial locomotion performances.

2. The congenitally or early blind were at least on the same level in spatial locomotion performances as the late blind.

3. With the blind, the variances of the locomotion tests were accounted for by three factors: an auditory factor (pitch discrimination and audiometric measurements), an obstacle-sense factor and a tactual-spatial factor.

4. Thus, for the blind, the spatial performances based on "the tactual and ambulatory perceptual systems" obtained loadings on the same factor. The hypothesis of an intermodal spatial ability thus found support at least partly with the blind.

5. In the sighted, however, the visual, tactual, and locomotion tests formed three separate uncorrelated factors. This is a further piece of evidence indicating that the sighted are unable to make use of visual imagery in tasks of the present kind.

Comments: What was found to be true for the helpfulness of "optification" in the case of "tactual-perceptual systems" also applies to "ambulatory-perceptual systems."

The finding that the congenitally blind were equal to the other subjects in the mastery of spatial-locomotion patterns is of particular theoretical interest and importance. All our experiments speak against the view advanced by von Senden, and apparently shared by Worchel, that the blind can learn only various time and muscle-tension schemata but do not possess any genuine spatial sense. The congenitally blind do possess a spatial sense, but an insurmountable linguistic barrier makes it logically impossible for a sighted individual to recognize its qualitative phenomenological character.

Further Comments. The same basic idea mentioned above was expressed by Shemyakin (1959), a Russian investigator whose considerations were primarily at a speculative level:

> "The word representation usually denotes a graphic image of some object. Representations about a locality which participate in orientation and are necessary for orientation in the locality, cannot in the least be reduced to visible images of the local objects. Essential for these representations is the order of the position of the local objects and their arrangement in space."

He also maintains that, when blindfolded the sighted do not at all invariably rely on visual images in spatial orientation. The following passage is particularly interesting:

> "The process of space cognition in blind persons is realized differently than in sighted persons. The result, however, must always be differentiated from the process. Sightless persons, though limited on a sensory basis as compared with sighted persons, learn the same laws of space as do the latter and are capable of creating a subjective image adequate to reality. When speaking about differences between space representations in sighted and in sightless persons, it should be remembered that these differences relate to the process of the reflection of space in the human mind and not to its results; this, as will be proven in several examples, is the same in both."

The words ". . . are capable of creating a subjective image adequate to reality" are crucial from the point of view of interpretation. Obviously, according to the Russian view, the learning of spatial relationships is based on conditioning, like all other mental processes, and need not be necessarily sensory material. Different ways through different sensory routes or, in other words, different conditioning processes lead to the same resultant performance. Western researchers have perhaps been excessively tied to the traditional view that "the representations" in the mind must be sensory material, feeling that at least "the final image" of the mental process must be concrete. This line of thought naturally leads to that preconceived idea according to which different sensory-material processes are bound to lead to different performances or results.

Tactual-Perceptual Systems

Gomulicki (1961). Gomulicki used maze experiments in his study of the transposition of spatial performances from one perceptual system to another.

Two mazes, similar in form but different in other respects, called, let us say the *ambulatory maze* and the *tactual maze*. The former, constructed from ropes and pasteboard walls was a path that a man was able to traverse normally. The other was a miniature maze, in which the stylus could be moved a groove.

Congenitally blind and sighted subjects from the ages of 5 to 16 were compared longitudinally with one another. On both mazes, the subjects were required to make repeated trials up to the criterion of three successive error-free trials, or to a maximum of 30 trials in an attempt to reach the criterion. The stylus maze was 1/30 the size of the large one. In order to investigate transfer, both groups were divided into two sections, and in each case, one section took the ambulatory maze and the other the tactual maze first.

The main results were as follows:

1. Transfer was found to be significantly greater from the ambulatory to the tactual maze than vice versa. It was discovered, in fact, that performance on the ambulatory maze was not facilitated at all by prior familiarity with the tactual maze.

2. The direction of transfer was the same for the sighted and the blind.

3. At the age of five, the blind did significantly worse than the sighted on both tests.

4. The blind caught up with the sighted or slightly exceeded them at the age of 14 on the tactual maze and at the age of 16 on the ambulatory maze.

Comments: It should be stated that the mazes did not favor any optically familiar patterns, but they were not very complicated either. After the age of 16 the possibility of making use of visual imagery was of no help in the tactual-perceptual system or in the ambulatory-perceptual system. In this respect the results support the views presented in the preceding chapters.

But why are blind children so definitely retarded at an early age? Gomulicki's results open up a variety of theoretical views. The following quotation is of special interest:

> "Those with a good sense of spatial orientation use the first trial to build up for themselves a general idea of the layout of the maze, the specific details of which can be determined in later trials. This general idea may be in the form of a mental image of the pattern as a whole, or as a series of segments in a particular sequence. Reliance on kinesthetic and tactile cues leads, essentially to a second type of image. The blind may be able to synthesize their kinesthetic and tactile impressions into some sort of overall appreciation of the maze pattern, but it is only the sighted who can translate them into visual terms and create a map of the maze, within which the separate segments find their place. Not all of the sighted subjects

do, in fact, use this method, but the mere possibility of translating non-visual cues into visual terms gives them a decided advantage from the outset. With increasing age, the blind children rapidly improve in the efficiency of their use of available cues, and sooner or later actually overtake the sighted subjects, who have been able to make only indirect use of the sense on which they normally rely almost exclusively for spatial orientation." (Gomulicki, 1961.)

It should be noted that Gomulicki was apparently not surprised to find that the older of his blind subjects were equal in spatial orientation to their sighted peers. The problem with which he seems to be occupied is why the younger blind are inferior to their sighted peers. Gomulicki's line of argument may be understood as follows:

1. When Gomulicki speaks of a "good sense of spatial orientation," he undoubtedly considers that the congenitally blind also possess a primary-spatial ability in the sense that they are able to form a "general idea of the layout of the maze." However, he does not make a decisive difference between the older congenitally blind and the sighted in this respect.

2. This "general idea" may be a simultaneous mental image, or it may consist of a sequence of images of the relationships inherent in the patterns concerned. The best analogy is perhaps provided by a route along various streets in a town. We may have an image of such a route "as a whole," or we may imagine its course street by street.

3. When Gomulicki speaks of reliance on cues leading "essentially to the second type of image," he may have reference to either of two main possibilities: first, the memory for sequences of rather large parts of the whole pattern (street by street), or second, memory for systems of relationships of auditory and kinesthetic cues--perhaps approximately in von Senden's sense.

4. It is possible for a sighted person to form for himself a transposed visual map, and then to transpose this map into locomotion patterns.

5. Nevertheless, as soon as the spatial-central strategies have reached a certain degree within the ambulatory systems in a blind person, indirect transposition via vision is no longer of relative help to the sighted in spatial tactual and ambulatory performances.

Further Comments: Juurmaa and Suonio have conducted a series of experiments to find out how far the mastery of locomotion patterns is dependent on the presence of certain crucial external factors, to be published 1970). The following conclusions are based partly on these results.

1. The fact that the direction of transfer was the same with the sighted and the congenitally blind clearly indicates that the blind must also have some sort of a total image of an "ambulatory pattern," which was then of help in their performances on the tactual maze. This total image must have been created in the central nervous system, because the peripherical sensory and motor nervous pathways involved were wholly independent of each other. (Yet this confronts us with a further question: What are the functions on which that sort of mental spatial image is based? Or, to use Révész's term, of what kind is the "conceptual link" that is involved when a blind person transposes an ambulatory-spatial pattern into a corresponding tactual pattern?

2. It is likely that both groups made profitable use of successive cues or distinctive features of the route. For this

reason the transposition in the direction of tactual to ambulatory was so difficult. It should be kept in mind, however, that the direction in which transposition is easier obviously depends on the experimental design employed.

3. What, then, are the functions on which ambulatory patterning is based in the blind? Juurmaa and Suonio eliminated both auditory and kinesthetic cues in their experiments. The tasks in the experiments were similar to those described in the preceding chapter. The occlusion of hearing had surprisingly little effect on locomotion patterning. The effect was, however, relatively greater in the blind than in the sighted. The blind make profitable use of auditory cues, but it seems that hearing is far from being a necessary condition for the mastery of locomotion patterns. (The ability to avoid obstacles is an entirely different thing.) The possibility of using kinesthetic cues was eliminated by stopping the subjects in random places and disrupting their rhythm of time and movement. This arrangement also had relatively little effect on the performances. It seems obvious, in consequence, that the congenitally blind *somehow* form within ambulatory perceptual systems a spatial pattern on functions on their central nervous system and that this pattern can be transposed into other "perceptual systems" or modalities.

4. Let us consider the following three ways in which spatial patterns might be transposed from the "ambulatory-perceptual systems" to "tactual-perceptual systems" and vice versa.

   a. Direct transposition.

   b. Transposition via audition (auditory cues)

   c. Transposition via vision (visual imagery).

(In principle vision and audition may of course serve simultaneously as mediating modalities, but here we will confine ourselves to the above three alternatives only.)

The results described seem to indicate that the first alternative is in one way or another possible. (See the Working Hypothesis on page 99.)

Regarding the second alternative, it is obvious that the blind do use auditory cues in locomotion patterning. But we have practically no knowledge about the extent to which they form mediating auditory patterns or the extent to which these cues serve only as "associative-memory recordings."

As to the third alternative, as already mentioned, the results support conceptions presented in the preceding main section.

Transposition Based on Memory, Visual-Perceptual and Tactual-Perceptual Systems and Vice Versa

All the studies discussed so far have had the following underlying idea in common: indirect conclusions concerning the role played by visual imagery in spatial performances based on senses other than vision can be drawn by comparing the results of the early blind, the late blind, and the sighted.

The interrelations between visual-spatial functioning and tactual-spatial functioning can also be investigated by employing another method of approach and sighted subjects only. The main experimental designs involve the investigation of cross-modal form recognition and cross-modal transfer of form learning.

The Transfer-of-Learning Approach, Gaydos (1956). Gaydos had two groups of sighted subjects. One group first learned to recognize, blindfolded, 12 various forms by active touch. The criterion of recognition was the learning of verbal symbol assigned to the figure concerned. (The symbols were familiar first names.) After the subject had twice been able to name all the figures correctly, the same figures were presented to him visually, but otherwise the task was the same. The other group had to learn the figures first visually and then tactually.

The main results were as follows:

1. There was no significant difference between the modalities in initial learning.

2. Transfer was markedly great in both directions.

3. However, transfer was greater in the direction tactual-visual than in the reverse direction.

Comments: The figures used were scarcely meant to be visually familiar, and Gaydos does not say anything suggesting that they were. Nevertheless, a majority of the figures were such that they produced, both visually and tactually, the impression of an associatively familiar optic pattern. (It is rather easy to learn that "square is Joe," "parallellogram is Bill," etc.) In this associative sense, the "optification" naturally entered into the picture in tactual form discrimination, and also obviously it explains why the groups compared were on the same level in initial learning. (Gaydos did not, however, pay attention to this point.)

Though the difference in transfer between the two directions was significant, it was not large (touch, 2.05; vision, 1.05). Thus, in tactual relearning, one more trial was necessary, on the average, compared with visual relearning. Gaydos puts forward the following assumption:

> "The result is not unexpected, since learning to identify forms by touch alone, which is a relatively unfamiliar process, may have prompted the Ss of Group I (touch group) to explore the shapes more thoroughly. The Ss of Group II may have been able to learn initially on the basis of more generalized properties which may not always have been sufficient to allow recognition by touch. . . . *Accordingly, the efficiency of transfer seems to depend not on rate, but rather on the degree, of initial learning.*" (Italics by J. J.)

As will be shown later, the results related to the direction of transposition have been rather contradictory, and are naturally dependent on the experimental design used. Regarding Gaydos' speculation, it should be pointed out that in future similar studies *the rate and degree of learning variables must necessarily be controlled.*

The Problem of Intermodality of Perceptual Illusions. The study of illusions has occupied the psychology of perception from the outset. This is due naturally to the fact that elimination of a certain factor (or factors) has made it possible to investigate its effect on normal misperceptions in the perceptual field. Traditionally, illusions have been associated with vision. The illusions are of utmost importance in investigating the relative importance of the parts played by the central and peripheral nervous systems in perception. If our working hypothesis (page 99) is tenable, at least some illusions are likely to occur in the fields of senses other than vision too.

In fact Révész already held that "many of the optic-geometric illusions have haptic analogues." As early as 1938, Bean had demonstrated, although unsystematically, that the Müller-Lyer illusion, the Poggendorf illusion, and the Zöllner illusion were experienced by the early blind.

From the point of view of transposition of spatial relationships the following study by Rudel and Teuber (1963) is of special interest and relevance. They employed only Müller-Lyer pattern. The main problem was: "Would there be a tactual analogue of the decrement, i.e. would repeated palpation of a tactile Müller-Lyer pattern lead to a decrement in the extent of the illusion? *And, if there are decrements of both visual and tactual illusions with repeated trials, would decrements transfer from one sense modality to the other?*" (There were 80 consecutive trials within both perceptual systems.)

The results were as follows:

1. The illusions occurred both through vision and through touch.

2. Training diminished the illusion significantly in both spheres.

3. *There was significant transfer in both directions.*

4. *Transfer was significantly greater in the direction tactual-visual than vice versa.*

The authors state, moreover, that "since the decrement in an illusion on repeated trials took place without the awareness of the perceiver, this transfer effect is not likely to be explained by the verbal mediation."

Rudel and Teuber used seeing blindfolded subjects. Tsai (1967) discovered, however, *that the illusion was most accentuated in the congenitally blind; thus, the tendency toward optification cannot possibly explain the coming into existence of the illusion.*

It should be mentioned in this context that, according to Fisher (1966), the extent of the Poggendorf illusion does not differ significantly under these two kinds of conditions (vision and touch). According to Over (1966) again "both visual and tactual judgments made of Müller-Lyer figures were found to be a function of the angle of the arrowheads. For both modes of judgment, a larger illusion was found for the bisection (inverted T) than the horizontal-vertical figure. The results suggest that theories which attempt to explain illusions in terms of processes which are specific to vision are invalid."

Comments: The results incontestably suggest that the laws obeyed by perception are, in principle, independent to a considerable extent of the sense modality involved, obviously this cannot be accounted for in terms of any theories of perception thus far advanced.

As to the direction of transfer, Gaydos' assertion that tactual palpation makes it necessary to "explore the shapes more thoroughly" is one possible explanation.

The dependence of various illusion patterns on different "perceptual systems" is a highly interesting and important object of further research. No doubt, the specific studies related to the transfer of learning and to its direction are not the least relevant to research of the development of central spatial strategies related to different "perceptual systems."

Recognition approach. Rudel and Teuber (1964). The series of experiments with children carried out by Rudel and Teuber is theoretically important, especially in regard to the developmental aspects of the transposition phenomena. Using children of between three and six years old for subjects, they investigated the transposition of form recognition (discrimination).

A figure was presented to the subjects who then had to recognize it by choosing it from five alternatives. Two series of shapes were employed, an easy and a difficult one. Series I consisted of a cube, sphere, cylinder, pyramid, and cone. Series II consisted of four irregularly shaped blocks, with quite similar "profiles."

There were four types of experimental situations:

1. Visual-visual. The subject was presented a figure for five seconds. Following this, five figures were shown in succession, one of which was the figure first presented.

2. Visual-tactual. The arrangement was identical, except that this time the subject had to recognize the correct figure by employing active touch.

3. Tactual-visual.

4. Tactual-tactual.

The results were as follows:

1. The difficulty of the tasks, between Series I and II, was of definitely greater consequence than the differences among the four experimental arrangements.

2. The order of four variants, from the easiest to the most difficult, was the same irrespective of the series, namely, visual-visual, visual-tactual, tactual-visual, tactual-tactual.

3. There was a distinct difference between the five- and six-year olds and the three- and four-year olds. For example, it proved impossible to administer the tactual-tactual variant to the four-year olds. Thus reliable conclusions can only be drawn regarding five-year olds.

Comments: It should be noted that the direction in which transposition is easier in this kind of experiment differs from that met in Gaydos experiments, and in the experiments concerning the decrement in Muller-Lyer illusion. The subject's age must, however, be taken into consideration.

Second,"the cross-modal learning need not be more difficult than intramodal." The authors state: "This problem of perceptual equivalence across modalities thus does not seem to be too different from the problem of equivalence within a particular modality."

The importance of this point can hardly be overrated. The authors then put forward a view bearing a resemblance to the hypothesis which I advanced in 1959 and on which later investigations have rested to a large extent. Rudel and Teuber write, "There is some common aspect of perceptual activity which permits one to utilize information from within a sensory channel or from several channels in such a way that invariant properties of objects are extracted."

It seems apparent indeed that the criterion of a general theory of spatial patterning within the central nervous system independent of the sense modality concerned is overdue. The absence of a theory that could form a frame of reference for the results obviously explains why the results and the inferences drawn from them have remained fragmentary.

Rudel and Teuber do not let the apparent dominance of vision blind them, but argue sagaciously, "That visual presentation, for children in our study, was so much easier than tactual should, of course, not be overinterpreted. A different type of task, more appropriate to haptic exploration, might have yielded an opposite rank order of difficulty between modalities."

It should be mentioned in this connection that Blank, Altman, and Bridger (1968) found that by employing very simple figures, children three to four years of age were able to recognize visually-presented figures tactually afterwards, but not tactually-presented figures visually. The direction was the same as in Teuber and Rudel's experiments.

The above results support Gomulicki's observations that during the early years of life functional strategies develop remarkably slowly within the "tactual perceptual systems."

<u>Lobb (1965)</u>. Lobb's experiments differed from the other studies considered, especially in that the figures employed were "random shapes" generated along the lines suggested by Lawrence and Laberge. In this sense, the figures were optically unfamiliar.

The study consisted of two parts. The form-discrimination tasks included in the first part were assumed to be more difficult compared with those in the second part. However, the procedure employed was the same in both cases. Use was made of five sets; each set included four shapes, of which one was identical with the standard used. Lobb employed four combinations, but the group of subjects was different in each combination. The combinations were:

1. VV = visual standard--visual choice

2. VT = visual standard--tactual choice

3. TV = tactual standard--visual choice

4. TT = tactual standard--tactual choice

Time intervals were carefully controlled. Learning of the standard lasted 15 seconds, and a choice was required in 10 seconds.

Lobb used the terms reinforcement modality (*R*), and test modality (*T*) after the manner of Estes (1960). The first was simply the modality through which the standard was learned, whereas the second was the choice or recognition modality. Lobb also sought to investigate the relative contributions of the *R* and *T* modalities to the performance.

The results concerning the main questions were as follows:

1. Group VV was superior to the other three groups on both the easy and the difficult series.

2. The difference was more distinct in the difficult than in the easy series.

3. Group VT was second best.

4. Group TT was inferior to other groups. In the difficult series, however, it did not differ greatly from group TV.

5. Both the visual *R* modality and the visual *T* modality were independently superior to touch.

6. There was a definite tendency for the performance to improve from one set to the next.

Comments: Although the figures used were unfamiliar, considering everyday visual experience, they were not, however, unfamiliar in the tactual performances after visual exposure within Lobb's experimental arrangement. Hence, the results have no bearing on the criticism made above of Worchel's conclusions. According to my hypothesis, early-blind, late-blind, and sighted subjects would have been likely to do equally well on Lobb's TT variants.

On the other hand, had shapes similar to those employed by Lobb been used by Gaydos, the transfer of learning would probably have been greater in the direction VT than in the direction TV. At least operationally, Lobb and Gaydos investigated different phenomena.

Cashdan (1968). Cashdan's experiments, again differed from the above studies in that the mode of exposure of stimulus figure was successive both visually and tactually. Cashan is completely justified in maintaining that although "the stimuli have been objectively identical, no investigator up to this point has compared performance in two modes under conditions of equivalent stimulation. That is to say, in visual discrimination tasks the total stimulus is presented to S, whereas under haptic conditions S is exposed to a succession of stimuli due to the very nature of manipulative activity." Cashdan's procedure is of utmost interest and, therefore, the following quotation is called for:

> "The stimuli used in the study were nonsense forms adopted from a study by Gaydos (1956). Two comparable sets of stimuli were constructed, one for haptic presentation and one for visual presentation. (Haptic = tactual.) Each (tactual) figure was arbitrarily divided into five equal segments by a knot. The visual counterpart of each figure was divided into five segments, each of which was drawn on a separate card in a position relationally correct to the total figure. Thus in each exposure condition (tactual or visual), S was exposed to a series of segments comprising a figure. In the test condition, however, S had to choose the correct figure from an array of constructed forms."

The following observations of results are of particular interest:

1. Irrespective of the manner of exposure of the stimulus (successive or simultaneous), the VV-category seems to be superior to all others.

2. The direction VT is superior to the direction TT.

3. The other results are ambiguous.

Comments: Cashdan paid no attention to the fact, mentioned earlier, that the Gaydos figures were visually familiar to a large extent. They were not "nonsense figures," as Cashdan supposed. In principle, this may be the underlying factor which explains the superiority of vision. On the other hand, within the response or test modality the figures were presented simultaneously.

Cashdan's approach to the analysis of various factors involved in transposition phenomena is important. In further studies it should be employed by using random shapes and successive exposure both in the stimulus and in the response conditions. The number of segments to be presented successively, and their size, are further variables that should be controlled.

General considerations. All the studies described in this section have been concerned with form discrimination in one way or another. From the results it seems evident that the central nervous system is able to transpose spatial relationships from visual-perceptual systems to tactual-perceptual systems and vice versa. This is tantamount to maintaining that the central nervous system forms some kinds of concepts of spatial relationships, which are, in principle and to a certain extent, independent of the "perceptual systems." These concepts obviously furnish a basis for form discrimination. What, then, are the concepts like that are generally formed via the central nervous system?

At least two general hypotheses concerning the nature of form discrimination have been advanced (Pick, 1965). Pick and Pick (1966) describe them briefly:

> "One of these hypotheses is a 'schema' or prototype hypothesis (for example, Bruner, 1957; Solley and Murphy, 1960) which suggests that improvement in discrimination involves a matching process and depends on the learning and storing in memory of prototypes or models of the relevant forms. The second hypothesis is a distinctive feature hypothesis (Gibson, Gibson, and Osser, 1962; Pick, 1965) which suggests that improvement in discrimination depends on learning of the dimensions of difference which are critical for distinguishing between the relevant forms. Two hypotheses may be crudely conceived as suggesting 'memory image' learning on the one hand, and differentiation learning on the other."

Pick (1965) examined the validity of these two hypotheses separately within visual and within tactual-perceptual systems, but made no cross-modal experiments. Her summarizing conclusion was:

> "In terms of the tasks involved in these experiments, one may interpret the results as suggesting that the detection of distinctive features will always facilitate improvement in discrimination but that under conditions of successive comparisons, schema construction will independently facilitate such improvement."

The same hold true within both modalities. (The stimulus forms were letter-like forms of the kind used in the developmental study of Gibson et al. (1962). Pick, Pick, and Thomas (1966) used a practically similar experimental design in their cross-modal study. The results supported the hypothesis that the learning of the dimensions of difference is basic to improvement in such discriminations and suggested that this learning can be transferred from one modality to another. The conditions under which prototype learning accompanies the learning of the dimensions of difference, and is transferred from one perceptual system to another, cannot be defined unequivocally.

Gibson and Gibson (1955) write in their important article:

> "Repetition and practice is necessary for the development

of improved percept, but there is no proof that it incorporates memories. . . . The observer sees and hears more, but this may be not because he images more, or infers more, or assumes more, but because he discriminates more. . . . Perhaps the ability to summon up memories is merely incidental to perceptual learning and the ability to differentiate stimuli is basic."

It is my feeling that experiments of the form-discrimination type are not, as a rule, the most important and interesting from the view of study of the transposition phenomena. This is because most of them have been based on the discrimination of "distinctive features," rather than on the mastery of the whole figure. The situation is different where the response system is based on reproduction. Unfortunately, such experiments have rarely been made.

However, Pick's results indicate that "under conditions of successive comparison, schema construction will independently facilitate such improvement." Successive means here that the figures to be compared are presented successively, and this has been the case in all studies considered in this section. It can be assumed, therefore, that in those studies "memory image" transposition has also been in question.

Various experimental modifications have been commented upon previously in this section. Some further remarks on the problem of illusions are called for in this connection. After the passage quoted above, Gibson and Gibson continue:

> "This theoretical approach to perceptual learning, it must be admitted, has points of weakness as well as points of strength. It accounts for veridical perception, but it does not account for misperceptions."

The modality-independent existence and cross-modal decrement via learning of certain perceptual illusions remain indeed unexplained on the basis of pure "distinctive feature" hypothesis. Perhaps letter-like forms particularly favored the "distinctive-feature" hypothesis. On the other hand, had the exposure time been longer, the results would have been more compatible with the "memory-prototype" hypothesis.

Regarding sense dominance, the above results indicate that in transposition, the direction VT is clearly superior to the direction TV, in children aged three to four years. In fact, three-year old children were unable to compare forms under TT conditions. A clear distinction should obviously be made between a preference for the use of a certain perceptual system in general manipulation (for example, in play) and on ability to form spatial patterns on the basis of this sense. This point should be taken into account in developmental analysis of the phenomena of transposition.

Transposition in All Combinations in the Direction of Visual Systems--Tactual Systems--Brachial Systems, Based on Actual Concrete Simultaneous Sensations

Birch and Lefford (1963). The study conducted by Birch and Lefford is important at least in three respects.

1. Transposition was explored longitudinally.

2. Three perceptual systems were involved in all mutual combinations. In addition, this study is almost the only one in which the brachial-perceptual systems have been taken into consideration.

3. Equivalence relationships among the visual, tactual, and brachial systems were explored on the basis of actual concrete sensations of two senses simultaneously.

Birch and Lefford use the term "kinesthetic sense" mainly in the sense the term "brachial perceptual system" was defined in this paper. The following quotation shows what exactly, they intended to investigate.

"The kinesthetic sense, in this study refers to the sensory inputs obtained through passive arm movements. In the current investigation such a motion entails input from the wrist, elbow, and shoulder joints, and from the arm and shoulder musculature as its principal components. . . . Kinesthetic information was provided by placing the subject's arm behind a screen and with the arm out of sight passively moving it through a path describing the geometric form. This was accomplished by placing a stylus held in normal writing position in the subject's hand. The examiner gripped the stylus above the point at which it was held by the subject and then moved the stylus and hand through the path of a track inscribed in a linoleum block which described the geometric form. . . . In a kinesthetic trial the movement was always started at the topmost point of the figure and continued in a clockwise direction for the right hand and in a counterclockwise direction for the left hand. In putting the subject's hand through the motion, a short pause (approximately one second) was made at each point of the course where there was a change of direction. For each kinesthetic trial the subject's hand was put through one complete circuit from topmost point to topmost point. . . . In making the tactual-kinesthetic comparisons, both hands were utilized simultaneously."

Eight blocks selected from the Seguin Form Board, were used as stimuli. The subjects were 145 students of ages ranging from five to eleven years, and their median IQ was 115. Two kinds of error were distinguished: (a) an error when nonidentical forms were judged as being the same and (b) an error when identical forms were judged as being different.

Results: Only the main results shown in Figures 1 and 2 are presented here, and the following conclusions drawn from them:

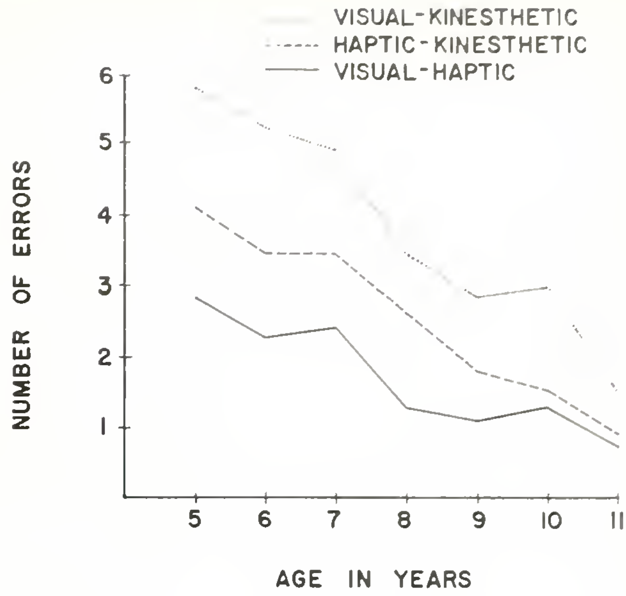

Figure 1. Mean Errors for the Intersensory Judgment of Non-Identical Forms at Different Ages.

1. In the early school years, the extent and patterning of intersensory equivalence changes with age.

2. The easiest direction seems to be VT. The difference between VT and other directions is greatest in ages five and six.

3. The effective translatability of visual and tactual information into brachial does not reach the level of accuracy of visual-tactual integrations of the five-year-old, until the children are several years older.

4. The most difficult direction is visual-kinesthetic throughout the age range covered.

5. On the whole, development is most rapid between the ages of six and eight.

6. Relatively more errors were made in the intersensory judgment of identical forms as being the same, than were made in judging non-identical forms as being different.

Comments: Birch and Lefford have presented this important assumption:

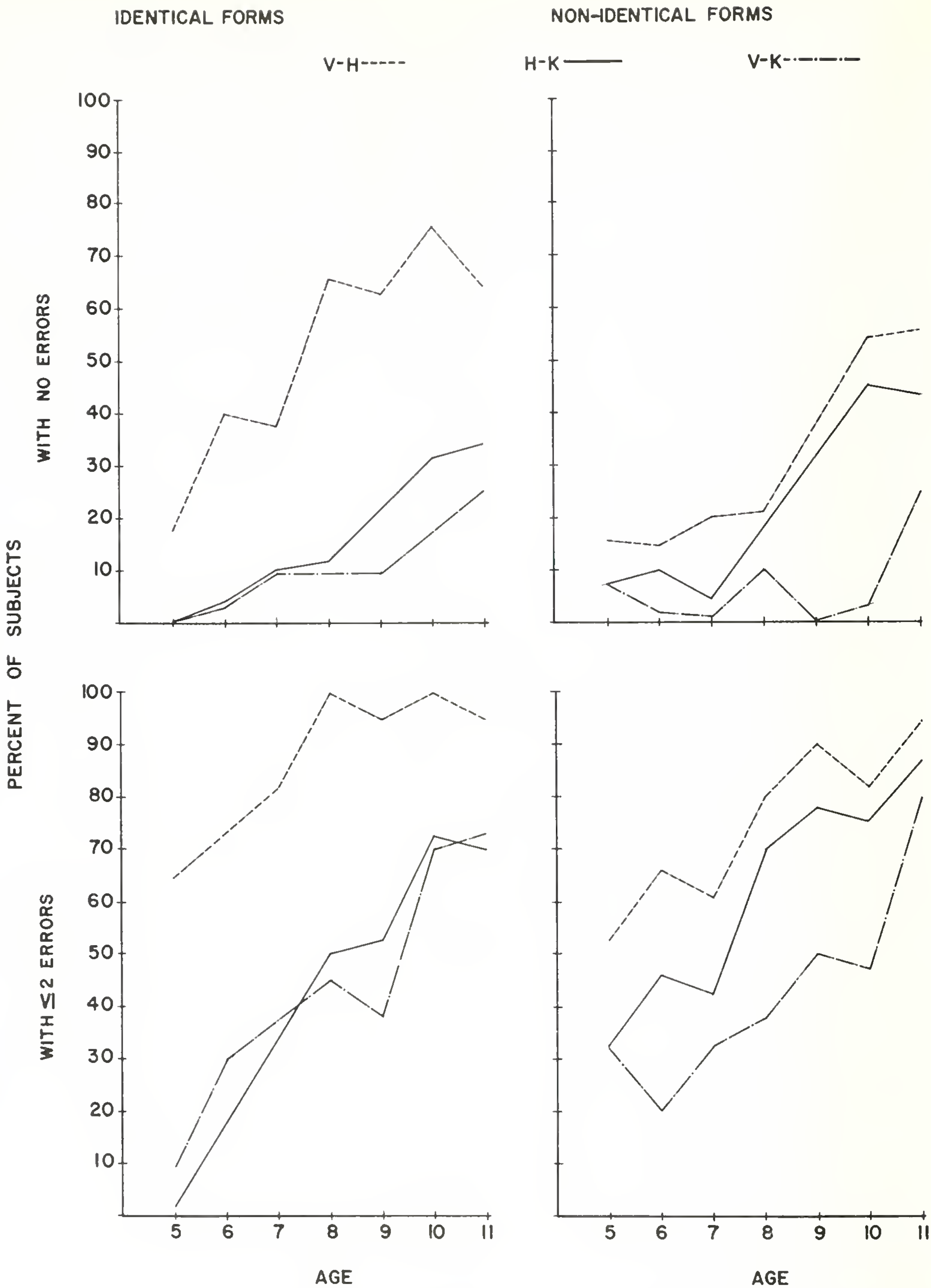

Figure 2. Percentages of Subjects at Each Age Level Who Meet Two Criteria of Accuracy in Intersensory Judgment.

"It is possible that such differential age-specificity in the development of varieties of intermodal equivalence is one of the important factors underlying frequently noted discrepancy between accuracy in the perceptual recognition of shapes and gross inaccuracy in their reproduction. Support for such an inference is provided by the fact that there is a close correspondence between ages for the development of effective visual-kinesthetic intermodal equivalence in the judgment of different forms and the age level at which children can copy such forms accurately from a visual model."

Transposition should be discussed, at least in broad outline, in terms of:

1. Perceptual acuity
2. Modality-specific spatial ability
3. Process of intersensory integration.

Birch and Lefford suppose that "it would be expected that visual-tactual functioning would be markedly inaccurate in children of three, but would rapidly improve thereafter." This assumption is consistent with the results of Teuber and Rudel mentioned earlier. The results are also in accord with interesting experiments of Abravanel (1968). His research was concerned with correspondence between elementary attributes of spatial position (up-down, inside-outside, etc.). According to Abravanel "Ss aged three and four years showed little accuracy in Sameness-Difference judgments, whereas significant increases in accuracy were found by those aged five and six."

The poor performance of younger children in transposition is due obviously to relatively less developed perceptual acuity and inner-modal spatial ability. It should be pointed out here that beyond a certain degree of complexity of the patterns, an inner-modal inability in patterning the forms to be transposed may lead, in adults as well as in children, to inferior transposition performance. In the study of transposition phenomena, inner-modal spatial ability should clearly be distinguished, in principle, from cross-modal spatial functioning. The former should be controlled carefully, since it is a precondition for the latter.

The period of rapid development between ages six and eight is in accord with the rise in the conceptualization level observed at these ages. (Acquisition of the level of concrete operations, according to Piaget.)

The children aged five were unable to relate visual perceptions to brachial ones or vice versa. This result is, however, consistent with the fact that children learn rather late and slowly to reproduce visual patterns by drawing. The following hypothetical explanations may be presented for the observed order of difficulty.

1. The superiority of the direction VT may have been due to associative experience, as the figures employed were visually familiar. Yet, in any case, this direction is likely to be easiest, because seeing children have relatively little experience with the brachial perceptual system.

2. The reason why the direction TB was easier than VB may lie in the fact that the relevant strategies of the central nervous system are relatively more similar in the former than in the latter case.

3. The direction VB was the one where both the central strategies for the two perceptual systems involved and the experience gained through them in the past had the least in common. Moreover brachial strategies are likely to be highly complex and an ability to use them in accurate spatial manipulation develops relatively slowly. This is why the early blind are retarded to such a great extent in simple dexterity performance between the ages of five to twelve, as

has been shown by Gomulicki (1961).

It would have been interesting to know the correlations between inner-modality spatial performances in these three "perceptual systems."

> "Some factors for greater difficulty in the judgment of identical forms than in the judgment of nonidentical forms are readily apparent. To make a correct judgment of similarity, the subject must become aware of all of the parts of both forms as well as their total organization if congruence is to be recognized. However, in order to make correct judgment of difference the subject need only become aware of some noncongruence between any of the parts of the two stimuli."

It is easy to see that what Birch and Lefford say is in agreement with "prototype-memory" and "distinctive feature" hypotheses.

Transposition in the Direction Cutaneous Perceptual and Visual Perceptual Systems and Vice Versa

Krauthamer (1968). Krauthamer's experiments are important at least in the following respects:

1. Unlike most other experiments, they were concerned with the cutaneous perceptual systems.
2. Both simultaneous and successive modes of exposure were used. (The comparisons were carried out successively, but the exposure of any one figure was either simultaneous or successive.)
3. The forms used were visually unfamiliar.
4. The experiments included both inner-modality and cross-modality tasks.

The following description of the procedure also illustrates what kinds of performance were investigated:

> "The test consisted of 32 nonsense patterns, approximately 3 x 3 cm in size and arranged in eight sets of four similar patterns." Crossmodal task: "A nonsense pattern was first shown to S in one modality, e.g. vision, and designated by E as standard Pattern. Following this initial exposure the same pattern was again presented but now tactually (tactual = cutaneous), as one of a set of four similar patterns. The order of these four Comparison Patterns was randomized. . . . The heteromodal Standard Pattern was shown to S before each comparison, and the complete presentation of one set, consisting of four crossmodal comparisons, was designated as one trial. Criterion for success consisted of two errorless consecutive trials (eight paired comparisons). Ss were not informed of the results of their performance." On modality-specific (inner-modality) tasks the procedure was practically the same.
>
> Successive stimulation: "The patterns were prepared as plywood stencils which guided a plastic stylus when the patterns were traced on S's palm. For visual presentation the stylus was replaced by a modified flashlight projecting a pinpoint of light on a translucent glass window."
>
> Simultaneous stimulation: "In this case the patterns were exposed visually as drawn in black on small white cards. The patterns for tactile presentation resembled cookie-cutters. They consisted of thin copper strips partially embedded in blocks of wood which E gently pressed into S's palm."

The order of testing for the Ss was as follows:

Task sequence	Modality-specific tasks 1st	2nd	Crossmodal task 3rd	N
Group 1	Visual	Cutaneous	Cutaneous-Visual	12
Group 2	Visual	Cutaneous	Visual-Cutaneous	12
Group 3	Cutaneous	Visual	Visual-Cutaneous	12
Group 4	Cutaneous	Visual	Cutaneous-Visual	12
				48

The subjects were 48 college students. Modality-specific tasks were thus invariably performed before cross-modal tasks. The main results are shown in Figure 3.

Conclusions:

1. In the case of modality-specific tests, visual-form discrimination was significantly superior to cutaneous-form discrimination, irrespective of the method of stimulation.
2. Within the visual-perceptual system, the method of simultaneous stimulation was significantly superior to the successive stimulation.
3. In contrast, cutaneous-pattern discrimination required the same number of trials with either method of stimulation.

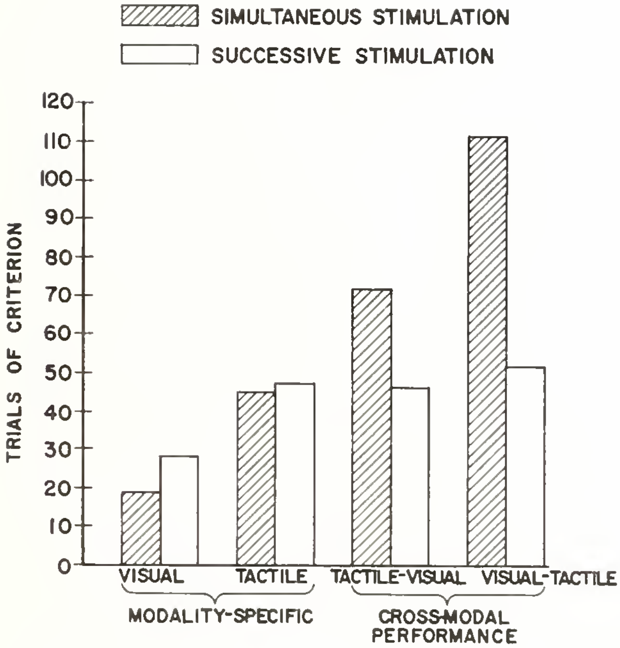

Figure 3. The Number of Trials to Criterion on the Modality-Specific and Cross-modal Tasks for Two Different Methods of Stimulation.

4. When in the case of cross-modal tests, the method of successive stimulation was used, the identification of forms across two different modalities was no more difficult than inner modality-cutaneous tasks.
5. The above result was virtually the same in the direction of cutaneous-visual as in the direction visual-cutaneous.
6. With simultaneous stimulation, however, performance on the cross-modal tasks was markedly inferior to all other results. Despite the superiority of simultaneous stimulation in the previous modality-specific phases the groups averaged nearly twice as many trials as the successive stimulation groups.
7. Simultaneous cross-modal performances in the direction visual-cutaneous proved to be the most difficult. That is, the most difficult among Krauthamer's experiments was the one where the subject had to identify a previously perceived, simultaneous, visual pattern with a simultaneous pattern felt on the palm of the hand.

General considerations. Certain of Krauthamer's results seem complex and difficult of interpretation. Nevertheless, his experimental design includes several aspects, both technical and theoretical, that are relevant to the analysis of transposition phenomena. It should be mentioned first, in addition to the results listed above, that according to more detailed analysis of the data, prior cutaneous inner modality training (see the order of tasks) did not lead to relatively better visual inner-modality performance. Likewise, prior visual training did not lead to relatively better cutaneous performances when the stimulation was successive.

The modality-specific results in visual form discrimination seem natural enough and need not be discussed further. But how can we account for the finding that the inner-modality discrimination of cutaneous forms was equally easy with simultaneous and with successive stimulation?

It would seem that two hypothetical starting points present themselves. The first is the bipolar character of perceptual activities of the skin or the cutaneous-perceptual systems. Thus, in the case of successive stimulation, cutaneous-perceptual systems are active in a sense, despite the fact that the palm of the hand is immovable. From this we could expect the successive method of stimulation to be superior to the simultaneous one. Second, in Krauthamer's figures with simultaneous stimulation, perceptual differences comparable to those involved in two-point discrimination may be in question. In either case, some distinctive differences in detail may explain the result.

Both starting points will also prove useful in the interpretation of the crossmodal results. The columns of the successive stimulation are equally high for the directions cutaneous-cutaneous, cutaneous-visual, and visual-cutaneous. The explanation may lie simply in the activity peculiar to the cutaneous-perceptual systems when these are stimulated successively. Compared with the simultaneous method, the successive method makes it possible for the subjects to form a clearer pattern which they can then relate to visual patterns. But this fails to explain the equality between the two crossmodal directions. Perhaps the subjects were restricted to keep in their mind certain clearly distinctive features which were equally easy to recognize both as stimulus and response pattern across modalities. Further research is needed to find out how far results like these can be explained in terms of the stimuli alone.

Why was it then that cross-modal performances were so poor with simultaneous stimulation? Here we come to the two-point discrimination hypothesis. In the cutaneous-cutaneous situations, the observer compared various sizes and distances phenomenologically within the same perceptual system. But impressions of this kind are very difficult to relate to phenomenologically wholly different visual impressions. The point is that practically no impression of pattern comes into being in the simultaneous case.

Krauthamer himself felt that he was unable to explain the results. He did not, however, extract all the information that could have been extracted from the data, but was apparently content with the observation that cross-modal form discrimination is possible to some extent. Nevertheless, his experimental designs were important.

It would certainly be of interest to investigate systematically how cutaneous-perceptual systems correlate with one another in the various parts of the body. A further important research object would be to analyze the interrelationships of cutaneous perceptual systems (especially with successive stimulation) and tactual perceptual systems. Regarding the simultaneous stimulation method, the following question can be raised. Does the coming into existence of a pattern depend, not only on the form concerned, but also its size? The figures employed by Krauthamer were comparatively small (3 x 3 cm). How would the patterning and cross-modal form recognition have turned out if the figure had measured say 15 x 15 cm, and had been presented to the skin of the back? This is an unexplored area where there is scope for imagination.

In this connection it is only possible briefly to mention that the "Vision Substitution System" developed by Bach-Y-Rita et al. (1967, 1969) makes use of the cutaneous perceptual systems of the back.

> "Four hundred solenoid stimulators are arranged in a 20 x 20 array built into a dental chair. The stimulators, spaced 12 mm apart, have 1 mm diameter Teflon tips which vibrate

against the skin of the back. The subject manipulates a television camera mounted on a tripod, which scans objects placed on a table in front of him. . . . The subject can aim the camera, equipped with a zoom lens, at different parts of the room, locating and identifying objects or persons. . . . As the blind become more familiar with the objects, they learn to recognize them from minimal or partial cues. This skill permits them to describe with accuracy the layout of objects on a table, in depth and in correct relationship, even though the objects may be overlapping and partially visible." (Bach-y-Rita et al., 1969.)

Interesting is the following observation:

"Our subjects spontaneously report the external localization of stimuli, in that sensory information seems to come from in front of the camera, rather than from the vibrators on their back."

Crucial from the point of our main theses concerning spatial functioning, and the transposition phenomena related to spatial functioning, are the following words of Bach-y-Rita (1967):

"Sensory plasticity is defined here as ability of one sensory system (receptors, afferent pathways, and the central nervous system representation) to assume the function of another system."

This amounts practically to the same as the statement of Teuber et al.:

". . . there is some common aspect of perceptual activity which permits one to utilize information from several channels."

The central problem is: what kinds of hypotheses or theory can be built on the basis of these general ideas?

Summary of Empirically Established Facts

It would seem that the following facts concerning the phenomena of transposition relating to spatial functioning have been established empirically:

1. Previous visual experience is of help in the tactual recognition of familiar optic figures and in operations with relationships involved in such figures.

2. Previous visual experience is also of help in the reproduction and mastery of ambulatory patterns that are visually familiar.

3. To generalize, what is involved above is associations in the central nervous system of representations of systems of relationships familiar from prior experience.

4. Insofar as the patterns concerned are not visually familiar, visual imagery is not of help in performances based on tactual and ambulatory-perceptual systems.

5. Transfer of maze learning seems to be greater in the direction from ambulatory-perceptual systems to tactual-perceptual systems than in the opposite direction. No answer resting on empirical evidence can be given to the interesting question how far this result can be generalized.

6. In the learning of sets of figures, transfer effects undoubtedly occur in man both in the tactual-visual direction and in the visual-tactual direction. The direction in which transfer is greater obviously depends to a great extent on experimental arrangements. If the figures concerned are visually familiar, transfer seems to be greater in the tactual-visual direction than in the reverse direction.

7. Particularly interesting is the observation that there is significant transfer in the decrement of illusion in the Müeller-Lyer pattern through repeated trials both in the tactual-visual direction and in the opposite direction. Transfer is, however, significantly greater in the tactual-visual direction.

8. In form recognition in the visual-tactual and tactual-visual directions the visual component rather than the tactual seems to be the decisive one.

9. Investigations of transposition phenomena by means of comparisons based on actual concrete simultaneous sensations have revealed that ability for transposition in the visual-tactual direction seems to develop earlier than ability for transposition between any other perceptual systems, namely, at the age of four or five. A similar ability in the tactual-brachial direction develops two years later. The most difficult direction is visual-brachial, which is not mastered until the age of eleven or so.

10. Regarding the cutaneous-perceptual systems only the following seems to be evident. Cross-modal form recognition is possible both in the visual-successively operating cutaneous systems direction and in the opposite direction, and it is equally easy in both directions. Nothing definite can be said for the present concerning the simultaneous-operating cutaneous systems.

11. The most important result concerning the developmental aspects is that the congenitally blind catch up with the sighted with respect to tactual and ambulatory performance at the age of 16 or so. In other words, purely tactual and ambulatory-spatial strategies develop relatively slowly in the absence of visual cues, but finally they reach the same level as the strategies supported by visual images.

REFERENCES

Abravanel, E. "Intersensory Integration of Spatial Position During Early Childhood," *Perceptual and Motor Skills*. 1968, Vol. 26, pp. 251-6.

Axelrod, S., and L. D. Cohen. "Senescence and Embedded-Figure Performance in Vision and Touch," *Perceptual and Motor Skills*. 1961, Vol. 12, pp. 283-8.

Bach-y-Rita, P. "Sensory Plasticity. (Applications to a Vision Substitution System.)" *Acta Neurologica Scandinavia*. 1967, Vol. 43, pp. 417-26.

Bach-y-Rita, P. et al. "Vision Substitution by Tactile Image Projection," *Nature*. 1969, Vol. 221, pp. 963-4.

Bean, C. H. "The Blind Have 'Optical Illusions,'" *Journal of Experimental Psychology*. 1938, Vol. 22, pp. 283-9.

Birch, H. G., and A. Lefford. "Intersensory Development in Children," Monographs of the Society for Research in Child Development, No. 28, 1963 (5, Whole No. 89).

Birch, H. G., and A. Lefford. "Two Strategies for Studying Perception in Brain-Damaged Children." In H. G. Birch (ed.) *Brain Damage in Children*. New York: The Williams and Wilkins Company, 1964.

Blank, M., L. D. Altman, and W. H. Bridger. "Transfer of Form Discrimination in Preschool

Children," *Psychonomic Science.* 1968, Vol. 10, pp. 51-2.

Berg, J., and F. Worchel. "Sensory Contributions to Human Maze Learning: A Comparison of Matched Blind, Deaf, and Normals," *The Journal of General Psychology.* 1956, Vol. 54, pp. 81-93.

Cashdan, S. "Visual and Haptic Form Discrimination Under Conditions of Successive Stimulation," *Journal of Experimental Psychology.* 1968, Vol. 76, pp. 215-18.

Drewer, J. "Early Learning of the Perception of Space," *American Journal of Psychology.* 1955, Vol. 68, pp. 605-14.

Drewer, J. *Dictionary of Psychology.* London: Penguin Books, 1956.

Estes, W. K. "Learning Theory and the New 'Mental Chemistry,'" *Psychological Review.* 1960, Vol. 67, pp. 207-23.

Ettlinger, G., and C. B. Blakemore. "Cross-Modal Matching in the Monkey," *Neuropsychologia.* 1967, Vol. 5, pp. 147-54.

Ettlinger, G., and C. B. Blakemore. "Cross-Modal Transfer Set in the Monkey," *Neuropsychologia.* 1969, Vol. 7, pp. 41-7.

Ewart, Anne G., and F. M. Carp. "Recognition of Tactual Form by Sighted and Blind Subjects," *American Journal of Psychology.* 1963, Vol. 76, pp. 488-91.

Fisher, G. H. "Autokinesis in Vision, Audition and Tactile-Kinaesthesis," *Perceptual and Motor Skills.* 1966, Vol. 22, p. 470.

Fisher, G. H. "A Tactile Poggendorff Illusion," *Nature.* 1966, Vol. 212, pp. 105-6.

Fleishman, E. A., M. M. Roberts, and M. P. Friedman. "A Factor Analysis of Aptitude and Proficiency Measures in Radiotelegraphy," *Journal of Applied Psychology.* 1958, Vol. 42, pp. 129-37.

Gaydos, H. F. "Intersensory Transfer in the Discrimination of Form," *American Journal of Psychology.* 1956, Vol. 69, pp. 107-10.

Gibson, Eleanor J., J. J. Gibson, Anne D. Pick, and Harry Osser. "A Developmental Study of the Discrimination of Letter-like Forms," *Journal of Comparative Physiological Psychology.* December 1962, Vol. 55, pp. 897-906.

Gibson, J. J. "Observations on Active Touch," *Psychological Review.* 1962, Vol. 69, pp. 477-91.

Gibson, J. J. *The Senses Considered as Perceptual Systems.* Boston: Houghton Mifflin Company, 1966.

Gibson, J. J., and Eleanor J. Gibson. "Perceptual Learning: Differentiation or Enrichment?" *Psychological Review.* 1955, Vol. 62, pp. 32-41.

Gomulicki, B. R. "The Development of Perception and Learning in Blind Children," The Psychological Laboratory, Cambridge University, 1961.

Guilford, J. P. *The Nature of Human Intelligence.* New York: McGraw-Hill, 1967.

Juurmaa, J. "Intermodaalisista lahjakkuustekijoista." ("On the Intermodal Ability Traits.") *Ajatus.* 1959, Vol. 22, pp. 93-113.

Juurmaa, J. *An Analysis of the Components of Orientation Ability and Mental Manipulation of Spatial Relationships.* Reports from The Institute of Occupational Health, Helsinki, No. 28, 1965.

Juurmaa, J. *Ability Structure and Loss of Vision.* American Foundation for the Blind, Research Series, No. 18, 1967.

Juurmaa, J. *On the Interrelations of Auditory, Tactual, and Visual Spatial Performances.* Reports from the Institute of Occupational Health, Helsinki, No. 54, 1967.

Juurmaa, J. "Analysis of Orientation Ability and Its Significance for the Rehabilitation of the Blind," *Scandinavian Journal of Rehabilitation Medicine.* 1969, Vol. 1, pp. 80-4.

Juurmaa, J. "On the Accuracy of Obstacle Detection by the Blind," *The New Outlook for the Blind.* Numbers 3 and 4, 1970.

Juurmaa, J. "The Spatial Sense of the Blind. A Plan for Research." *Research Bulletin No. 24* (The American Foundation for the Blind), 1972.

Juurmaa, J., and K. Suonio. "Optification Tendency in Tactual Spatial Manipulation: An Experimental Study." Reports from the Institute of Occupational Health, Helsinki, No. 68, 1969.

Katz, D. *Der Aufbau der Tastwelt.* Leipzig, 1925.

Krauthamer, G. "Form Perception Across Sensory Modalities," *Neuropsychologia.* 1968, Vol. 6, pp. 105-13.

Lobb, H. "Vision Versus Touch in Form Discrimination," *Canadian Journal of Psychology.* 1965, Vol. 19, pp. 175-87.

Lowenfeld, V. "Tests for Visual and Haptical Aptitudes," *American Journal of Psychology.* 1945, Vol. 58, pp. 100-11.

Luria, A. R. *Human Brain and Psychological Processes.* New York: Harper & Row, 1966.

Luria, A. R. *Higher Cortical Functions in Man.* London: Tavistock Publications, 1966.

Over, R. "A Comparison of Haptic and Visual Judgments of Some Illusions," *American Journal of Psychology.* 1966, Vol. 79, pp. 590-5.

Piaget, J. B., and B. Inhelder. *The Child's Conception of Space.* London: Routledge, 1956.

Pick, Anne D. "Improvement of Visual and Tactual Form Discrimination," *Journal of Experimental Psychology.* 1965, Vol. 69, pp. 331-9.

Pick, Anne D., H. L. Pick, and Margaret L. Thomas. "Cross-modal Transfer and Improvement of Form Discrimination," *Journal of Experimental Child Psychology.* 1966, Vol. 3, pp. 279-88.

Révész, G. *Psychology and Art of the Blind.* London: Longmans, 1950.

Rock, I., and C. S. Harris. "Vision and Touch," *Scientific American.* 1967, Vol. 216, pp. 94-104.

Rudel, Rita G., and H. L. Teuber. "Decrement of Visual and Haptic Müeller-Lyer Illusion on Repeated Trials: A Study of Cross-modal Transfer," *Quarterly Journal of Experimental Psychology.* 1963, Vol. 15, pp. 125-31.

Rudel, Rita G., and H. L. Teuber. "Cross-modal Transfer of Shape Discrimination by Children," *Neuropsychologia.* 1964, Vol. 2, pp. 1-8.

Schachtel, E. *Metamorphosis.* New York: Basic Books, 1959.

Schlaegel, T. F. "The Dominant Method of Imagery in Blind as Compared to Sighted Adolescents," *Journal of Genetic Psychology.* 1953, Vol. 83, pp. 265-77.

Schopler, E. "Visual Versus Tactual Receptor Preference in Normal and Schizophrenic Children," *Journal of Abnormal Psychology.* 1966, Vol. 71, pp. 108-14.

Shemyakin, F. N. "Orientation in Space: General Problems of Orientation in Space and Space Representation." In B. G. Anan'yev et al. (ed.) *Psychological Science in the USSR Volume I,* U.S. Joint Publications Research Service, Washington, 1959.

von Senden, M. *Space and Sight.* London: Methuen, 1960.

Tsai, L. S. "Müeller-Lyer Illusion by the Blind," *Perceptual and Motor Skills.* 1967, Vol. 25, pp. 641-4.

White, B. W. "Visual and Auditory Closure," *Journal of Experimental Psychology.* 1953, Vol. 48, pp. 234-40

Witkin, H. A. *Personality through Perception: An Experimental and Clinical Study.* New York: Harper and Row, 1954.

Witkin, H. A., Judith Birnbaum, Salvatore Lomonaco, Suzanne Lehr, and Judith L. Herman. "Cognitive Patterning in Congenitally Totally Blind Children," *Child Development.* 1968, Vol. 39, No. 3, pp. 767-86.

Wilson, J., and H. M. Halvarson. "Development of a Young Blind Child," *Journal of Genetic Psychology,* 1947, Vol. 71, pp. 155-75.

Worchel, P. *Space Perception and Orientation in the Blind.* Psychological Monograph, 1951, Vol. 65, No. 15.

Zaporozhets, A. V. "The Origin and Development of the Conscious Control of Movements in Man." In N. O'Connor (ed.) *Recent Soviet Psychology.* New York: Liveright, 1961.

THE "PERFECT" BRAILLE SYSTEM

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There are three main reasons for using contractions in braille.

1. Contracted braille books take up less space.

2. It is easier to read short words than long words in braille.

3. It is faster to write contracted braille than noncontracted braille.

The first reason is not considered here for obvious reasons. The second and third reasons cannot be dismissed as easily. Contractions have to be learned. If the braille system is made too complicated, it takes a long time to learn it. In examining the development of the braille systems, much of the work has been concerned with the development of complicated and advanced systems. In so doing many contractions have been inserted without considering the pedagogical difficulties involved. One is impressed with the idea that these contractions are of some value in the system. In actuality some existing contractions can be shown to be of almost no practical value.

The answer to the question "How could we construct the 'perfect' braille system?" might be devise a system with as many character savings as possible, but with a very high degree of simplicity.

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The following pages contain a report on the methods and the results of a revision of the Danish braille system. The revised Danish braille system has been in use since its acceptance in September 1971.

SOURCE MATERIAL

The following source material was used:

1. The 4089 most commonly used Danish words.

2. *Midt i en jasstid* (a Danish book with 46,000 words, equal to 260,000 characters).

The 4089 words were taken from a variety of literature containing a total of 1,000,000 words. The occurrence of each of the 4089 words was counted and the number of times the word occurred was said to be the word's "value." Each one of the 4089 words was then punched on cards together with the word's value and coded for transcription into braille characters.

The book is punched into cards character by character, including spaces and punctuation, and the material is ready to be processed by a computer.

Looking at the material we find that it is a collection of letters, spaces, and punctuation, which we call characters. Putting these characters together we can create different theoretical character combinations. If the combination of characters is set up so that we start with a space and end with a space, and the combination has a meaning, we have a word (full word). Taking out two or more consecutive characters in the word results in a partial word.

A list of words is made by listing each word on a separate line. A text is made by setting the words after one another on one or more lines in such a way that they have meaning.

Characters, words, and part-words written with normal alphabetic letters are called inkprint. Transcribing a word from inkprint to braille without transcribing character-by-character, but using one or more braille characters, results in a full-word contraction in braille. Transcribing a part of the word in inkprint to one or more braille characters results in a part-word contraction in braille. Grade 1 braille is inkprint transcribed to braille character-by-character (full words). Grade 2 braille is a combination of full words and part-word contractions.

Grade 2 braille is an abbreviated version of the inkprint text. The characters "saved" is represented by the number of characters by which the text is reduced when going from inkprint to braille. A six-character word in inkprint that transcribes to braille in four characters now has a character saving of two. By multiplying character saving by the value of the word the result is a product indicating the importance of the abbreviation, or the savings value.

A five-character inkprint word transcribing to a three-character braille word, having a word value of 100 has a savings value of 200. In a five-character word that in braille is reduced by four characters having a word value of 10, the savings value is 40. The first word is more valuable in braille even though this word is only reduced by two and the other word by four characters because the first word will be in a text more often than the second.

The use of contractions is valid, but may result in misunderstanding of the abbreviation. Special rules (and exceptions) have to be established for the use of certain contractions.

THE COMPUTER PROGRAMS

Technical research on the source material used different computer programs. The result of these runs on the computer (IBM-360/75) is discussed later. The following is a description of the programs.

Program A

This program deals with the 4089 words. Word value is sorted in an ascending sequence. At the same time, the savings value for each word is computed and the words sorted in ascending sequence by savings value.

Program B

This program deals with the 4089 words as well as the book. Since the 4089 words on punched cards contain information on how the words are translated into braille, it is possible to compute how many characters are saved by the braille abbreviation. Thereafter the program reads through the book and counts how often each word appears and totals the number of characters in the inkprint text. The 4089 words are now sorted into ascending order according to the number of occurrences of each word in the book. It is now possible to print how many times the word occurred, how many characters the abbreviation of this word in the whole book saves, and finally the percentage of savings of the total number of characters in the book. The accumulated savings value is printed at the same time.

Program C

This program deals with the 4089 words. The contraction for each word is investigated. For each part-word contraction in a word, the savings value of this particular part-word contraction is computed. Then the part-word contractions are sorted in ascending sequence. The part-word contractions according to the accumulated savings value for each part-word contraction are also sorted.

Program D

This program deals with the 4089 words. From the Danish alphabet, all possible theoretical character combinations of two characters (841) are established. The 4089 words are searched for occurrence of any of these combinations. When found, the accumulated number is computed from the word's value, and each theoretical combination is sorted according to this value.

It is possible to control all the above programs so that subtotals can be computed at certain specified places in the program. It is possible to specify that only certain words, part words, or groups of words and part words are to be taken into consideration while the programs are running. For all programs it is possible to specify that the results are to be plotted as a curve or diagram. It was necessary during this work to make certain special programs to investigate special details.

RESULTS

The aim of the revision was to create a braille system which was both simple and effective, and whenever these two goals were not simultaneously possible, to reach a compromise agreeable to both. Accordingly, the following guidelines were set up:

1. Use only full-word contractions if they have an acceptable savings value and only as many as are found reasonable from a pedagogical point of view.

2. Use part-word contractions only if they have an acceptable savings value and only as many as are found reasonable from a pedagogical point of view.

3. The system is designed to have as few rules and exceptions as possible.

4. If a particular contraction forced the setting up of a special rule, simplicity was considered above savings value.

Comments (1)

In the study of savings value of full-word contractions, we find that 100 is a reasonable maximum number of full-word contractions. Using Program B and the "old" Danish braille system it is possible to compute the savings value for each of the full-word and part-word contractions. Since we have determined from the various programs that the saving of braille characters is 26 percent, we can define an absolute. In other words, we know how big a value of saving is needed for a one-percent saving in characters. The 500 most commonly used words were selected and contracted to one- or two-braille characters. The savings value for each of these words was computed and sorted in ascending sequence according to this value, showing that if more than 100 full-word contractions were used, the percentage of saving for the words above this number would be very small. Using 100 full-word contractions gives an 18-percent saving. Using 500 full-word contractions gives us 22.5-percent saving. The added burden of 400 full-word contractions is at a saving of only 4.5 percent.

Comments (2)

Research indicated the use of more than 30 part-word contractions is not practical. In the "old" Danish braille system there were 58 part-word contractions. Using Program C we found that there was a great difference in the savings value of each of the 58 part-word contractions. We had two groups: 29 good ones and 29 poor ones. Taking the accumulated value of saving into account, the 29 good part-word contractions represented 95 percent of the total saving of characters for all the 58 contractions. It also was obvious that the 29 poor part-word contractions were contractions which often used the so-called contraction sign. The goal seemed to be about 30 part-word contractions. But we had to make sure that every combination of letters in which there was value-of-saving should be contracted and which in the "old system" was not, and then to see if we had any more unused braille characters. Using Program D and excluding all combinations which because of overlapping were worth nothing, we found 27 possible good ones, of which 21 already existed. Of the 27, we could only have 22 plus five, three- or four-character part-word contractions, which in the end gave us 27 part-word contractions. Ten of these are also full-word contractions and are the only ones which can be used as full-word contractions too.

Comments (3) and (4)

In all the research it was found that any expansion of the number of rules and exceptions to get a larger saving of characters is of no value, but it is necessary to have *some* to exclude misunderstandings.

The final result of this work was a proposal for a revision of the "old" Danish braille system. The characteristics of the new system are as follows:

1. 100 full-word contractions (plus 30 extra because of certain compound words having pedagogical values).

2. 27 part-word contractions.

3. 28.6-percent character saving.

4. 3 rules.

5. 5 exceptions for the use of full-word and part-word contractions.

6. Punctuation rules.

The table below shows comparisons among some braille systems.

CONCLUSION

The "perfect" braille system is obtained by using the following rules:

1. Use approximately 100 full-word contractions.

2. Use approximately 30 part-word contractions.

3. If possible, do not use any rules and exceptions.

4. Do not use the so-called contraction sign.

5. The first paragraph of *How to Write Grade 2 Braille* must be

It is never wrong to write Grade 1 braille!

	The "old" Danish System	The Revised Danish System	English-American Usage*
Number of full-word contractions	49	130	140
Full-word contractions usable as part-words	36	10	Almost all
Other part-word contractions	22	17	48
Character-saving value	26.0%	28.5%	26.5%

*A Frequency Count of Symbology of English Braille, Gr. 2, American Usage by Kederis, Siems, and Haynes in *The Education of the Blind*, December 1965.

AN EXPLORATORY STUDY OF PIAGETIAN SPACE CONCEPTS IN SECONDARY, LOW-VISION GIRLS

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Space is that part of the individual's world which involves the position of objects in their relationship to self, to each other, and to the spatial field (Gibson, 1950). When children have low vision, either a concomitant lessening of spatial efficiency may be expected or else a tremendous amount of adaptation must take place in order to compensate for the visual loss. Knowledge and understanding of developmental spatial concepts is an indispensable aspect of the education and psychology of visually-limited children. While there are numerous studies dealing with space perception of the blind (Worchel, 1951; Cratty, 1971; Juurmaa, 1966; Hatwell, 1959; Axelrod, 1959; Gottesman, 1971), there is little research concerning the development of representational space in low-vision children. Piaget seems to be the only investigator to have systematically studied the development of representational space in children (Laurendeau and Pinard, 1970).

According to Piaget, the essence of spatial intelligence lies in the individual's reasoning capacities. These abilities are defined in terms of mental operation. Initially the child develops concepts of space through establishing relationships between experience and action, through manipulating the world by action, through learning how to represent the external by means of mental relationships between experience and action, and through learning how to represent the external by means of trial and error. Upon learning to use emerging operations as a means of solving a problem, the child still relies on the concrete; he uses the present as immediate reality and is unable to cope with alternate possibilities. It is only after the integration of several thought processes into a system of reference can the child use formal operations. At this level he is now operating on hypothetical propositions rather than on just what he experienced. Table 1 shows the development of representative space.

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TABLE 1

Development of Representational Space

A. Sensorimotor or Perceptual Space (0-24 months)

1. Reflexive and Primary Circular Reactions (0-4.5 months)

   Neither perceptual constancy of shape and size nor permanence of solid objects exists; absence of visuomotor coordination.

2. Secondary Circular Reactions and Coordination of Secondary Schema (4.5-12 months)

   Shapes and dimensions of objects--development of perceptual

TABLE 1 (Continued)

constancy in size and shape; beginning of reversibility of movement.

3. Tertiary Circular Reactions and Invention of New Means through Mental Combinations (12-24 months)

   Relationships of objects to each other--emergence of mental image (symbol) with first attempts at drawing; space is no longer purely perceptual, but becomes partly representational.

B. Pre-Operational Space (2-7 years)

   Piaget and Inhelder (1967) describe the preconceptual, intuitive level as the transition between perceptual/ sensorimotor space and spatial representation of the image. Slowly from the ages two to seven representations begin to refer to more complex physical actions and to coordinate these among themselves, giving rise to rudimentary and isolated transformations--internalization of spatial schemata.

C. Representational Space

1. Concrete Operations (7-11 years)

   Thought now disengages itself from the necessary limitations of the images; the internalized action becomes mobile and reversible; operations are still concrete, dependent upon the presence of the manipulable object (real or represented).

2. Formal Operations (11+ years)

   Internalized action which no longer requires the object--completely removed from real action. The possible condition the real. System of references complete for global thought. Child operates on hypothetical propositions.

SPATIAL RELATIONS

Piaget and Inhelder (1967) maintain that fundamental distinctions exist between perceptual/ sensorimotor space and representational space. Perception is the knowledge of objects resulting from direct contact with them. Representation or imagination involves the evocation of objects in their absence or, when it runs parallel to perception, in their presence. It completes perceptual knowledge by reference to objects not actually perceived.

Both sensorimotor and representational space develop according to three major types of spatial relationships (Table 2).

TABLE 2

Spatial Relations

Topological Space

Deals exclusively with intrinsic relationships without attempting to locate objects in relation to others; no reference point external to the object; perception of object's proximity, order, closure; homeomorphism is a basic notion of topological equivalence.

Projective Space*

Coordination of perspectives and the reversibility of points of view; requires locating objects in relation to each other; child is reference point to before-behind, left-right, above-below, but ignores objective distance.

Euclidean Space*

Coordinate of difference perspectives of an object but also requiring conservation of surfaces, lengths or distance (leading to metric system); concrete operation coordinates the objects among themselves with reference to a total framework.

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*Projective and Euclidean Space develop parallel to each other, distinct but closely related and interdependent.

Topological space is the most primitive form and depends upon qualitative relations inherent in a particular figure. Topological relationships include:

1. Proximity (a point belongs to each of its neighbors).
2. Separation (elements which are distinguished or separated).
3. Order (a synthesis of proximity and separation).
4. The relationships of surrounding or enclosure.
5. Continuity and discontinuity.

These topological principles are primitive in that they are purely internal to a particular figure whose intrinsic properties they express. Except for the factor of continuity and discontinuity, they do not express the relation among figures in a more complex field.

Projective space takes account, not only of internal topological relationships, but also of the shapes of figures, their relative positions and apparent distances, though always in relation to a specific point of view. Whereas topological concepts develop step by step and without a reference system, projective concepts operate with reference to coordinated perspectives and to planes on which figures are projected.

Euclidean space involves the conservation of straight lines, angles, curves, and distances. The dimensions of Euclidean space move from the concept of the simple straight line to the concept of surface involving the addition of the left-right or above-below to before-behind relation, and finally to the concept of volume which is the simultaneous consideration of the left-right, above-below and before-behind relations.

From a psychological point of view both projective and Euclidean concepts are the outcomes of topological ideas incorporated into a system of viewpoints. Both concepts develop independently from topological concepts, but are interdependent in their evolvement.

PURPOSE

There is little reported research on the development of spatial concepts on the representational level with visually limited children. The purpose of this exploratory study is to examine Piaget's theoretical development of spatial cognitive development in the low-vision child.

An exploratory type of field study, according to Katz (1953), *seeks what is* rather than *predict relations* to be found. Exploratory studies have three purposes: to discover significant variables in the situation; to discover relations among variables; and to lay groundwork for later, more systematic and rigorous testing of hypotheses (Kerlinger, 1964). The major purpose of this study is the third one cited by Kerlinger--to lay groundwork for later, more systematic and rigorous testing of generated hypotheses.

The aims are to examine the appropriateness of Piaget's methods and materials for assessing spatial development in low-vision children, and to assess if there is any indication of deviation from Piaget's hierarchy of spatial development in low-vision students.

METHOD

Piaget does not employ an experimental method because it is not appropriate for the problems he studies (Elkind, 1971). Piaget concentrates on the natural history stage of inquiry during which relevant phenomena must be carefully observed and classified.

The subject is presented with a problem involving the manipulation of objects. His attempts to solve the problems are observed. A clinical approach places emphasis on the thought processes involved. Conversation is directed toward the organizational activities within the individual subject rather than with the manipulation of environmental cues. Emphasis is on the process used "to obtain a solution" rather than on the correctness or incorrectness of the solution (Stephens, 1966).

Piaget's method of assessment can be used not only to evaluate at what spatial conceptual level the subject operates, but can supply information of the order and manner in which the subject begins to imagine or conceptualize the various spatial entities and spatial characteristics of objects of his spatial world.

Subjects

A sample of 10 girls was selected from Daily Living Skills Summer Programs of three Los Angeles County districts. They were low-vision secondary school students whose visual acuity ranged from 20/70 to 20/400--all were large print readers. They were in normal intelligence range, between the ages of 12 and 18, and free of any major auditory or additional physical impairments.

Instruments

Five Piagetian tasks were selected which assess how subjects deal with topological, projective, and Euclidean space. They were:

	Task	Simple Description	Space
I.	Study of Knots	Knots (K)	Topological
II.	Coordination of Perspectives	Mountains (M)	Projective
III.	Affinitive Transformation	Rhombus (R)	Transition to Euclidean
IV.	Localization of Topographical Space	Village (V)	Shift from Topological to Projective and Euclidean
V.	Diagrammatic Layout	Layout (L)	Shift from Topological to Projective and Euclidean

All tasks except Coordination of Perspectives were reproduced according to the description of Piaget and Inhelder (1967). The Coordination of Perspectives followed the Laurendeau and Pinard adaptation.

RESULTS

Because the operations in Task I-IV are constantly tied to action, they are concrete not formal operations. The reasoning required in these tasks involve the manipulation of concrete operations and are not limited to verbal propositions. Of the ten subjects, nine mastered topological space, but not one mastered all four tasks of projective and Euclidean space at the concrete operation stage. Since concrete operation develops from 7 to 11 years, it would be expected that all subjects operate on the concrete level for topological, projective and Euclidean space. This was not evidenced in this low-vision sample of secondary school girls. Table 3 reports the number of subjects who achieved concrete operations on the various tasks.

TABLE 3

Concrete Operations

Tasks	Space	Subjects Operating at Concrete Operations
Study of Knots	Topo-logical	9
Coordination of Perspectives (Mountains)	Projec-tive	2
Affinitive Trans-formation (Rhombus)	Transi-tion	3
Rotation of Model Village (Village)	Transi-tion	5
Diagrammatic Layout (Layout)	Transi-tion	0

The significant result of this study is that the visually-limited subjects were not able to achieve total decentralization of thought, thereby not allowing their spatial concepts to develop independent of perception and action. Table 4 shows the stages attained by the subjects in the various tasks. According to Piaget, subjects at the chronological ages of those in this study should be able to decentrate their thoughts from actions. All should be operating at Substage 111B, none were in Coordination of Perspectives (mountains) and Diagrammatic Layout.

Diagrammatic Layout required mastery of distance and proportions at Substage 111B. Coordination of Perspectives required the point-to-point nature of correspondence between position and perspective at this final stage. The correspondence between all possible points of view provides the essential unity and homogeneity of projective space.

As was reported by Laurendeau and Pinard (1970), Coordination of Perspectives (mountains) was more difficult for the subjects than Location of Topographical Positions (village). Locating the positions (village) is aided by topological cues (neighborhood, enclosure)". . . and the subject has only to recognize the position of an object in relation to several others which retain their present position on the reversed board (Laurendeau and Pinard, 1970, p. 402)." In this topological task the variation of perspective is only a single 180° rotation, whereas in Coordination of Perspectives the subject is required to rearrange several objects concurrently. Each item on the task required a new orientation and perspective.

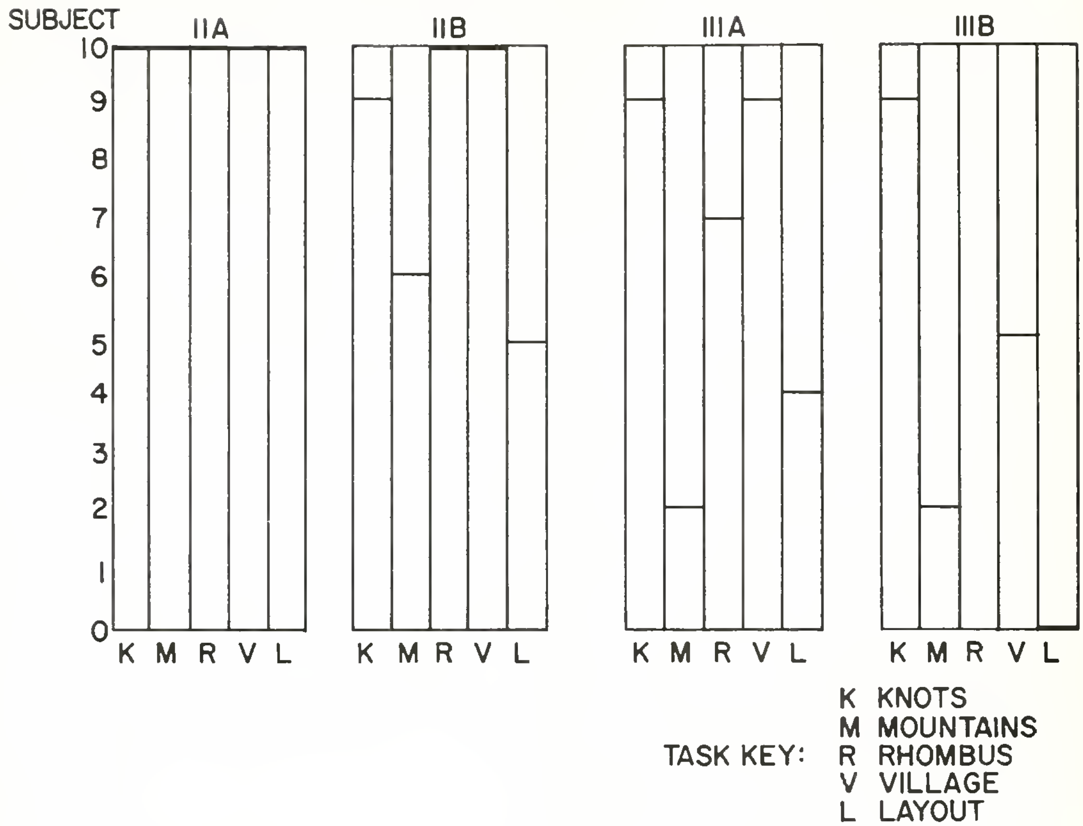
Visual efficiency (VE) scores (Barraga, APH, 1970) were available for each subject. As a point for speculation the two lowest VE scores were compared to the two highest in respect to substages attained on Tasks I-V. Visual efficiency, determined by this means, did not appear to be related to stage attainment except for Diagrammatic Layout (refer to Table 5). On Task V, Diagrammatic Layout, none of the S's attained Substage 111B, 4 "high" VE scorers attained Substage 111A, 1 "low" at Substage 11B. Substage 11A was attained by one "high" and four "lows." This trend does indicate a need for further investigation into those variables affecting visual efficiency scores and stage attainment.

DISCUSSION

Topological Space

In the task involving topological space (knots), the subject was to examine the mental analogues of the action of "surrounding" (or intertwining) in terms of the action of following or assembling one element after another. The model is analyzed with the aim of re-establishing the correspondences and rearranging the elements. Although the basis of homeomorphic analysis is the structural equivalence between figures, each figural object is considered in isolation. Perceptual proximities are totally inadequate for this purpose, since

TABLE 4
NUMBER OF SUBJECTS ATTAINING SUBSTAGES



the separation of elements is required, both for effecting the mental transfer between the model and copy, and for the preliminary analysis which must precede it. The subject, in order to accomplish this task, must perform certain concrete operations.

Topological space is primitive in that it is purely internal to the particular figure whose intrinsic properties it expresses, and does not involve spatial relationships between two or more figures. The development of topological space prior to that of projective or Euclidean space was substantiated in that nine of the ten subjects mastered the concrete operations required of this task, without concomitant achievement in the tasks involving projective and Euclidean space. The one subject who failed this task and who was still operating on an intuitive level did not achieve mastery on any of the projective or Euclidean tasks.

<u>Projective Space</u>

The task Coordination of Perspective (mountains) requires several distinct objects to be coordinated in bi-dimensional projective space (left-right, before-behind) according to several different perspectives and according to the successive positions of an observer different than the subject himself. Egocentric responses to this task include those that exactly reproduce the point of view as seen by the subject as he leans toward the toy man to see the same thing as he does. Partial decentration responses would include focus of right-left relations while before-behind relations may be reversed. Total decentration requires the subject to focus simultaneously on projective right-left relations while reversing before-behind relations.

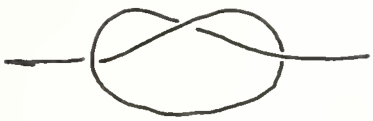
Although the task does not derive from formal level (since the subject is not required to consider two different systems of relations

The Study of Knots

Task 1

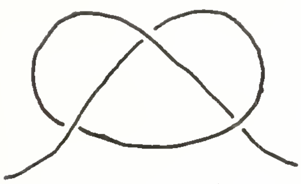
Taut, ordinary knot

Task 2



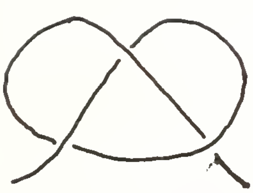
Slack, ordinary knot

Task 3

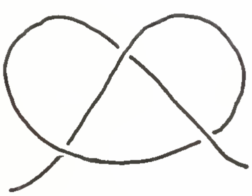


Expanded, slack knot (clover knot)

Task 4

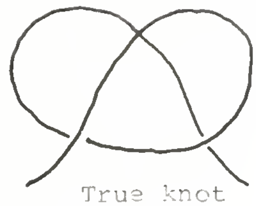


Left-hand clover

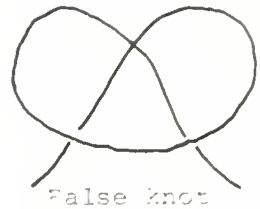


Right-hand clover

Task 5



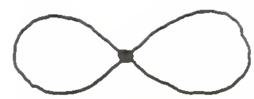
True knot



False knot

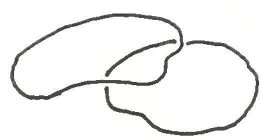
Task 6

True figure of eight



False figure of eight

Task 7

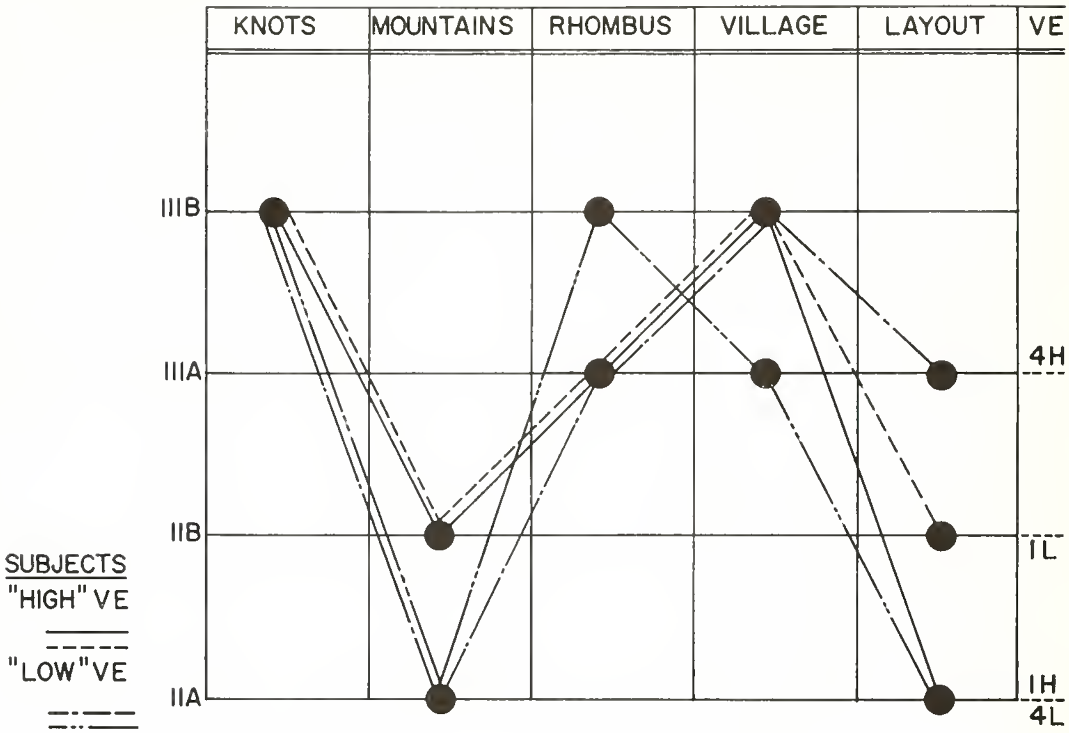


Superimposed circles

Intertwined circles

TABLE 5

VISUAL EFFICIENCY RATED TO TASKS



at once) the Coordination of Perspectives requires a degree of complexity which places it at the last period of the concrete operational stage. Two of the ten subjects mastered the concrete operations involving bi-dimensional projective space.

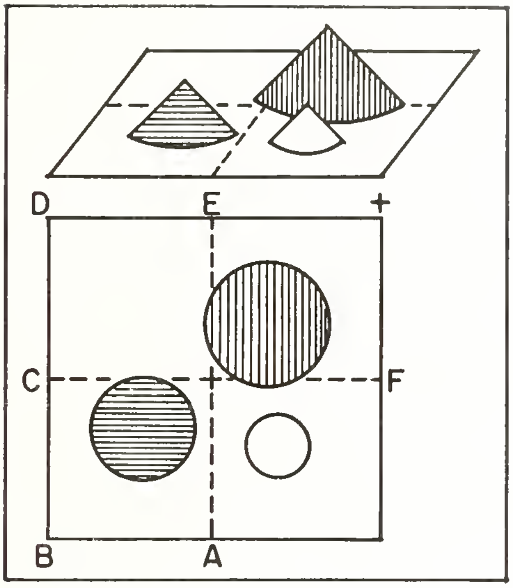
In discussion of projective space for these low-vision subjects certain comparisons require stating. Possibly due to the visual loss, the subjects are less able to handle planes of depth in particular, projection in general. The subjects' ability to conceptualize projective space is the testing focus in Coordination of Perspectives (mountains) where the mountains are hidden (behind) or in front of others (before) each other in the various pictures. Depth projection is required. The question raised is that when a child is lacking in visual depth perception does this inhibit projective space conceptualization?

Coordination of Perspective reflected more than the other tasks quality and insufficiency of verbal responses. The low vision subjects appeared to be less verbal, more reticent in their responses than the protocols of Piaget and Inhelder (1967) and Laurendeau and Pinard (1970). The attitude of the less one says, the less one is incorrect may be operating.

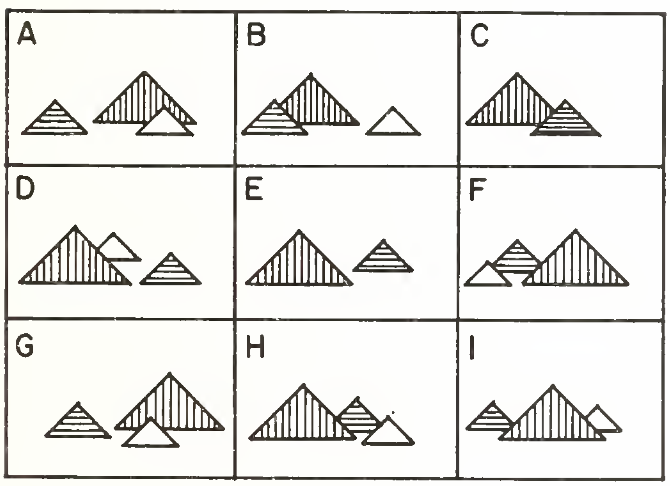
Transition to Projective and Euclidean Space

All the subjects on the rhombus test were able to see that the parallelism of the sides were linked operationally with the transformation of the figure as a whole and were not simply perceived or imagined intuitively. Whereas the responses were characterized by an emergence of concrete operational thought, only three of the ten subjects were able to give explicit formulations of the way in which the relationships function or were able to deduce the whole process in advance.

Tasks IV and V (Localization of Topographical Positions and Diagrammatic Layout) both dealt



COORDINATION OF PERSPECTIVES



with the extension of topological concepts into projective and Euclidean concepts. The subjects were forced to coordinate projective points of view, as well as Euclidean relationships involving distances and axes. Layout, V, also includes an element of proportion. The former task needed only concrete operational thought for completion whereas the Diagrammatic Layout requiring more than one comprehensive system of relations which relied on formal abstract operations for mastery. Five subjects attained the concrete operational stage of thought in Task IV; none reached concrete or formal operations required for mastery in Task V.

Diagrammatic Layout required projection by selection of one point of view; a system of coordinates using straight lines, parallels and angles; and scale reduction (similarity and proportion). Hence the construction embodied elements previously tested. Not one subject mastered all four tasks of projective and Euclidean space. The four subjects who attained Substage 111A in Diagrammatic Layout were still operating at Substage 11A (2 S's) and Substage 11B (2 S's) in Coordination of Perspectives. This again indicates the need for further investigation of projective space at the representational level.

Two major hypotheses come from this study:

1. Visually-limited subjects while showing mastery of topological space are deficient in their understanding of projective and Euclidean spatial relationship.

2. Visually-limited subjects show levels of thought that oscillated between intuitive ideas and the emergence of concrete operational thinking. Chronologically, subjects can be expected to have mastered all the spatial relationships on the concrete operational level.

IMPLICATIONS

Since spatial concepts are internalized actions and not merely mental images of external objects or events; it does seem essential, especially for the education of visually-limited children, that more emphasis should be upon the sequential growth and development of spatial concepts. Depending upon the child's cognitive developmental level of topological, projective, and Euclidean space concepts, an educational setting can offer structured programming utilizing spatial relationships. The child by means of adequate and varied experiences can be expected to progress sequentially from perceptual and preoperational to concrete and formal operations.

Studies have indicated that didactic instruction can facilitate the transition from one stage to another (Templen, 1966; Englemann, 1967). Verbal didactic instruction can include such procedures as prior verbalization of principles, use of verbal rules and confronting the child with his contradictions.

Although there is increasing educational concern with spatial concepts, the developmental nature of these has not been a source of concern. Curriculum deals almost entirely with topological space or positional aspects of space, seldom including coordination of perspectives on a two-dimensional or three-dimensional basis. "To arrange objects mentally is not merely to imagine a series of things already set in order, nor even to imagine the action of arranging them (Piaget and Inhelder, 1967, p. 454)." This statement has far reaching implications for orientation and mobility school personnel and teachers of the visually handicapped concerned with educational aspects of orientation and spatial awareness.

Spatial concepts are actions internalized in a series of states. At each stage the child's mental operations are transformed. There is an active transformation beginning with muscular adaptation, to imitation and delayed imitation at the conceptual or imaginal level.

A spatial field is a single schema. "Every effective assimilation has as its counterpoint a more or less effective accommodation." (Piaget and Inhelder, 1967, p. 455.) Therefore the spatial conceptual levels of children are constantly adapting, but dependent upon the quality and variety of experiences actively encountered. Piaget's theory adds important dimensions to problems concerning orientation of visually-limited student projection of fields, rotation of planes, coordination of perspectives.

Because the low-vision subjects included in this study continually oscillated between egocentric and decentration of thought, it does appear indicative of some characteristic learning behavior. If children with low vision, those effectively utilizing their residual vision, are persistently performing with partial decentration, there may be a need for additional experiences at the preoperational and concrete levels in order to compensate for the strongest inclinations or bonds to the perceptual level. These low-vision students as a group were functioning at high levels of visual efficiency. Does this affect their ability to achieve total decentralization required for concrete and formal operations? Or, will they remain longer at partial decentration? And do they require more experiences with projective space?

The next implication is quite relevant to the study of geometry. Concrete and formal operations are necessary for application of geometric principles. Many visually-limited children are extremely deficient in mathematical and geometric concepts. Many of the subjects were not operating at the concrete level of projective and/or transitional to projective and Euclidean space. Piagetian tasks do appear to offer greater insight into the mental operations of visually-limited children in respect to spatial orientation, mathematical and geometrical concepts. The practice of offering high school geometry to a visually-limited secondary student who is not functioning at the concrete level appears extremely questionable. The student would require for success in geometry at least transitional conceptual abilities and the ability to project.

In conclusion, operational space encompasses much more than the concerns of today's curriculum--positional concepts, body image, position location plus coordination of more than one perspective without concrete empirical props. Opportunities to develop mental operations using similarity and proportion are also indicated. The conceptual development of children up to representational space (formal operations) includes a wide array of spatial relationships--topological, projective and Euclidean. These concepts begin development below two years of age.

REFERENCES

Axelrod, S. "Effects of Early Blindness: Performance of Blind and Sighted Children on Tactile and Auditory Tasks," *American Foundation for the Blind Research Series No. 7*. New York: American Foundation for the Blind, 1959.

Barraga, N. *The Teacher's Guide for Development of Learning Abilities and Utilization of Low Vision.* Louisville, Kentucky: American Printing House for the Blind, 1970.

Cratty, B. J. *Movement and Spatial Awareness in Blind Children and Youth*. Springfield, Illinois: Charles C. Thomas, 1971.

Elkind, D. "Two Approaches to Intelligence: Piagetian and Psychometric," in D. R. Green, M. P. Ford, and G. B. Flamer (eds.) *Measurement and Piaget*. New York: McGraw-Hill Book Company, 1971.

Engelmann, S. "Teaching Formal Operations to Preschool Advantaged and Disadvantaged Children," *Ontario Journal of Educational Research*, 1967.

Gibson, J. J. *The Perception of the Visual World.* Boston: Houghton Mifflin, 1950.

Gottesman, M. "A Comparative Study of Piaget's Developmental Schema of Sighted Children with that of a Group of Blind Children," *Child Development*, 1971, Vol. 42, pp. 573-80.

Hatwell, Y. "Perception tactile des formes et organisation spatiale tactile," *J. de Psychologie*, 1959, Vol. 56, pp. 187-204.

Juurmaa, J. "An Analysis of the Ability for Orientation and Operations with Spatial Relationships in General," *Work-Environment-Health*, 1966, Vol. 2.

Katz, D. "Field Studies," in L. Festinger and D. Katz (eds.) *Research Methods in Behavioral Studies*. New York: Holt, Rinehart and Winston, Inc., 1953.

Kerlinger, F. N. *Foundations of Behavioral Research.* New York: Holt, Rinehart and Winston, Inc., 1964.

Launrendeau, M., and A. Pinard. *The Development of the Concept of Space in the Child.* New York: International Universities Press, Inc., 1970.

Piaget, J., and B. Inhelder. *The Child's Conception of Space.* New York: W. W. Norton and Company, Inc., 1967.

Stephens, W. B. "Piaget and Inhelder-Application of Theory and Diagnostic Techniques to the Area of Mental Retardation," *Education and Training of the Mentally Retarded*, 1966, Vol. 1, pp. 75-86.

Templen, Kaya. "Development of Concept of Class Membership in 6-7 year old Children," *Voprosy Psikhologii*, 1966.

Worchel, P. "Space Perception and Orientation in the Blind," *Psychological Monographs* #65, American Psychological Association, 1951.

EARLY VS. LATE BLINDNESS: THE ROLE OF EARLY VISION IN SPATIAL BEHAVIOR

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The question of space perception has intrigued psychologists for decades and philosophers for centuries. What information do people use in constructing a concept of space, and what factors affect their ability to orient and locomote in space? No matter what the theoretical orientation, a great deal of emphasis is usually put on the role of vision. Much of human locomotor behavior is visually guided, such as picking our way through an obstacle course or walking along a narrow path. Much of our closer motor behavior, such as threading a needle or writing, is also visually guided. It is not surprising, therefore, to find that most writers stress the role of vision in structuring the space in which we live.

The question also arises, though, what sort of compensation the blind person makes if he cannot use vision to structure space or to direct his behavior in space? There has been a wealth of research directed to comparisons of blind and sighted Ss in various spatial tasks. The results are mixed: the blind are at a great disadvantage in some tasks but better in others. Where the blind are found to perform better, the notion of sensory compensation is often advanced; that is, because of the lack of vision, blind people come to rely more on the other senses. This conclusion cannot be questioned: many blind people locomote very successfully, and it is beyond doubt that they are using their other senses to direct such performance. However, it has also been suggested that the remaining senses attain a degree of sensitivity in the blind that is impossible for sighted people. The literature is mixed on this question, but Rice (1970) has recently reviewed this literature and concludes, like Hayes (1941), that the weight of the evidence contradicts this notion.

In any case, the spatial behavior of the blind is an important topic, and the apparent dependence of sighted people on vision for their spatial behavior raises a specific question. What is the role of vision for the spatial behavior of the blind? Specifically, are there differences between the congenitally or very early blind and those people who have substantial early-visual experience and become blind later? What is the effect of the early-visual experience? Does it retain effectiveness in providing a spatial structure, or does the adventitiously-blinded person come to structure his space in the same way that the congenitally-blind person must from birth? These questions are the concern of this review.

One recurring hypothesis about the function of vision for the late blind is that having had vision for some time, the later blind retain a visual frame of reference. Although various writers have approached this notion from different angles, it seems fair to represent the general view as follows. Infants and young children tend to look toward sources of sound, and they tend to track and direct their motor movements, especially hand movements, visually. The result of this accumulated practice in associating spatial events with visual locations is that a visual framework is built up and retained. Even though the later blind child does not receive any direct visual input, the organizational function of his visual experience continues to be effective. In the present review, the intent is to assess the relevant research literature with respect to this general hypothesis of the role of early visual experience for the adventitiously blind.

Even a brief overview of the literature shows that researchers have made conclusions about spatial behavior from a wealth of different testing situations. There are many aspects of spatial behavior, and it is important to keep distinct the various ways in which the concept may be approached. One obvious distinction bears on the modality or combination of modalities being tested. There is a substantial body of work dealing with motor behavior, including both near space tasks such as finger-maze learning and far space tasks such as whole-body locomotion. Another body of work deals with auditory spatial localization and orientation to auditory cues. Finally, although it is far less complete, a third body of work deals with auditory-motor relations and organization. The general organization of this review follows these three categories.

Although many comparisons have been made between blind Ss and blindfolded sighted Ss, it is the conclusion of the present authors that these comparisons are of limited value. An increasing body of literature on normally-sensed Ss indicates that the functioning of the various modalities cannot be considered separately. Especially in tasks involving spatial behavior, sighted Ss seem to rely on vision even to interpret the information gained through the other spatial modalities. Restricting their vision, then, removes the organizational function that vision normally performs, as well as removing the direct visual spatial information. The blindfolded sighted person is in effect a person who has just become blind. It takes a great deal of adjustment to get along without a modality on which one has depended for years, and thus the blindfolded sighted S is not an appropriate control for comparison with the blind.

A far more informative comparison may be made between congenitally- and adventitiously-blinded Ss. Many researchers have made such comparisons. Often, though, Ss who became blind very early in life are grouped together indiscriminately with the congenitally blind. This is a risky approach, since it seems likely that it is the early vision that is especially important in structuring space. Thus the length of early vision is an important variable.

The length of time that an adventitiously blind person has had to adjust to the absence of vision is also a notable factor. Less attention has been paid this variable in the research literature than that of length of early vision. Wherever possible, these two factors will be considered together in the present review. It should be pointed out that often the age of onset of blindness is difficult to ascertain, and is often arbitrary, since in many cases blindness is progressive over a period of months or years.

In sum, much of the work on spatial behavior has not carefully distinguished the characteristics of the blind Ss, and for the purposes of this review, such work is virtually useless. There is a substantial body of research that is relevant and well reported, however. In this review, we will outline this work, with the goal of evaluating the effects of early vision on the spatial behavior of the blind.

FORM PERCEPTION AND MAZE LEARNING

The large category of motor behavior may be divided into two general sections, one dealing with manual performance close to the body, and the other including studies of locomotion and orientation of the body in space. Manual performance in turn may be divided into form perception studies and maze learning studies.

Sylvester (1913) reports a study on form perception comparing congenitally blind with two groups of adventitiously blind, those who became blind before the age of three, and those who became blind later than three. Teen-age children (mean age 13 to 15) explored a form board and the blocks, then they attempted to fill in the board. Although no statistics were reported (in spite of ample numbers of Ss), the results for both average time-per-trial and average number of errors indicate that the congenitally blind were worst, then the early blind, with the later blind being substantially better than the early blind. Sylvester concluded that the early visual experience provided residual visual imagery that was more effective than the necessarily purely tactual performance of the totally blind. No information was provided about the length of blindness.

Worchel (1951) compared congenitally blind with adventitiously blind on several tasks of form recognition and discrimination. His Ss ranged from 8 to 21 years, averaging about 15. Sixteen Ss were blind from birth, and 17 became blind at ages ranging from 1 to 11 years. His first experiment involved presenting S with a cutout block and having S draw the form, describe it verbally, and choose a matching shape from a set of four alternatives. On both form reproduction and verbal description, the adventitiously blind were significantly better than the congenitally blind. Virtually all Ss performed the matching perfectly, so that there was no difference between the groups. For the reproduction and verbal report tasks, the correlations between age at blindness and performance were also highly significant: the more visual experience S had before becoming blind, the better he could perform these tasks. Unfortunately, Worchel does not provide data to allow assessment of the effect of the length of blindness. That is, it is impossible to determine whether those Ss who have been blind longer show a better adaptation to their condition, regardless of the age of onset of blindness.

In a second task, Worchel had Ss feel the two parts of a form, one part with each hand, then choose one large form (of four) that corresponded to the combination of the two separate forms. Again, the adventitiously blind performed significantly better than the congenital group, and again the correlation between the age of blindness and performance was significant with the adventitious group.

Drever (1955) reports a replication of Worchel's block combination task with teen-age children (mean 15, range 12-19). His results corroborate those of Worchel in finding a significant superiority of later blind Ss (onset after the age of four) over early blind Ss (blind from birth and up to four years). A second task involved guiding S's hand over a pattern of pegs on a pegboard, then rotating the board 180° and having S recreate the pattern. In this spatial relations task, the early blind were significantly worse than the late blind. Drever also analyzed the effect of length of blindness on his performance results and found no relation between length of blind experience and either performance measure.

Studies of the maze-learning abilities of blind and sighted Ss have a long history. Carr (1921) cites data of Koch from three blind Ss tested in a stylus maze. One S who had some residual vision performed similarly to sighted Ss, while two Ss who had been totally blind from birth were much worse both in number of errors and in time to acquisition. Koch and Ufkess (1926) report a more controlled experiment along the same lines, using Ss ranging in age from 14 to 26, mean 18.4. They concentrated in particular on the amount of visual experience before the onset of blindness. Among the adventitiously blinded Ss, there were small but reliable correlations indicating that Ss who had more visual experience needed fewer trials and made fewer errors. Although Koch and Ufkess do not analyze the length of blind experience, enough data are provided that such an analysis may be made. Within the group of 10 adventitiously blind, the length of blind experience ranged from less than a year to 15 years. The rank order of correlation of length of blindness with trials to criterion was significant in a direction indicating worse performance for those Ss who had been blind longest. Correlations of length of blindness with number of errors and with time spent in the maze were not significant.

Knotts and Miles (1929) studied learning of both high relief (finger) and stylus mazes with blind and sighted Ss. Since the blind group was extremely heterogeneous with respect to age of onset and extent of blindness, the following subgroups were formed for the purpose of analysis: no detail vision later than the fourth year, blindness as a result of accident or illness after the fifth year, and partially blind since birth. The first two groups are of special interest as representing early and late blindness. Although the small numbers preclude meaningful statistical analysis, the performance was clearly better by the later blind Ss. On the finger maze, which Knotts and Miles argue is a better test for blind Ss than a stylus maze, only one of the nine later blind Ss performed worse than the mean or median of the early blind group.

Knotts and Miles did not analyze for the effect of length of blindness on maze performance, but the data allow retrospective assessment of this effect. Three performance measures were reported, trials to criterion, number of errors, and time in maze. For the stylus maze, length of blindness did not correlate significantly with any of the three measures. For the finger maze, however, all three measures were significantly correlated with length of blindness. The direction of the relation corroborated that found for Koch and Ufkess' results: the longer S had been blind, the worse his performance was.

Duncan (1934) reports a similar study using a raised finger maze. Her subject population was also quite heterogeneous, and precise statistical analysis is unwise. However, Duncan's results parallel those of Knotts and Miles quite closely, and thus they corroborate the conclusion that the later blind Ss are better at finger maze learning. Again it is possible to analyze retrospectively the relation between length of blindness and performance. Of those 11 adventitiously blind Ss whose vision had changed from fairly good to LP or worse, the length of blind experience ranged from 6 to 18 years. Neither trials to criterion nor maze time correlated significantly with length of blindness. The correlation of number of errors with length of blindness was also not statistically significant, although it was suggestively high (0.51) in a direction indicating that Ss who had been blind longer performed worse.

Berg and Worchel (1956) report an experiment in which congenitally and adventitiously blind Ss, ranging in age from 7 to 21 years, were compared on two finger maze learning tasks with normal and deaf Ss. The mazes were a U maze, which was a right angle maze with 24 two-choice points, and an X maze, with 10 choice points. The X maze was a series of end-to-end diamonds, where S had to learn which side of each diamond was not blocked. Berg and Worchel found no difference between the congenitally and adventitiously blind on the U maze, but the later blind Ss were significantly better on the X maze on both errors and trials to criterion measures. Although the authors do report the age of onset and CA of their adventitiously blind Ss, the data are not reported in sufficient detail to allow assessment of the relation between maze performance and length of blindness.

ORIENTATION OF THE BODY IN SPACE

Several larger scale spatial relations paradigms have also been used in research with the blind. Worchel (1951) used a task in which S was led over two sides of a large right triangle and then asked to return to the starting point via the hypotenuse. In a variation on the task, S was led along the hypotenuse of the triangle and asked to return to the starting point via two other legs of a right triangle. Deviations of S's end point from the correct position were tabulated and analyzed. Although the sighted Ss were significantly better than the blind, there was no difference between the congenitally and the adventitiously blind groups. Further, the correlation between age of onset and performance was not significant within the adventitiously blind group for either performance measure. The absence of an age of onset effect is noteworthy, especially since this same group of Ss had shown such effects on the other tasks that Worchel used, as discussed above. One is tempted to suggest some difficulty with the triangle task, since Worchel found that the correlation between performance on the hypotenuse task and that on the two-side task was not significant.

McReynolds and Worchel (1954) tested congenitally and adventitiously blinded Ss on their ability to orient to geographical directions and to describe relative directions of various well-known places. The measurement scale used was very rough: responses were recorded only to the nearest 20° of direction. Most of the tasks produced no advantage of the adventitiously over the congenitally blind. McReynolds and Worchel do report that within the adventitiously blind group, there was a "slight trend" in four of the six tasks for those who became blind later in life to perform better. None of these differences was significant, however. Information about the effect of length of blindness is not available in the report.

Somewhat akin to the body orientation work is the research on the so-called "veering tendency" of the blind. When asked to walk in a straight line, Ss without vision tend to curve to one side or the other. Although some early research on the veering tendency exists, it tends to be spotty and fails to report important variables such as etiology of blindness. The later work is more useful. For the present purpose, a study by Cratty (1967) serves to illustrate the veering paradigm. Cratty tested individuals with various visual handicaps and mobility histories in a large open field on which straight lines were marked out. The S was started in a straight line and instructed to continue to walk straight. The path was plotted by E, who walked behind S. The results for early and late blind Ss are somewhat difficult to interpret. Older Ss who became blind from disease or accident veered more than younger Ss who had been blind from birth. Subjects blind from birth veered less overall than the adventitiously blind. Although the congenitally blind were better at maintaining a straight line motion, it is apparent from Cratty's graphically presented results that the adventitiously blind deviated more often early in the path but reapproached the correct path later, to an average position similar to that of the congenitally-blind group. It is interesting to note, with regard to this superiority in veering performance by the congenitally blind, that Cratty, Peterson, Harris, and Schoner (1968) report a marked superiority of the adventitiously blind in walking through curved pathways with varying radii. Cratty et al. point out that the congenitally blind may have a less accurate sense of laterality, since their ability to distinguish left from right was poor. It may be that while the congenitally blind are better in maintaining a straight-line direction, the adventitiously blind have an advantage when somewhat more complex types of spatial performance are required, such as walking curved paths.

A second variable of major importance is the length of blindness. In Cratty's (1967) study, Ss who had been blind for 6 to 10 years veered significantly more than those blind for 20 or more years. The group blind from 11 to 20 years performed intermediately. Thus, a blind practice effect seems to be operating in Cratty's results, although its effect may be a very long-term, gradual one.

In summary of the tactual and motor performance studies, it is safe to conclude that for the form discrimination and maze-learning paradigms, the evidence is overwhelmingly in favor of superior performance of the later blind. However, in Worchel's (1951) body locomotion task there was no difference, nor were there significant differences in the body-orientation tasks of McReynolds and Worchel (1954). In Cratty's (1967) veering work, the early blind performed better. What is the typifying difference between those tasks on which the later blind perform better and those for which there is either no difference or the reverse relation? Several factors are clearly involved. First, the later blind performed better on those tasks that involve close motor activity, activity in near space, such as finger-maze learning and haptic-form discrimination. On the tasks involving gross-body movements in extended space the early blind were equal or better, with only the exception of the Cratty et al. (1968) curved-path task. It would not have been surprising to find the reverse pattern of results: that is, to find the congenitally blind performing better on the near space tasks, since they have had extensive direct experience with near space and little or no contact with extended space. One possibility for explaining this apparent ambiguity is that the adventitiously blind may learn relatively slowly to replace their visual experience of extended space by a motor experience of that space. That is, they would naturally have more practice with non-visual near space than with non-visual far space, so they would do better on the near-space tasks. With more practice they might surpass the congenitally and early blind on the far-space tasks as well. The length of blindness results of Cratty (1967) lend support to this formulation. However, to the extent that the length of blindness factor can be assessed for the near-space tasks, the evidence is clearly against the hypothesis. Where significant correlations were found, they were in favor of better performance by the less practiced blind Ss.

Of course, the two factors, length of early vision and length of blind practice, are not independent. It may be that the length-of-blind-practice factor is operative, as evidenced by Cratty's (1967) results, but that it has a far weaker effect than the early-vision factor. Especially in groups of Ss that are relatively homogeneous with respect to age, the strong operation of an early-vision factor would preclude the emergence of a length-of-blindness factor. This situation seems quite likely, in fact, in view of the strong effects of early vision in the near-space tasks.

Another possibility has already been mentioned, namely, that the difference may lie simply in task complexity. The straight line locomotion task is clearly a simple one: it involves no remembering or execution of turns or curves. Thus it is not surprising that the congenitally blind can perform this task well. Cratty's length-of-blindness results may represent a situation where the lack of early vision does not hinder the congenitally blind, and where the adventitiously blind gradually overcome their early reliance on vision. In fact, the Cratty et al. (1968) results suggest that introducing even a slight complexity into the task swings the balance in favor of the later blind. The maze-learning and the form-discrimination tasks are clearly more complex in the sense of requiring spatial information to be stored and remembered. It seems to be just this type of complex spatial task on which the blind person with a history of early vision is at an advantage.

THE ROLE OF INTELLIGENCE

Intelligence is another variable found by several investigators to bear on performance on these tasks. Of the studies discussed in the previous sections, Koch and Ufkess (1926), Knotts and Miles (1929), Duncan (1934), McReynolds and Worchel (1954), Drever (1955), and Berg and Worchel (1956) have considered the intelligence question.

Koch and Ufkess found significant correlations between intelligence scores (Army Alpha) and trials, errors, and time scores on maze performance of both blind and sighted groups. These correlations suggest that intelligence was an important factor, with higher I.Q. Ss performing better. The correlations tended to be somewhat stronger for the blind group than for the sighted, but the authors suggest that this may be due to the somewhat greater heterogeneity of the blind group. It is interesting, however, that this difference in the strength of relationship between I.Q. scores and maze performance between blind and sighted groups has been found in a number of studies, and it may be more important than Koch and Ufkess suggest.

The Knotts and Miles and the Duncan studies were quite similar experiments using finger mazes. Both found that chronological age was not a significant correlate of performance. Knotts and Miles found high negative correlations of I.Q. (Stanford-Binet) with performance as measured by number of trials to learn, time to learn, and number of errors on the finger maze for the blind group. The same correlations were significant for the sighted group, but they were again less strong than for the blind (a negative correlation in this case means the higher the I.Q., the fewer errors, fewer trials, etc.). The stylus maze used by Knotts and Miles produced stronger correlations for the sighted group. The authors point out, however, that the stylus maze is a less appropriate task for the blind, since they are not used to performing tasks at the end of a stylus or pencil as are the sighted. The indication of a difference between blind and sighted groups is supported, although less markedly, in the study by Duncan. With the exception of the trials to criterion-I.Q. correlation, the performance-I.Q. correlations were more negative for the blind than for the sighted group. Duncan provides a breakdown of the blind Ss into degree of blindness groups, and it is noteworthy that although there were only six totally blind Ss for whom I.Q. scores were available, the negative correlation between I.Q. and errors was especially strong in this group. Duncan used the Chapman Group Intelligence Examination.

In the Berg and Worchel (1956) maze-learning study, reference is made to I.Q. effects, but I.Q.-performance correlations are not reported in detail. A significant positive correlation of 0.45 is reported for the sighted group between I.Q. (California Mental Maturity Test) and trials to criterion on the U maze. It seems safe to assume that a negative correlation was intended, since a positive correlation as reported would mean that higher I.Q. Ss needed more trials to attain criterion.

Drever's (1955) study of tactual figure recognition and pattern orientation included measures of I.Q. (Terman-Merrill) and C.A. Drever reports no significant correlations between either I.Q. or C.A. and any of the performance measures for either the blind or the sighted group. In a similar study, however, Ewart and Carp (1963) found significant effects of I.Q. (Stanford-Binet for sighted; Interim Hayes-Binet or Verbal WISC for blind). This study was not reported earlier because no breakdown of results for early and late blind Ss was provided. The Ss were 30 blind children, none of whom had more than light perception, and 24 of whom were blind from birth. The task involved feeling a stimulus shape, then choosing a matching shape from four choices. Ewart and Carp found no significant correlations of C.A. with performance. There was a significant correlation between tactual performance and I.Q. for the blind group, where the high-I.Q. Ss performed better. For the sighted group, the correlation was not significant.

McReynolds and Worchel (1954) studied the ability of blind and sighted children to orient themselves to and describe geographical directions. As mentioned earlier, the measurement scale was extremely rough, and none of the four status variables, C.A., I.Q. (Hayes-Binet), total vs. partial, congenital vs. accidental, produced significant differences in performance. It is interesting, however, that within the group of totally blind Ss, including both congenital and accidentally blind, there was not a single case where the performance mean for the high I.Q. Ss was lower than that for the low I.Q. Ss. That is, on 12 comparisons, covering low and high C.A. groups on each of six tasks, in every case the performance of the high I.Q. group was as good as or better than that of the low I.Q. group. The four way analysis of the performance results was apparently too cumbersome to draw this difference out as an interaction effect; in any case, there is a strong suggestion from the data that I.Q. was a determinant of performance among the totally blind.

The evidence about the possible relation of intelligence to spatial relations and orientation performance in the blind certainly is not conclusive. Where differences have been found among blind Ss, high I.Q. has been found to relate to good performance. Among the sighted Ss, the same rule may hold, but the correlations tend to be weaker. This statement must be taken as extremely tentative, because of the difficulty of comparing I.Q. scores between blind and sighted Ss. Where the same test is administered to both blind and sighted, it may be differentially valid for the two groups. Where different tasks are administered, the problems of comparison are more obvious yet. It is not surprising, of course, to find that especially in tasks involving learning (such as the maze tasks), I.Q. correlates with performance. The suggestion that the relation may be stronger for the blind, and that it may extend to non-learning tasks, deserves some attention. One possibility, for example, is that tasks involving a visual frame of reference may be relatively easy for the sighted and may thus not be differentiated by I.Q. The same task may be relatively more difficult for the blind because of the lack of a visual frame of reference, and the blind may depend more on verbal or other cognitive interventions for successful performance.

TYPES OF MEDIATION

The question of differences in mediational use between blind and sighted Ss has been considered in the literature, although because of the serious methodological and definitional problems, only very limited conclusions may be drawn. A common suggestion has been that blind Ss, lacking visual imagery, depend on verbal or motor imagery. Dependence of the blind on verbal mediation as a substitute for visual imagery might account for the apparently greater relation of performance to I.Q. in the blind.

Hartlage (1969) compared the abilities of blind (etiology and onset unreported) and sighted Ss to use spatial and non-spatial relational concepts. The Ss ranged in school grade from second to 12th. No differences were found between blind and sighted on the non-spatial relational items, but the blind were significantly worse than the sighted on the spatial items. Although there was a significant effect of grade level, no changes in the relationship between blind and sighted were reported over grade. Hartlage's results suggest that differences in use of relational concepts between blind and sighted are not a result of general cognitive deficiencies in the blind, but rather to specific aspects of performance that may be attributed to the lack of visual experience in structuring space.

Rubin (1964) studied the conceptualization abilities of the adventitiously and congenitally blind, but his tests were not specifically of spatial concepts and are not appropriate to this discussion. Analysis of his results does, however, permit the addition to Hartlage's (1969) conclusion that there are no basic conceptualization differences between congenitally and adventitiously blind.

Many researchers have discussed imagery in blind and sighted Ss. Fernald (1913) tested two blind Ss, one with slight residual vision since early in life, and the other virtually blind since birth. Fernald's imagery results are difficult to interpret because of the lack of methodological detail in the report. She concludes, however, that the partially-sighted S used primarily visual imagery, but with some auditory, smell, and taste reports. Tactual imagery was rarely mentioned, in contrast to the totally-blind S, who used it predominantly but reported no visual images. Heavy use of verbal imagery by both Ss is also reported, with the suggestion that verbalization was used in preference to the modality-specific types of imagery.

Schlaegel (1953) reports a study along the same lines that is much more useful than that of Fernald. The S heard words or phrases and responded by writing down whether his initial image was see, hear, muscle, touch, temperature, smell, or taste. The blind group, mean age 16.2, was heterogeneous with respect to age of onset and extent of blindness. No difference in distribution was found between the blind group as a whole and the sighted group. However, significant differences emerged from an analysis of the blind Ss when they were divided into subgroups on the basis of amount of residual vision. These groups were heterogeneous with respect to age of onset. For those Ss with LP or worse, the dominant mode of imagery reports was the auditory, 36.4 percent as compared to 27.9 percent visual images. An intermediate blind group consisted of Ss who could detect some movement to those who could count fingers at five feet. This group showed an imagery distribution that was primarily visual, 42.4 percent, with 29.8 percent auditory images. This distribution was virtually identical to that of the sighted control group, which had 41.7 percent visual and 30.8 percent auditory. The third blind group included Ss with vision better than 5/200. This group showed substantially more visual images, 58.6 percent, and somewhat fewer auditory images, 25.8 percent, than the other groups. A further division of the blind groups, on the basis of age of onset, is particularly suggestive about the role of early vision in imagery type. In the lowest vision group, Ss with onset less than five years reported almost no visual imagery at all, while those with later onset showed about 57 percent visual imagery, or more than the sighted control group. A similar difference, although less marked, appeared for the intermediate group. For the blind group with most vision, the division by age of onset did not provide a distinction. It is also interesting that many of the images reported as visual by the totally-blind group were, upon closer examination, found to be primarily verbal descriptions or images which the S had reported as visual, simply as a figure of speech.

Finally, in discussing the unexpectedly high percentage of visual images reported by the intermediate and best vision blind groups, Schlaegel points out that these partially sighted Ss may in this situation have somehow sensed pressure to respond in visual terms. Thus, the visual percentages for these groups may be artifactually high, although it is difficult to judge the importance of this pressure variable.

In any case, Schlaegel's study of modes of imagery supports the basic conclusions of Fernald, that some residual vision produces a greater report of visual images. An important additional result of Schlaegel's study was that the age of onset was also an important determinant of the type of imagery reports.

Unfortunately, for our purposes, neither Fernald nor Schlaegel made a strong distinction between spatial and non-spatial imagery. The results of Hartlage (1969) suggest that this might be an important distinction. Indirect evidence about spatial imagery can be obtained from the motor performance studies discussed earlier. Several of these studies include reports of interviews with S about the way in which he felt he had learned the task. Knotts and Miles (1929) asked S to report how he had learned the stylus and finger mazes that were used. The S's responses were classified as verbal, verbal-motor, motor, or visual. Knotts and Miles do not adequately report their response classification criteria. Responses were apparently counted as verbal if they made reference to counting, while motor responses were those for which Ss said that they remembered by the "feel." The major differences between blind and sighted were a greater incidence of verbal responses for the blind (51 percent, vs. 38 percent for the sighted), greater incidence of motor responses for the blind (28 percent, vs. 18 percent for the sighted), but a greater incidence of verbal-motor responses for the sighted (36 percent, vs. 18 percent for the blind). Visual responses were rare but were more common for the sighted. It is interesting that Ss who reported using a verbal method were better at the maze learning. Thus the greater dependence of the blind on the verbal method, together with the notion that I.Q. test performance depends heavily on verbal behavior, suggests that the intelligence factor is more important for the blind than for the sighted. The lack of adequate specification of classification criteria, however, makes any interpretation of the results extremely tenuous.

Duncan (1934) makes a similar analysis of the introspective reports of Ss about their approaches to maze problems. Responses were classified as verbal, visual, kinesthetic, or verbal-visual. The only notable difference in the distributions of blind and sighted Ss occurred in the verbal category, where the sighted Ss showed a somewhat greater frequency (54 percent vs. 44 percent). The blind group gave a substantial percentage of visual responses (23 percent). Unfortunately, Duncan does not provide a tabulation of these responses by degree of blindness or age of onset categories. From the results of Schlaegel (1953), it is reasonable to assume that the visual responses occurred primarily in those blind Ss who had either residual vision or who had considerable visual experience before becoming blind. It is interesting to note that Duncan's conclusion about the efficacy of the verbal approach is similar to that of Knotts and Miles (1929): maze performance was better for those Ss who reported verbal approaches.

A final maze-learning study in which method of solution is discussed is that of Berg and Worchel (1956). This study was conducted to shed light on maze learning in general, rather than to investigate differences between blind and sighted Ss. The blind were used as Ss who could not employ a visual solution, while the deaf were used as Ss who could not employ a verbal solution. Two mazes were studied. The U maze was chosen because it was thought to require a visual or motor solution, while the X maze was chosen as a task in which a verbal approach would be more effective. It was predicted that the sighted Ss would be superior on the U maze, while no difference between blind and sighted should occur for the X maze. (Other predictions were made of relations between the sighted and deaf groups.) On the U maze, no significant differences were found between blind and sighted in either trials to criterion or number of errors, although the small differences favored the sighted group. Since it was thought that either motor (kinesthetic) or visual solutions would be appropriate for this maze, it may be that the blind used primarily motor strategies, while the sighted used visual. Unfortunately, Ss were not questioned about the specific strategy used. On the X maze, the sighted performed better than the blind on both trials to criterion and error measures. Division of the blind group into congenitally- and adventitiously-blind subgroups significantly favored the adventitiously blind.

Thus, the blind-sighted comparisons did not support the predictions based on the *a priori* assumptions about most effective strategy. Aside from the riskiness of these assumptions, one problem is the grouping of congenitally and adventitiously blind Ss. Seven of the blind Ss had at least three years of vision before blindness and other evidence suggests that these Ss may indeed have used visual strategies. In any case, this study is of little use in investigating imagery differences, since imagery differences were assumed as an independent variable rather than measured as a dependent variable.

Worchel (1951) compared blind and sighted Ss on two form identification tasks and a locomotor spatial relations task. He obtained introspective reports from the Ss about how they solved the tasks, and although distributions of response types are not reported, several interesting points are made in the discussion. In all tasks, the congenitally blind were more uncertain about the nature of any imagery they had used. In the task where identification and verbal description of a form were required, the congenitals' descriptions tended to be in tactual terms, referring often to the "feel" of the shape. The adventitiously blind, however, tended to refer to "mental pictures," and Worchel interpreted these reports as indicating a visual imagery resulting from early vision. Sighted Ss tended even more strongly to visual imagery, visual interpretation of the tactual experience. In a task where S was to feel two shapes and report what their combined shape would be, the reports are more vague but tend to repeat the conclusions for the first task. In the task where S was led over part of a triangle and was to complete the figure, the tendency was for some sighted and blind Ss to make use of time estimates. Such an approach would presumably depend on verbalization, although not of a complex nature. The sighted Ss also reported visualization, but this tendency was not marked among the adventitiously blind, even for those Ss who had reported visualization in the first two tasks.

Worchel's study in general supports the notion that the sighted, and to a lesser extent the adventitiously blind, tend to make use of visualization in approaching these tasks. It is interesting to note that on the third task, where the tendency of the adventitiously blind to report visualization was not strong, performance within the blind group did not relate significantly to age of onset of blindness, or to the congenital-adventitious distinction. On both form tasks, where more visualization was reported for the adventitiously blind, these Ss also performed better on the task than the congenitally blind. It is tempting to suggest that it is the visualization approach that leads to better performance. However, as noted earlier, the adventitiously blind were superior to the congenitals on the tasks requiring near-space performance, while there was no difference on the extended-space tasks. The relation between this distinction and the tendency to visualize remains uncertain, and designation of cause and effect is risky. Research on this cluster of variables seems potentially valuable.

In summary, it must be said that the imagery question is undecided. Part of the problem is, of course, the difficulty of measuring imagery directly or assessing it from verbal reports. Some investigators have concluded that their sighted or adventitiously blind Ss must have used visual imagery since their performance was better than that of the congenitally blind. This type of conclusion is simply a labeling of results, not a measure of imagery, since it is not necessarily the case that visual imagery leads to better performance.

Even where relatively direct assessments of imagery reports have been made, such as in the studies by Schlaegel (1953), Knotts and Miles (1929), Duncan (1934), and Worchel (1951), the relation of imagery to performance in spatial tasks is unclear. Comparison of blind and sighted is risky, as is that of various blind groups, since it seems quite possible that differing histories of experience with the visual world may produce differences in the use of spatial relations vocabulary. Vocabulary differences may then artifactually be interpreted as representing real differences in imagery.

Even if, in the face of these difficulties, adequate measures of imagery could be made, the question of the function of visual and other types of imagery is complex. The study by Worchel (1951) in particular suggests that different spatial tasks may evoke different types or degrees of imagery within the same Ss. Even more important in assessing the real effectiveness of visualization is the question whether any reliance on visual imagery by the adventitiously blind is really advantageous. It may be, for example, that in certain situations a reliance on residual visualization may tend to prevent the adventitiously blind from developing modes of mediation that may in the long run be more effective for them. This question has implications for modes of mobility training, as will be discussed later in the paper.

AUDITION

There is some work with auditory localization that may be brought to bear on the spatial relations question. One facet of this work is the so-called facial vision, or obstacle sense, of the blind. Hayes (1941) summarizes the older work on this question. A study by Supa, Cotzin, and Dallenbach (1944) represents an excellent attempt to specify the nature of the obstacle sense of the blind. Two blind and two sighted Ss were tested in a number of conditions in which cues were gradually reduced until Ss could no longer avoid obstacles. The general conclusion of the study was that auditory cues are especially important in the performance. The differences between the blind and the sighted Ss, and in particular the response of the sighted Ss to blindfolded experience, are of interest to the present review. In the first experiment, S was instructed to walk toward a wall from varying distances, indicate when he first sensed the wall, and again indicate when he was at arm's length from the wall. Both blind Ss performed the avoidance task almost perfectly from the start, while the sighted Ss made a number of mistakes where they ran into the wall. The sighted Ss also veered while approaching the wall, while the blind Ss approached it directly. The difference between blind and sighted is not surprising, since the sighted Ss can be considered to be newly blinded Ss in the situation, without the benefit of the extensive experience at being blind. However, a second set of 25 trials was administered, and the improvement of the sighted Ss was striking. They decreased from 15 and 19 collisions to six and one. From these results it is clear that the initial difference between blind and sighted was a temporary one, and that practice had a very rapid effect in bringing the sighted Ss to successful performance. Worchel and Mauney (1951) also report a successful training study.

Kohler (1964) reports experiments that bear on the question of trainability of the obstacle sense. A sound emitting device was developed that could be fastened to S's chest, in order to provide a controlled sound emission. Kohler studied both blind and sighted Ss, and he found both groups to benefit markedly from extensive practice. With several weeks of practice, Ss attained a level of performance that was about "three times better than the natural performance of well-trained blind people." Although a group trained without the device did show an improvement, the group using it improved much more. In regard to the Supa et al. (1944) results discussed above, it is also interesting that blindfolded sighted Ss improved markedly.

Juurmaa (1970) reports a laboratory training study similar to that of Kohler in that a device was used to produce a constant signal whose echo could provide information about the characteristics of targets. Although Juurmaa did not compare early- with late-blinded Ss, his results, like those of Kohler and Supa et al., indicate that training in the use of such devices is very effective. Juurmaa used tasks such as having S report when a target started moving, when a target was a given distance away from S, and size and material differences. The distance judgment tasks were particularly benefitted by the device.

Several other researchers have studied echolocation in laboratory settings. Kellogg's (1962) work serves as an example of this approach. Two blind (at 5 and 10 years of age) and two sighted Ss were tested for their ability to identify differences in distance, size, and texture of stimuli. The research was directed toward the question of echolocation: how well can Ss use reflected sound in making these determinations? Most Ss used some voiced signal to produce echoes. Kellogg found the blind Ss to be better at distance and texture discrimination: in fact, the performance of the sighted control Ss was close to chance. The size-discrimination results were difficult to interpret.

Although Kellogg's results favor performance of the blind, several qualifications should be advanced. First, the very bad performance of the sighted Ss seems questionable in the light of other echolocation and location data which shows blindfolded sighted Ss to perform well above chance. Second, the results of Supa et al. (1954) indicate that sighted Ss quickly learn to use auditory cues that are initially useless to them. It may be that the differences that Kellogg found would have decreased with practice in the situation.

Rice and others also report experiments on the ability of blind Ss to detect and localize small targets by means of reflected sound. Interestingly, in these studies there is a tendency for the earlier blind to perform better than later blind. Rice, Feinstein, and Schusterman (1965) used a training study to determine the target-size-detection threshold for five adult Ss who had been blind for at least five years. Subjects had to make a yes/no judgment about the presence or absence of a disc target of varying size. Although the Ss did differ in terms of detection threshold, the group was fairly homogeneous in performance level. The mean threshold target size improved with training to 4° or 5°.

Rice (1970) reports that a sixth S was subsequently added to the group of five, and that this S reached the trained level in far fewer training trials than the earlier Ss. This best S had become blind before six months of age, while the others had had vision for three to 25 years before becoming blind. In an attempt to determine whether the blindness onset factor was responsible for the marked difference in echodetection performance, Rice tested additional early-blind Ss, as well as other late-blinded and sighted Ss. All early-blind Ss had lost vision prior to six months of age, while the late-blind Ss had had vision for at least three years. Rice again found significant differences favoring the early blind over the late blind in training trials to a criterion. In addition, a difference was found in favor of the early blind in threshold target size for a given distance.

Rice (1970) also reports an echolocalization study comparing five early-blind, three late-blind, and three sighted Ss, all of whom had been in the detection experiment. In the localization procedure, a 10° target was presented at azimuth location ranging from 90° left to 90° right of S's straight ahead. The S was instructed to emit a sound while his head was straight ahead, then move his head to point his nose toward the target. The groups performed quite comparably with targets at 15°, but further laterally, the early-blind group performed substantially more accurately than the other two groups. Thus Rice found that early-blind Ss were better at both echodetection and echolocation than late blind or sighted Ss. Juurmaa and Jarvilehto (1965) also report the degree of obstacle perception to be negatively correlated with age at blinding. In summary of the obstacle sense and echodetection work, differences between early and late blind have not routinely been reported. Where differences have been found, they have favored the early blind.

Fisher (1964) reports a very interesting series of spatial localization experiments involving both audition and touch. Fisher's work was directed toward investigating possible differences between blind and sighted Ss, and he unfortunately did not make useful distinctions among his blind Ss. Five blind adults participated, three blind from birth and two who had had some vision until about six years old. Five sighted controls were also tested. Fisher's apparatus allowed presentation of auditory targets in the horizontal plane, and tactile targets to which S's hand could be guided along a track. Various types of response could be required. In the initial experiment, S made verbal judgments about which of two successively-presented auditory or tactile stimuli was to the left of the other. No differences were found between blind and sighted Ss. In a variation on this basic localization experiment, Fisher had S respond by turning his head toward either an auditory or a tactile target. Again, there were no differences in localization variability for either modality between blind and sighted Ss. The blind Ss did exhibit larger constant errors, but Fisher attributed this difference to the tendency of his blind S to orient the head off to the side, rather than straight ahead as the sighted Ss did. Thus on simple localization tasks, Fisher concluded that there was no important difference in performance between blind and sighted Ss.

A third experiment involved intermodality comparisons of auditory and tactile locations. The S reached out and touched the tactile target: this contact activated the auditory target, and S judged which of the two stimuli was farther to the left. Averaging the variance scores produced a very significant difference in favor of the sighted group. However, it should be noted that three of the blind Ss performed virtually the same as three of the sighted Ss. Two sighted Ss were much worse than these six, and the remaining two blind Ss were very much worse, with variances hundreds of times greater than those of the three best blind Ss. It was the effect of these two very bad Ss that produced the difference in means between blind and sighted. The three best blind Ss all performed better than the three worst sighted Ss. Thus the conclusion that the blind were worse seems unwarranted. It would be of particular interest to have information about the etiology and onset of blindness, but this information is unfortunately not provided in the report.

The fourth experiment of Fisher was extremely informative in the context of the present review. Fisher reasoned that the restrictive experimental conditions of his laboratory may have removed from the blind Ss the spatial context that they normally have available for localization and orientation. In the fourth experiment, various "contexts" were reintroduced, with the thought that an artificial frame of reference might help the blind. The Ss made the same type of auditory-tactile comparison that they made in Experiment 3, but in the presence of an auditory or a tactual context. The context consisted of a signal at S's straight-ahead. It is not specified in the report whether the context remained available during the trial or terminated before the trial began. Although it is extremely risky to draw general conclusions from Fisher's small groups, and especially so since the range of performance within each group was large, the results suggest that the blind Ss were aided in more cases by the introduction of a context than were the sighted.

THE "FRAME OF REFERENCE" NOTION

Fisher's context results raise some interesting questions. Fisher designed the conditions with the notion that the blind may have been more adversely affected by the impoverished experimental situation than the sighted Ss. In the light of the argument that blindfolded sighted Ss are effectively newly blind, it is reasonable to ask why they could perform so well in this intermodal task even without the artificial context. One possible answer is that the sighted Ss retained a visual context that served them better than the artificially reintroduced context served the blind. Specifically, the sighted had had visual experience for years, including a great deal of experience with hearing a sound somewhere in the environment and looking there and seeing a sound producer. Similarly, they had had years of experience visually guiding their hands. It seems not unreasonable to suggest that even when their eyes were closed, the long history of associations of auditory and tactile experience with visual experience may still have allowed the sighted Ss visual referencing or interpretation of the auditory and tactile stimuli. If normally sensed individuals refer other modality information to a visual framework, and if it is this referencing that blind individuals cannot do, then the blind would certainly be at a disadvantage where they had to perform relatively complex spatial tasks such as those required in Fisher's Experiment 3.

A comparison of sighted, congenitally-totally blind, and blind with some residual vision reported by Warren and Pick (1970) provides support for this notion. Warren and Pick used a conflict paradigm to compare the relative dependence on auditory and proprioceptive cues for localization of a target. The pattern of change over age for blindfolded Ss with some residual vision was remarkably similar to that of blindfolded sighted Ss, while the pattern for the totally blind was quite different. In addition, consistency in localizing unconflicted auditory and proprioceptive targets was assessed. The performance of the sighted was much better than that of the totally blind, while the performance of the partially blind was quite similar to that of the sighted group. It seems reasonable to suggest that it was a visual frame of reference which allowed the better performance of the partially sighted and the sighted Ss. The visual frame of reference notion clearly carries implications about the nature of intermodal organization. There is a group of studies bearing directly on the organization question. These studies look not for differences in *quality* of performance, but rather for differences in the *type* of performance between congenitally and adventitiously blind, or between blind and sighted Ss. Pick, Klein, and Pick (1966) studied form orientation judgments of normally-sighted, partially-sighted, and totally-blind Ss, age six years to adult. The procedure was similar to that used by Ghent (1961), in which S is presented a pair of forms, one of which is upside-down with respect to the other. The S is asked to choose which of the forms is upside down. Since the forms used by Pick, et al. (1966) were the letter-like nonsense forms reported by Gibson, Gibson, Pick, and Osser (1962), there was in fact no correct answer. The sighted Ss gave visual responses that indicated a strong consistency in orientation judgment over age. Their responses to the tactually presented forms, however, did not show consistent orientation judgments. The group of totally blind Ss also failed to show consistent tactual judgments, suggesting that they had not acquired an organization of the tactual mode parallel the visual organization of the sighted Ss. The partially sighted group, however, showed an interesting pattern of tactual judgments. Their judgments did show good consistency, and in fact the pattern was similar to the pattern of visual judgments of the sighted group. The effects of the partial vision seem clear: although these Ss were legally blind, they retained enough visual influence to structure their judgments of tactual stimuli. The fact that the structure was similar to that of the sighted Ss' visual structure is important: it indicates that the visual effect is not an influence toward tactual structuring in general, but rather a specific influence toward structuring in a particular way. The fact that the totally blind Ss did not show any tactual structure is especially important: it suggests some visual influence is necessary to produce any tactual structure at all.

A study by McKinney (1964) with young children serves to illustrate a similar point. The S held his hand palm up on the table with his eyes closed. E touched one finger, then after a three-second delay, S pointed with his other hand to the finger that had been touched. Three conditions differed according to what happened during the 3-second delay. In one condition nothing happened, in a second condition, E turned S's target hand over before response, and in the third, E turned S's hand over, but returned it to the original orientation before response. The four- to six-year old sighted Ss made significantly more errors in the second condition than in either of the conditions where response was performed with the hand in its original position. A group of congenitally-blind children was tested in the same conditions, and a different pattern of results emerged. They made the most errors in the double turn condition, least in the no turn, and an intermediate number in the single turn condition. McKinney suggested that the sighted Ss were able to perform well in the double turn condition because they formed and retained a visual image of where the stimulated finger was in relation to the whole hand. Such an image would be misleading when a single reversal was given, and their performance was worse in that condition. When a double turn was made, the hand returned to its original position, for which the image was again appropriate. The congenitally-blind Ss, however, could use no such visual image, and their performance deteriorated steadily as the number of intervening operations on the hand increased. Thus, the effects of visualization in tactual performance produced a different type of functioning for the blind Ss than for the sighted.

Bitterman and Worchel (1953) report a study on judgments of phenomenal horizontal and vertical in which conclusions similar to those of McKinney about the effects of vision on body judgments may be reached. The manual settings of a rod to the horizontal and vertical did not differ for congenitally-blind and sighted Ss. However, when S was tilted 42° to one side, the judgments of the blind were significantly more accurate than those of the sighted group. Bitterman and Worchel suggest that the normal dependence of sighted Ss on vision interfered with their performance when blindfolded, while the blind Ss were at less of a disadvantage.

Hermelin and O'Connor (1971) report a study that does not apparently support the conclusion of McKinney with respect to visualization. Hermelin and O'Connor trained various groups of Ss to associate each of four fingers with one of four words. The S learned to press a button with the finger appropriate to the stimulus word presented. After acquisition, the positions of S's fingers on the buttons were reversed, so that it could be ascertained through further testing whether S had associated the word with the particular finger or with a particular spatial location. The 10 blind Ss included seven blind from birth and three who became blind during the first year. Of the responses that could be classified as finger or location responses, the blind children gave 70 percent finger responses, the blindfolded sighted children gave 78 percent finger responses, while a group of sighted children who performed with vision throughout the task gave only 40 percent finger responses. Thus, there was no evidence for a marked difference between blindfolded sighted Ss and early blind Ss: both groups gave predominantly finger responses. The group that performed with vision showed much more responding to spatial position. Hermelin and O'Connor concluded that Ss performing without vision responded to the immediate sensory input, rather than to a position in space independent of modality. The performance of the groups in this study does not challenge the conclusions of McKinney (1964), however. The blind Ss were all congenitally or early blind, and it is not surprising that they show few location responses. The predominance of finger responses for the blindfolded sighted Ss may be taken to indicate lack of visualization of external space, but it may just as well be taken to indicate that visualization of the hands themselves was taking place. It may be noted in this regard that the "visual image" discussed by McKinney was of the child's hand, not of locations in external space. In fact, an extension of this work reported by Smothergill (1969) specifically tested whether the mistakes in McKinney's more difficult tasks could be attributed to confusion between a spatial location and the finger that occupied that location. Smothergill found that external spatial location could not account for the errors, and thus he supported the conclusion that the visual image was of the hand itself. In the light of these results, it is reasonable to argue that visualization may have occurred in the Hermelin and O'Connor work, but that it was visualization of S's hand, rather than visualization of external space.

DISCUSSION

Although direct evidence about the visual frame of reference notion is meager, much of the evidence discussed in this review is consonant with the hypothesis. Of the form discrimination, maze performance, and body locomotion and orientation research, only the veering task reported by Cratty (1967) showed a significant superiority of the early blind over the later blind. Of the auditory work, only the echodetection work by Rice (1970) showed an advantage of early blindness. Both types of exception represent relatively simple spatial tasks. It is in the more complex spatial tasks that differences favoring the later blind have routinely appeared. Spatial tasks may be "complex" in various ways. Tasks requiring intermodal comparisons are complex, and it may be especially for these tasks that early-visual experience is effective in producing a frame of reference to which incoming spatial information may be referred. Tasks such as imagining the combination of two separate forms are also complex: here the demand on S is to retain one source of input in memory, put another source with it, and combine the various sources. This storage of spatial information is clearly involved in maze-learning tasks, and the later blind have routinely been found superior in these studies.

Early vision, then, may allow the establishment of a frame of reference whose effects endure even after vision is lost. The performance differences between congenitally- and adventitiously-blind Ss on the more complex tasks point to the enduring efficacy of this frame of reference. Earlier in this paper the general hypothesis was advanced that the frame of reference for auditory localization is built up over a period of time by repeated instances of hearing a sound producer, looking, seeing a sound producer, and associating the sound location cues with the visual position. Wertheimer (1961) has demonstrated a close relation of audition with visuomotor activity at birth: his newborn S looked toward a clicking sound presented off to one side. More compelling evidence of an early auditory-visual link has been provided more recently by Aronson and Rosenbloom (1971). Given the tendency to respond visually to an auditory stimulus, it is not difficult to imagine the gradual refinement of the looking response, as well as the increasing dependence on the visual mediation of auditory stimuli.

In the case of visual-motor relations, much more is known about the early establishment of a crossmodal correspondence. This development may be viewed in various ways: Piaget (1952) speaks of visual and motor schemas, initially independent, which normally become coordinated at about three to four months of age. White and Held (1969) describe the infant's progress from the "swiping" stage (around 70 days of age) to mature, visually directed reaching (around 150 days of age). However the process is described, human infants start off with no visual direction of their motor behavior, and during the first year, they normally acquire a great deal of eye-hand coordination. This acquisition may be the most important difference between the congenitally blind and the later blind. Specifically, during the first year vision allows the child to see his fine motor movements, as well as to better conceptualize the temporal sequence of his movements. The early-late blind differences in performance on near-space motor tasks, such as form judgment and maze learning, are more easily understood when the nature of the first-year experience is noted.

The importance of early vision for cross-modal auditory-proprioceptive performance can be viewed in a similar way. When the sighted infant begins to reach for sound producers, vision helps in at least two ways, to direct the hand more accurately to the target, and in the case of targets that cease to make noise before the hand can grasp them, to mark the spatial location for the hand.

Thus, early vision is important not only to provide the infant with precise spatial information, but also to serve as a mediator both within and between the other spatial modalities. It should not be surprising that having had this early experience provides the later blind with a residual function not enjoyed by the congenitally blind.

The question of verbalization was raised in connection with the maze-learning results earlier in the review. Knotts and Miles (1929) found blind Ss who reported using verbal approaches to maze performance to be more successful than those who reported using motor approaches. It seems reasonable to expect the effectiveness of verbal approaches to be related to the age at onset of blindness. Specifically, if S lost vision before he had developed language to the point of labeling the spatial relations that he experienced visually, his later verbal mediation might be less effective than if he had a history of concurrent verbal behavior and visual experience. A result reported by Schlaegel (1953) lends some support to this notion. A group of blind Ss with loss of vision at less than five years gave almost no reports that were interpreted as visual images. Many of these Ss did have early vision, but most lost vision before their verbal behavior was mature. Thus while these Ss may have experienced visual images, perceptually speaking, they were unable to report these images verbally. Thus for verbal intervention to be very successful, it may depend on several years of visual experience.

Having had early vision certainly confers certain advantages on the adventitiously blind. However, it may also be that early vision can be a disadvantage. Specifically, dependence on a visual framework may prevent the newly-blind person from developing the remaining sensory abilities to their fullest capacity. Having had early vision to coordinate auditory and tactual function is surely not a disadvantage in itself, but an over-reliance on visual images and a tendency to retain visual dependence, as suggested by the results of Hartlage (1969), may prove disadvantageous.

This possibility is not merely of casual interest, especially when the implications of the research reviewed here are brought to bear on questions of the training of the blind. Should the mobility training of the later blind attempt to maintain the visual frame of reference, or should it discourage reliance on this residual function and encourage strictly non-visual spatial functioning? This question must not be misinterpreted. Many of the perceptual advantages of early vision for the other spatial modalities have already occurred before blinding, and much of the literature indicates that these advantages are not lost with blindness. The real question is, should the later blind person be encouraged, in his mobility training, to "think of where you saw this," to encourage his learning to relate new experiences to his residual frame of reference? Or should he be encouraged to experience new stimuli in only those modalities that are now available?

The training question takes a somewhat different form for the congenitally blind. If vision provides an organizational function for the sighted child, and if early vision provides a residual organizational framework for the child blinded after two or three years of age, what is the most effective remedial program that can be instituted for the child blind from birth? Certainly mobility programs instituted in the mid-elementary or later years are not optimal with respect to the variables discussed in this review. The fact that only two or three years of early vision can provide a lasting beneficial effect strongly suggests that in normal cases, significant perceptual function becomes established during the first couple of years. Perhaps psatial perception is especially plastic during that time but then loses its organizational plasticity. In fact, a great deal of deprivation research with animals suggests that the period of plasticity may be far less than five years. In short, it seems quite likely that the early years, perhaps up to five, provide the most fertile ground for establishing in the congenitally blind an auditory-proprioceptive organization that is maximally useful in structuring spatial relations.

The answers to the implied theoretical questions are less vital than the answers to the practical questions. Mobility programs should be structured around the answer to the question: "what works?" The intended function of this literature review has been to draw attention to the differences in perceptual capabilities between the early and late blind, and to suggest the dynamics that may lead to these differences. That there are such differences is clear. What they imply for questions of mobility and orientation training is not clear: these questions await variations in mobility procedures and careful evaluation research on mobility programs.

REFERENCES

Aronson, E., and S. Rosenbloom. "Space Perception in Early Infancy: Perception Within a Common Auditory-Visual Space," *Science*, 1971, Vol. 172, pp. 1161-3.

Berg, J., and P. Worchel. "Sensory Contributions to Human Maze Learning: A Comparison of Matched Blind, Deaf, and Normals," *Journal of General Psychology*, 1956, Vol. 54, pp. 81-93.

Bitterman, M. E., and P. Worchel. "The Phenomenal Vertical and Horizontal in Blind and Sighted Subjects," *American Journal of Psychology*, 1953, Vol. 66, pp. 598-602.

Carr, H. "The Influence of Visual Guidance in Maze Learning," *Journal of Experimental Psychology*, 1921, Vol. 4, pp. 399-417.

Cratty, B. J. "The Perception of Gradient and the Veering Tendency while Walking Without Vision," *Research Bulletin No. 14, American Foundation for the Blind*, 1957, pp. 31-51.

Cratty, B. J., C. Peterson, J. Harris, and R. Schoner. "The Development of Perceptual-Motor Abilities in Blind Children and Adolescents," *New Outlook for the Blind*, 1968, pp. 111-7.

Drever, J. "Early Learning and the Perception of Space," *American Journal of Psychology*, 1955, Vol. 68, pp. 605-14.

Duncan, B. K. "A Comparative Study of Finger-maze Learning by Blind and Sighted Subjects," *Journal of Genetic Psychology*, 1934, Vol. 44, pp. 69-95.

Ewart, A. G., and F. M. Carp. "Recognition of Tactual Form by Sighted and Blind Subjects," *American Journal of Psychology*, 1963, Vol. 76, pp. 488-91.

Fernald, M. R. "The Mental Imagery of Two Blind Subjects," *Psychological Bulletin*, 1913, Vol. 10, pp. 62-3.

Fisher, G. H. "Spatial Localization by the Blind," *American Journal of Psychology*, 1964, Vol. 77, pp. 2-14.

Ghent, L. "Form and its Orientation: A Child's Eye View," *American Journal of Psychology*, 1961, Vol. 74, pp. 177-90.

Gibson, E. J., J. J. Gibson, A. D. Pick, and H. A. Osser. "A Developmental Study of the Discrimination of Letter-like Forms," *Journal of Comparative and Physiological Psychology*, 1962, Vol. 55, pp. 897-906.

Hartlage, L. C. "Verbal Tests of Spatial Conceptualization," *Journal of Experimental Psychology*, 1969, Vol. 80, pp. 180-2.

Hayes, S. P. *Contributions to a Psychology of Blindness*. New York: American Foundation for the Blind, 1941.

Hermelin, B., and N. O'Connor. "Spatial Coding in Normal, Autistic and Blind Children," *Perceptual and Motor Skills*, 1971, Vol. 33, pp. 127-32.

Juurmaa, J., and S. Jarvilehto. "On the Obstacle Sense of the Blind," *Helsinki Institute of Occupational Health Monograph*, No. 28, 1965.

Juurmaa, J. "On the Accuracy of Obstacle Detection by the Blind--Part 2," *New Outlook for the Blind*, 1970, pp. 104-18.

Kellogg, W. N. "Sonar System of the Blind," *Science*, 1962, Vol. 137, pp. 399-404.

Knotts, J. R., and W. R. Miles. "The Maze-learning Ability of Blind Compared with Sighted Children," *Journal of Genetic Psychology*, 1929, Vol. 36, pp. 21-50.

Koch, H. L., and J. Ufkess. "A Comparative Study of Stylus

Maze Learning by Blind and Seeing Subjects," *Journal of Experimental Psychology*, 1926, Vol. 9, pp. 118-31.

Kohler, I. "Orientation by Aural Clues," *Research Bulletin No. 4, American Foundation for the Blind*, 1964, pp. 14-53.

McKinney, J. P. "Hand Schema in Children," *Psychonomic Science*, 1964, Vol. 1, pp. 99-100.

McReynolds, J., and P. Worchel. "Geographic Orientation in the Blind," *Journal of General Psychology*, 1954, Vol. 51, pp. 221-36.

Piaget, J. *The Origins of Intelligence in Children.* (2nd Ed.). New York: International University Press, 1952.

Pick, H. L., Jr., R. E. Klein, and A. D. Pick. "Visual and Tactual Identification of Form Orientation," *Journal of Experimental Child Psychology*, 1966, Vol. 4, pp. 391-7.

Rice, C. E. "Early Blindness, Early Experience, and Perceptual Enhancement," *Research Bulletin No. 22, American Foundation for the Blind*, 1970, pp. 1-22.

Rice, C. E., S. H. Feinstein, and R. J. Schusterman. "Echo-detection Ability of the Blind: Size and Distance Factors," *Journal of Experimental Psychology*, 1965, Vol. 70, pp. 246-51.

Rubin, E. J. "Abstract Functioning in the Blind," *American Foundation for the Blind Research Series*, No. 11, 1964.

Schlaegel, T. F. "The Dominant Method of Imagery in Blind as Compared to Sighted Adolescents," *Journal of Genetic Psychology*, 1953, Vol. 83, pp. 265-77.

Smothergill, D. W. "Age Changes in Memory and Modalities," Paper read at the meeting of the Society for Research and Child Development, Santa Monica, 1969.

Supa, M., M. Cotzin, and K. M. Dallenbach. "'Facial Vision': The Perception of Obstacles by the Blind," *American Journal of Psychology*, 1944, Vol. 57, pp. 133-83.

Sylvester, R. H. "The Mental Imagery of the Blind," *Psychological Bulletin*, 1913, Vol. 10, pp. 210-1.

Warren, D. H., and H. L. Pick, Jr. "Intermodality Relations in Localization in Blind and Sighted People," *Perception and Psychophysics*, 1970, Vol. 8, pp. 430-2.

Wertheimer, M. "Psychomotor Coordination of Auditory and Visual Space at Birth," *Science*, 1961, Vol. 134, p. 1692.

White, B. L., and R. Held. "Plasticity of Sensorimotor Development in the Human Infant," in J. F. Rosenblith and W. Allinsmith (eds.), *Causes of Behavior: Readings in Child Development and Educational Psychology* (2nd ed.), Boston, Mass.: Allyn & Bacon, 1969, pp. 60-71.

Worchel, P. "Space Perception and Orientation in the Blind," *Psychological Monographs*, 1951, Vol. 65, pp. 1-28.

Worchel, P., and J. Mauney. "The Effect of Practice on the Perception of Obstacles by the Blind," *Journal of Experimental Psychology*, 1951, Vol. 41, pp. 170-6.

METHODS AND PROCEDURES OF BRAILLE READING

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THE PROBLEM AND METHODS OF PROCEDURE

The Problem

The problem of this study was to determine:

1. The methods of teaching braille to blind children attending the elementary department of regular residential schools for the blind.

2. The characteristics of such children in the total school.

The Significance of the Study. Braille reading at the present time is being taught by teachers who basically have had only a course or two in the reading and writing of the code. Very few teachers of the blind have had courses concerned with the methodology of teaching the code to children. Therefore, it was significant to observe the replies of the teachers to the questions concerning braille reading. Also worth noting were the replies concerning the characteristics of those children attending the aforementioned residential schools.

Limitations of the Study. This research study was limited by various choices. The chief limitation was the choice of regular residential schools for the blind instead of local, day or itinerant program schools, which limited the sample. Another great limitation was the short amount of time given to the respondents.

METHODS OF PROCEDURE AND SOURCES OF DATA

Selection of the Sample. The regular residential schools for the blind, excluding the schools for the multiply-handicapped, were selected for the sample. Teachers and administrators were selected as the recipients.

Means of Gathering Data. Questionnaires were sent to administrators of the regular residential schools for the blind. Administrators were asked to please fill out Questionnaire B concerning the characteristics of blind children in regular residential schools for the blind. Administrators were also asked to have their teachers of the elementary department fill out Questionnaire A concerning the methods or procedures involved in the braille reading process.

Upon completion of both of the aforementioned questionnaires, administrators were asked to mail the replies to their point of origin. The data was tabulated by an average percentage or totaled.

DEFINITIONS

Braille. As used in this study, braille was the system of writing for the blind that uses characters made up of raised dots.

The Letter Method. The letter method was the perceiving of one letter at a time by the reading finger.

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The Whole Word Approach. As used in this research, the whole word approach was the perception of braille in wholes as the reading finger moves over the characters.

Grade One Braille. Grade one braille was a system of braille which only uses the braille alphabet.

Grade Two Braille. Grade two braille was a system of braille which uses the braille alphabet and braille contractions.

Phonemic Braille. Phonemic braille was a system of braille which uses a unique braille code that coincides with the Initial Teaching Alphabet.

SURVEY OF RELATED LITERATURE

The literature quoted in this chapter has been limited because of the paucity of research available on the methods or procedures of teaching braille reading and lack of information related to the pupils receiving such instruction in the residential schools for the blind. Only two current investigations were located concerning methods or procedures of braille reading. These two studies are reviewed later.

This chapter consists of three sections. Each section contains research concerning the following: Section I reviews research on braille reading; Section II reviews research on methods or procedures of teaching braille reading; and Section III includes a brief paragraph concerning the dearth of research on the characteristics of blind students attending the regular residential schools for the blind.

Braille Reading Past and Present

Some of the earliest investigations relating to the perceptual factors in braille was initiated by the Uniform Type Committee. This committee was organized to evaluate various punctographic systems in use at the time the investigation was made. The committee found that legibility was related to the number of dots contained within the braille characters. The characters that were most legible were braille characters containing fewer dots. Reading time was found to increase as the number of dots increased. Whole-cell contractions facilitated reading while lower-cell contractions retarded reading. Conclusions from this study indicated that interdot, intercell, and interline distance were near optimum.

One of the first scientifically based studies of braille reading was conducted by Burklen who studied extensively the mechanical factors involved in braille reading. He found that character legibility was determined by the configuration of dots in the cell rather than by the number, which findings led him to assume that the reading of words and sentences occurred through the apprehension of word forms in a comprehensive manner.

There has been a lack of agreement by researchers in the field of the blind concerning Burklen's findings. This is because he used large unyielding dots, greater distance between the dots, and because his subjects had to use rubber caps over their fingers during experimentation. These factors combined to produce a perceptual situation quite different from that found in actual braille reading. Burklen's research was based upon braille reading in German which was very different than English Standard Braille.

The first comprehensive book concerning braille reading was written by Maxfield, who agreed with most of Burklen's findings. She encouraged the use of both hands in the use of braille reading, and stated that the best readers read ahead with both hands; the right hand completing the line while the left hand drops down to the next line. Maxfield claimed that letters were actually perceived by the reading finger as it progressed over them, and that the whole-word approach was a superior method. The use of this method by two-thirds of the teachers of the blind today attests to Maxfield's influence.

Holland and Eatmen noted while studying the silent reading habits of blind children that good readers were readers who accomplished more rapid return sweeps and exhibited fewer regressive hand movements. Fast braille readers were found by Holland to use less pressure than slow readers.

Fertsch, while studying the silent reading speeds of blind children indicated that silent braille reading speeds were greater than oral reading speeds for both good and poor readers. She found that reading habits of blind children were formed prior to the third grade and were not appreciably affected thereafter. Correlating with earlier findings, she concluded that good readers covered a significant amount of material with independent movement of both hands, although twice as much material was read with the right hand than with the left.

In a survey of braille instruction in local and residential schools throughout the United States Lowenfeld, et al. found that children appeared to develop their own styles of reading but that the majority of teachers used the whole-word method with beginning readers.

Factors concerning the perceptual factors in the recognition of braille were collected from a series of nine studies implemented by Nolan and Kederis. A most significant finding of this study was that the perceptual unit in braille appears to be the individual braille character rather than the whole word. This implies the need for careful analysis of the whole-word concept currently used by the majority of teachers of the blind. Character recognition training was found to heighten oral and silent reading accuracy as well as oral reading speed. Nolan and Kederis suggested further that if the perceptual unit in braille is the individual character, that the process of word recognition appears to be sequential and integrative, one in which word recognition was the result of an accumulation of information over a temporal interval. The differences found between synthetic-recognition time and cover time revealed that information was integrated as the finger progressed from character to character with closure being obtained after all characters were covered.

Further findings by Nolan and Kederis revealed three critical areas in braille reading which seemed to be affected by variations in mental ability, character recognition, character integration and the use of peripheral clues. Children with lower mental ability, were slower to recognize and integrate information from braille than did children of normal intelligence. Intelectually average and bright children found contractions were an asset concerning the recognition of familiar words. The resulting implication was that braille ceases to be an effective medium for children with intellectual ability below a certain level. The cut-off point appeared to be much higher in braille than in print.

Methods and Procedures of Teaching Braille

A very recent study concerning the teaching of braille reading was initiated by Lowenfeld, Hatlen, and Abel to ascertain the status of braille reading instruction. Lowenfeld, Hatlen, and Abel's research was based upon a questionnaire concerning the status of braille reading and the application of reading tests to blind children in local and residential schools for the blind.

All residential schools throughout the country participated in the study by Lowenfeld et al. The replies from the regular residential schools were 100 percent. The replies from the local schools for the blind were only 86 percent.

Lowenfeld, Hatlen, and Abel found that most residential and local schools began reading instruction in the first grade after pre-reading activities had been initiated during kindergarten. They also noted that one-third of the schools began their reading instruction by using the braille alphabet while two-thirds of the schools began using whole words and/or meaningful sentences. Grade two braille was used by practically all schools from the beginning.

Concerning hand use, 85 percent of the teachers in both residential and local schools encouraged their pupils to use both hands for reading. Comments concerning hand use indicated that as children grew they devised their own way of reading regardless of methods taught.

Concerning finger use, two-thirds of the teachers in residential schools encouraged the use of the index fingers of both hands. In local schools one-third of the teachers encouraged the use of the index fingers of both hands. Various combinations of finger use were encouraged by both residential and local schools. Five percent of residential-school teachers and 16 percent of local school teachers let the child choose the fingers he preferred.

Lowenfeld, Hatlen, and Abel found that half of the teachers in both types of schools introduced braille writing as the teaching of reading was begun. About one-third of the teachers introduced it after some reading skills had been developed and 40 percent of the teachers questioned from both schools stated that they considered the child's individual level of ability before introducing it. The Braillewriter was universally used to teach braille writing.

Some additional information was received from a smaller number of teachers whose students took part in the reading tests given in connection with the study. Twenty residential and 41 local schools replied. In local schools, reading books and pre-primers were introduced at the beginning of braille instruction or after words and sentences were read. In residential schools, these books were introduced only after words and sentences were read. Reading instruction was found to be conducted in both residential and local schools by oral as well as silent reading. Double-spaced material was universally used in beginning-reading instruction.

One of the most recent studies concerning several approaches for teaching braille reading was initiated by Hartley and Rawls. They began a pilot study to determine the most effective approach concerning the teaching of braille reading to beginning-braille students. They used materials written in the braille media grade 1, grade 2, and phonemic. Two contract-reading series were used: Scott Foresman, *The New Basic Readers*, Curriculum Series (Robinson, Monroe and Artley, 1965), using an analytic or gestalt approach; and the *Lippincott Basic Reading Series* (McCraken and Walcutt, 1963), using a synthetic or decoding mechanical approach.

Materials for the study were prepared in grade 2 braille for each approach. Pre-primer, primer, and first grade books were available through the American Printing House for the Blind. Books using grade 1 braille were embossed by the Howe Press. Books in phonemic braille were developed using a braille code to match phonemic braille materials. A Scott Foresman Series (Robinson and others, 1965) was used.

Since the Lippincott Series was not available in phonemic braille code 44 phonemic braille symbols were assigned to this series using Webster's *New World Dictionary*, Elementary Edition (Guralmit, 1961).

Harley and Rawls used 39 beginning braille readers in classes located in six residential schools for the blind. The intellectual ability of the children ranged from mildly retarded to high-average. An overall median age of 7.7 years was found to be very close to the median age for each group. The amount of prior experience in educational programs varied widely among the children. Nursery school, head start, day-school programs and residential school kindergarten programs were the most common types of programs involved.

Teachers were prepared by a three day workshop. The experimental program began in September and continued until the end of the academic year. Experimental materials were introduced to the children following a readiness program in each group.

Progress reports were kept on the children and special problems encountered in the use of materials were noted by the use of a daily log. In every class teachers prepared all supplementary materials for the teaching of braille reading. Four groups using grade 1 braille prepared all supplementary reading material since no other materials were available.

The data that was analyzed consisted of scores concerning four variables: Mental Age, the Slosson Oral Reading Test Scores, and Gilmore Accuracy and Comprehension Scores. The results of these tests administered at the end of the academic year suggested that phonemic braille could be used successfully with beginning braille readers. The analytic approach appeared more effective for phonemic materials than the synthetic approach. The effectiveness of grade 1 approaches were not adequately measured.

Harley and Rawls suggested that a study of longer duration with more adequate materials would be necessary in order to make generalizations about the efficacy of the approaches involved in braille reading.

Characteristics of Residential School Blind Children

The literature concerning the characteristics of blind children in the residential schools for the blind was lacking. Many journals were reviewed concerning the aforementioned topic. No data was discovered concerning this topic.

In summary, while replication of studies remain to be done, the review of literature clearly suggested that the braille reading process is unique and complex. There existed a large amount of research available concerning braille reading. The existence of research concerning methods or procedures of teaching braille to children was scarce. No data was found concerning the characteristics of blind children attending the regular residential schools for the blind.

FINDINGS OF THE STUDY

A total of 39 questionnaires were mailed to regular residential schools for the blind throughout the United States. Questionnaires A and B were received from 19 regular residential schools for the blind. A summary of the results of the findings of these questionnaires appear in tabular form within this section. The findings that appear in the tables below were derived by

1. Adding the number of individual responses.

2. Adding the number of percentage responses and dividing their total by the number of responses.

3. Adding the number of individual responses and dividing their total by the number of responses.

The percentages that appear in some of the tables below indicate the average percentages of the responses. Comments of the teachers involved in this study and the combination of procedures used also appear henceforth.

QUESTIONNAIRE A

Braille Reading Readiness

The use of tactual experiences was found to be the procedure used most frequently by the teachers involved in the study. Tactual experiences were used, as indicated in Table 1, 47 percent of the time.

TABLE 1

Average Percentage of Procedures Used

Procedure	Average Percentage	Responses
Tactual Experiences	47	53
Concept Development	39	51
Aural Language	38	53
Hand Coordination	36	39

Other procedures listed concerning braille reading readiness were concept development, aural language, and the development of hand coordination. Concept development 39 percent, aural language 38 percent, and development of hand coordination 36 percent, were almost equally stressed.

Many teachers, as Table I indicates, stated that they used a variety of these procedures in their braille reading-readiness program. Some teachers stated that the percentage of the time these procedures were used varied with the individual child. One teacher mentioned that these procedures were closely related.

Initial Presentation of Braille

All teachers who replied to the question concerning the initial presentation of braille indicated that braille was presented initially as a result of tactual experiences. As indicated in Table 2, 44 teachers replied yes to this question. The question concerning the initial presentation of braille as a result of concept development received almost as many yes replies, 36, to this question. There were four no replies. The initial presentation of braille as a specific subject received the least number of replies, seventeen yes, and 11 no.

TABLE 2

Initial Presentation of Braille

	Yes	No
Result of tactual experiences	44	0
Result of concept development	36	4
A specific subject	17	11

Most teachers commented that they used a combination of all these methods concerning the initial presentation of braille. A few teachers mentioned that they taught braille initially as a result of concept development. Eight teachers indicated that they used all three of the aforementioned presentations. These teachers stated that they only used a combination of the three presentations. Nine teachers indicated that they used a combination of concept development and tactual experiences. They did not mark or check spaces marked yes or no. Four teachers checked the space indicating yes for concept development and tactual experiences. These four teachers also indicated that they used a combination of the two.

Beginning Braille Reading

The whole-word approach was the method most used by the teachers who replied to the question concerning the beginning of braille reading. Fifty-eight percent of the teachers, as indicated in Table 3 used this method. The order of character legibility ranked second in percentage of time used, 56 percent.

TABLE 3

Beginning of Braille Reading Methods

	Percentage	Responses
Whole word approach	58	46
Character legibility	56	38
Braille alphabet	36	31
Programmed instruction	27	12
Initial teaching alphabet	18	14

The braille alphabet, 36 percent, was found to be the third method that was used the largest percentage of the time. Two current approaches, the Initial Teaching Alphabet, 18 percent, and Programmed

Instruction, 27 percent, were the two lowest used methods in beginning braille reading.

Many teachers commented that the whole-word approach is used only as it is related to whole-word signs. One teacher stated that she used a combination of the braille alphabet and the whole-word approach.

Hand Technique

Fifty-two teachers, as indicated in Table 4, stated that they preferred the technique of teaching children to read with the use of two hands. One hand was to be used for the purpose of trailing.

TABLE 4

Hand Technique in Braille Reading

Two hands, one for trailing	52
Two hands, each independent	14
One hand, right or left	6

Fourteen teachers indicated that they taught reading by having children use two hands, each hand independent of the other. Only six teachers taught braille by having children read by using one hand, right or left.

Finger Technique

Forty-seven teachers as indicated in Table 5 stated that they encouraged children to read using the index finger of the right and left hand. Eight teachers encouraged their students to use the index finger of the right hand only. Five teachers stated that they encouraged children to use the first two fingers of the left and right hand. Twenty-one teachers stated that they allowed their children to choose their preference. Many teachers indicated that they taught children to use the index finger of the right and left hand.

Some teachers stated that they allowed their students to choose the method that was comfortable for them.

TABLE 5

Finger Technique Encouraged By Teachers

Fingers Left Hand	Fingers Right Hand	Responses
3, 2, 1	1, 2, 3	3
2, 1	1, 2	5
1	1	47
	1	8

Conducting of Braille Reading Classes

The results of the question concerning the conducting of braille reading indicate, as can be seen in Table 6, that oral reading, 61 percent, was the method of reading used the most.

TABLE 6

Average Percentage of Teachers Conducting Oral, Silent, or Aural Braille Reading

	Percentage of Time	Responses
Oral reading	61	62
Silent	40	55
Aural	22	31

Aural reading, 22 percent, as indicated by Table 6, was the lowest average percentage of the group. Silent reading with an average percentage of 40 percent was the method ranking second in percentage of time used.

Most of the comments indicated that teachers used oral and silent reading predominantly. Aural reading was mentioned by some teachers as a method used with slower groups.

Braille Approaches

The findings of the study (Table 7) indicated that teachers in regular residential schools for the blind used the whole-word approach an average of 95 percent of the time. The Initial Teaching Alphabet was used an average of 36 percent of the time. Grade I braille was found to be used an average of 33 percent of the time.

TABLE 7

Average Percentage, Use of Grade I, Grade II and the Initial Teaching Alphabet

Approach	Average Percentage	Responses
Grade II	95	54
I. T. A.	36	10
Grade I	33	15

Most teachers stated that they used Grade II braille. The Initial Teaching Alphabet was used more than Grade I braille in regular residential schools for the blind. Many teachers stated that they only used Grade I braille when teaching spelling.

Most of the teachers who replied to Questionnaire A used a variety of methods and procedures concerning the teaching of braille reading. Many teachers said that they used various combinations of methods and procedures in the braille reading process. They also stated that many of the methods and procedures indicated in Tables of Questionnaire A were related to each other.

QUESTIONNAIRE B

Number of Teachers and Pupils

The average number of teachers and pupils who attended regular residential schools for the blind is found in Table 8. The average number of teachers who taught in regular residential schools for the blind was 22. Sixteen schools for the blind responded to this question.

TABLE 8

Average Number of Teachers and Pupils in Regular Residential Schools for the Blind

	Average Number	Responses
Pupils	121	17
Teachers	22	16

The average number of pupils attending regular residential schools for the blind was 121. There were 17 responses to this question.

Home Situation

Seventy-one percent of the blind children as indicated by Table 9 lived in a home situation with two parents. There were 11 responses to this question. Nineteen percent of the blind children lived in a home situation with one parent. There were 12 responses to this question. Seven percent of the blind children lived with their grandparents. There were 9 responses to this question.

TABLE 9

Average Percent of Home Situation of Blind Children When at Home

	Average Percent	Responses
With two parents	71	11
With one parent	19	12
With grandparents	7	9
In foster home	6	13

Six percent of the blind children lived in a foster home. There were 13 responses to this question.

Blindisms

The results of the study found that 26 percent of the blind children in regular residential schools for the blind had blindisms.

TABLE 10

Average Percentage of Children with Blindisms

	Average Percentage	Responses
Blindisms	26	13

There were thirteen responses to the question concerning blindisms.

Questionnaire B, number three, concerning the percentage of blind children at each level was not used for the results of the study because it was not considered to be valid by many of the administrators. This question was considered unclear to the participants.

Questionnaire B showed that the average number of students attending the regular residential schools for the blind was 121. The average number of teachers in these aforementioned schools was 22. Most of the students at the regular schools for the blind lived with two parents when at home. The study also found that the average percentage of children with blindisms in the regular residential schools was 26 percent.

SUMMARY

This study was to determine the methods or procedures of teaching braille by the teachers of the elementary department of the regular residential schools for the blind, and to determine certain characteristics of these children.

Questionnaire A was concerned with the methods of procedures of teaching braille. This questionnaire was filled out only by teachers. Questionnaire B was concerned with the characteristics of blind children. Both questionnaires were sent only to the regular residential schools for the blind.

Questionnaires A and B were sent out to 39 regular residential schools for the blind. Replies were received from 19 regular residential schools. The data from these two questionnaires was tabulated by an average percentage or totaled.

Questionnaire A

The use of tactual experiences was found to be the procedure used mostly concerning braille reading readiness. Concept development, aural language and hand coordination were almost equally stressed by the teachers who participated in the study.

All teachers who replied to the questionnaire concerning the initial presentation of braille indicated that braille was presented as a result of tactual experiences. Concept development was stressed almost as much as tactual experiences. Very few teachers taught braille as a specific subject. Many teachers indicated that they used a combination of the above approaches.

The whole-word approach was the method used the largest percentage of the time by the teachers who replied to the question concerning beginning braille reading. The order of character legibility ranked second in this category. The braille alphabet was found to be the third method most used by teachers concerning the beginning of braille reading. A large majority of the teachers involved in the study indicated that they used the technique of teaching children to read with the use of two hands. (One hand to be used for the purpose of trailing.) A small number of teachers used the technique of teaching reading with the use of two hands right and left or one hand right or left.

Most of the teachers indicated that they encouraged children to use the index finger of the right and left hand. Very few teachers taught children to read with fingers of the right and left hand.

Most of the teachers indicated that they used oral reading of braille the most. Silent reading was used almost as much as oral reading.

Questionnaire B

Concerning Questionnaire B it was found that the average number of students attending the regular residential schools for the blind was 121. The average number of teachers in these aforementioned schools was 22. Most of the students at the regular schools for the blind lived with two parents when at home. The study also found that the average percentage of children with blindisms in the regular residential schools was 26 percent.

Twenty regular residential schools for the blind replied to Questionnaire A and Questionnaire B. These schools represented states in all sections of the country.

The replies formulated from Questionnaire A and Questionnaire B produced some results that were somewhat similar to Lowenfeld, Hatlen and Abel's research concerning braille reading. For example, in both studies most of the children in the residential schools for the blind used the whole-word approach, Grade 2 braille, the index finger of the right and left hand, encouraged the use of both hands in braille reading, and the use of oral and silent reading.

CONCLUSIONS

Questionnaire A

Tactual experiences and concept development were deemed the procedures that were most important concerning braille reading-readiness and the initial presentation of the code. The whole-word approach was found to be the method mostly concerning the beginning of braille reading although character legibility was almost equally stressed. Most of the teachers involved in the survey taught the hand technique of teaching children to read with two hands, one used for the purpose of trailing. Most of the teachers taught the finger technique of having children use the index finger of both hands. The whole-word approach is the method used by most of the teachers of the regular residential schools for the blind.

Questionnaire B

The study found that the average number of students attending the regular residential schools for the blind was 22. The average number of teachers in these schools was 121. Most of the students enrolled at these aforementioned schools lived with two parents when at home. Twenty-six percent of the students in the regular residential schools for the blind exhibited blindisms.

RECOMMENDATIONS

The conclusions drawn from the survey indicated that many teachers are using methods that are outdated. For example, most of the teachers involved in the study used the whole-word approach. Since the perceptual unit in braille is the individual braille character, this approach should be reevaluated and supplemented with extensive training in character recognition. Another approach teachers indicated use of was teaching children to read braille with two hands. This approach also should be reevaluated and supplemented by training in independent use of h ands in braille reading. While replication of studies remain to be done, sufficient evidence suggested that educators should reevaluate their approach to braille reading instruction.

APPENDIX

QUESTIONNAIRE A

Survey of Methods or Procedures Used in Teaching Braille

Questionnaire for teachers only

Please Check or Respond as Appropriate:

1. What percent of the time are these procedures used in the braille reading readiness program?
   a. Tactual experiences _____
   b. Concept development_____
   c. Aural language _____
   d. Development of hand coordination _____
   e. Other please specify ______________________________

2. How is braille presented initially?
   a. Result of concept development _____Yes _____No
   b. Result of tactual experiences _____ Yes _____ No
   c. A specific subject _____Yes _____No
   d. Combination of the above please specify ______________________________
   e. Other please specify ______________________________

3. What percent of the time are these methods used concerning the beginning of braille reading?
   a. The braille alphabet _____
   b. The whole word approach _____
   c. The order of character legibility _____
   d. Initial Teaching Alphabet _____
   e. Programmed instruction _____
   f. Combination of the above please specify ______________________________
   g. Other please specify ______________________________

4. What hand technique is taught concerning braille reading?
   a. One hand, right or left _____
   b. Two hands, one for trailing _____
   c. Two hands, each independent of the other _____
   d. Other please specify ______________________________

5. Please circle the finger (or fingers) which you encourage children to use in reading:

   Left hand: 4 3 2 1 — Right hand: 1 2 3 4

   Check if children are allowed to choose their preference _____

6. Percent of time braille reading is conducted by:
   a. Oral reading_____
   b. Silent _____
   c. Aural _____
   d. Other please specify ______________________________

7. Percent of time each of the following approach used:
   a. Grade one _____
   b. Grade two _____
   c. Initial Teaching Alphabet _____
   d. Other please specify ______________________________

QUESTIONNAIRE B

Survey of Characteristics of Blind Children in Residential Schools

Questionnaire for administrators

Please Check or Respond as Appropriate:

1. Number of teachers? ______

2. Number of pupils? ______

3. Percentage of blind pupils at each level?
   a. High _____
   b. Upper middle _____
   c. Middle middle _____
   d. Low middle _____
   e. Low _____

4. Percent of blind pupils where:
   a. Two parents live in the home _____
   b. One parent lives in the home _____
   c. Child lives with grandparents _____
   d. Child lives in foster home _____

5. Approximately what percent of the blind children have blindisms? _____

6. _____ Yes, please send a summary to:

   Name ____

   Address ______________________________________

   ____

REFERENCES

American Foundation for the Blind. *Directory of Agencies Serving the Visually Handicapped in the U.S.* New York: American Foundation for the Blind, 1971, pp. 1-164.

Education of the Visually Handicapped. Kentucky: Association of the Visually Handicapped, Inc.

Fertsch, P. "An Analysis of Braille Reading," *Outlook for the Blind*, Vol. 40, May, 1946, pp. 128-31.

Harley, Randal K. and Rachel F. Rawls. "Comparison of Several Approaches for Teaching Braille Reading to Blind Children," *Research Bulletin* No. 23, May, 1971, pp. 63-85.

Holland, B. F. and P. F. Eatmen. "The Silent Reading Habits of Blind Children," *Teachers Forum*, Vol. 6, September, 1933, pp. 6-11.

Lowenfeld, Berthold, George Abel, and Philip Hatlen. *Blind Children Learn to Read.* Illinois: Charles Thomas, 1969, pp. 1-185.

Nolan, C. Y. and C. J. Kederis. *Perceptual Factors in Braille Word Recognition.* Research Series No. 20. New York: American Foundation for the Blind, 1969.

Burklen, K. *Touch Reading of the Blind.* New York: American Foundation for the Blind, 1932.

Maxfield, K. *The Blind Child and His Reading.* New York: American Foundation for the Blind, 1928.

The New Outlook for the Blind. New York: American Foundation for the Blind.

Research Bulletin. New York: American Foundation for the Blind.

Uniform Type Committee of the American Association of Workers for the Blind, Fourth Biennial Report." *The Outlook for the Blind*, Vol. 9, 1915, pp. 1-92.

EDITOR'S NOTE OF AN ERRATUM

The footnote to the paper by Krzysztof Klimasinski, on page 65 of the *Research Bulletin* No. 24 (March 1972), should have noted that the paper was translated by Jacek Laskowski, and not by the author.

REPORT OF THE PERCEPTUAL ALTERNATIVES LABORATORY FOR THE PERIOD JULY 1, 1971 — JUNE 30, 1972

Emerson Foulke*

The function of a perceptual system is to gather the information upon which the individual depends in regulating his interactions with his environment. When a perceptual system fails to function, or functions inadequately, the affected individual must replace the information that is lost with information acquired by interpreting sensory data gathered in other ways and by other perceptual systems. On June 25, 1969, by act of the Board of Trustees of the University of Louisville, the Perceptual Alternatives Laboratory was established under the auspices of the Graduate School of the University of Louisville, for the purpose of investigating perceptual alternatives. Although the long-range objective of the laboratory is to explore the full range of perceptual alternatives, at its present stage of development, the research program is concerned primarily with the investigation of perceptual alternatives for individuals with visual impairment.

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ACQUIRING INFORMATION BY LISTENING TO SPOKEN LANGUAGE

The information that is ordinarily acquired by reading the printed page can also be acquired by listening to the recorded oral reading of another person. Though reading by listening is not as effective as the visual reading of a skilled visual reader, there are circumstances under which it may be a desirable alternative. The busy physician or executive may make more efficient use of his limited time by listening to recorded oral reading as he drives to and from work. The skilled worker may be aided in carrying out a complicated assembly requiring continuous visual monitoring by listening to a sequence of recorded oral instructions. The child with normal vision who does not learn to read effectively and who is not benefited by efforts at remediation, may find reading by listening the most viable alternative. Reading by listening is an obvious alternative for those who have little or no vision, and under many circumstances, it offers a better alternative than braille. Since its founding, the investigation of reading by listening has been a major component of the laboratory's research program. This investigation has included research intended to explicate the processes on which reading by listening depends, and research to evaluate a variety of applications of reading by listening.

The Development of an Instrument Enabling Student Interaction with Programmed Oral Instruction

In the annual report for the preceding year, a project was described in which the laboratory undertook, for the Kentucky State Department of Child Welfare, the development of an instrument suitable for the auditory presentation of programmed instruction, and the preparation, in a compatible recording format, of the programmed instruction for use with that instrument. The instrument which was developed incorporates a cassette player that has been modified so that any one of four parallel tracks, recorded on the cassette containing the programmed instruction, may be selected by an appropriate switch setting. The student starts by listening to a unit of recorded discourse, presented on track one of the cassette. At the end of this unit, he hears a multiple-choice question pertaining to the information that has just been presented. He then stops the cassette transport, takes from a compartment in the instrument a card on which the same question is written, inserts the card in a slot on the top of the instrument, and records his answer by pressing the point of a stylus, connected electrically to the instrument, through the center of a small circle, one of which is printed at the end of each answer choice. In so doing, he punctures the card, which provides an unerasable record of his answer choice, and completes an electric circuit that illuminates a number specifying the track on the cassette to which he will listen for comment concerning his answer choice. He then sets a selector switch for the indicated track, and presses a button which causes the illuminated number to disappear and the cassette transport to start. If he has made the correct answer choice, he hears a comment that is intended to reinforce his correct response. If he has made an incorrect choice, he hears a comment that is intended to help him understand his error and lead him to the correct answer choice. When he has heard the comment, he stops the cassette transport, returns the track selector switch to track one, and listens to the next unit of instruction. The success of this format requires the preparation of four comments, one for each of the four alternative answer choices, that can be reproduced in exactly the same amount of time. If they were not equated for playback time, the student would not be assured of finding the beginning of the next unit of instruction when he returns to track one after having listened to the comment concerning his answer choice. Adjustment of the playback time for the four comments was made partly by the author of the programmed instruction, who attempted to write comments of approximately the same length, and partly by the oral reader employed for their recording, who made further adjustments by varying her oral reading rate. On some occasions, these adjustments were inadequate, and the final adjustment was achieved through the time compression or time expansion of the recorded comments, using the laboratory's speech-compression equipment.

Fourteen units of programmed instruction were prepared with the format just described, five duplicates of each unit were prepared, and 12 of the instruments used for displaying these units were constructed. The use of these materials constitutes a major component of a rehabilitation program serving poverty affected children and adults in Eastern Kentucky, and although the project is not yet completed, reports of the effectiveness of this study system are consistently positive.

The Talking Dictionary

In the laboratory report for 1970-71, there was a description of a project undertaken in collaboration with Mr. T. V. Cranmer, Director of Services for the Blind, Bureau of Rehabilitation Services, Kentucky Department of Education, Frankfort, Kentucky 40601, the objective of which is to record on tape the oral reading of a dictionary in a manner that will permit the rapid search of the recorded format required for efficient use. The dictionary is presented on cassette. To prepare a cassette, two tape recordings are needed. One tape contains the full text of the dictionary and is recorded at a tape speed of 15/16 of an inch-per-second (ips), the playback speed of a modified cassette player on which the dictionary is reproduced. The other tape contains only the pronunciations of the words that are to be spelled and defined, and is recorded at the speed at which the tape in the cassette travels when the modified cassette player is in the fast-forward mode of operation. The signals from these two tapes are mixed and recorded on a cassette. The player used to reproduce this cassette has been modified so that the playback head is not withdrawn from the cassette when the player is placed in the fast-forward mode of operation, and continues to scan the tape in the cassette as it travels at the fast-forward speed. When the player is operated at 15/16 ips, the signal containing the full dictionary text is reproduced properly. The signal containing only the pronunciations of words to be spelled and defined is reproduced at a speed so much lower than the speed at which it was recorded that it is nearly inaudible. Only an occasional low-pitched rumble is heard, and it is quite unobtrusive. At the fast-forward playback speed, the signal containing the prounciations of words is reproduced properly, and displayed against a background of the high-pitched chatter that results from reproducing the signal containing the full text at the fast-forward speed. Since, at this speed, the signal containing the full text is uninterpretable, it adds only noise to the signal that is being processed by the listener, and therefore does not offer serious interference. Each word properly reproduced at the fast-forward speed is so located on the tape that its termination and the termination of the definition preceding the same word in the full text rendition occur at the same time. Each cassette contains a braille label showing the first and last word recorded on each track. To use this dictionary, the listener selects the cassette and the track in which he is interested, and plays it at the fast-forward speed until he hears the word for which he is searching. He then changes to the slow-playback speed and listens to the spelling and definition of that word. Of course, the time required by a listener to consult this dictionary is considerably greater than the time required by a visual reader to consult a print dictionary. However, if the alternative is a Braille Dictionary, the advantages are more apparent. The Talking Dictionary will require considerably less space and be significantly cheaper than a Braille Dictionary. Though a superior braille reader may consume less time in consulting a Braille Dictionary than in consulting the Talking Dictionary, the difference is not so marked as in the case of the visual reader, and it may disappear altogether in the case of a poor braille reader. Further, most of those who must read by listening do not read braille at all, and for them, the Talking Dictionary may provide the only alternative to dependence upon assistance of a visual reader in consulting a dictionary.

The Talking Dictionary project is still in progress. The past year has been spent in developing the electronic circuitry needed to automate the recording of cassettes. As the tape containing the full dictionary text, and the tape containing the pronunciations of words to be defined are reproduced, control tones, placed on these tapes by the reader when they were recorded, are sensed electronically and used to start and stop the transport on which they are played. The control tones constitute a program that ensures the synchronization of the signals obtained from the two tapes. Additional circuitry compensates for the continuous change in tape speed that results when a cassette player is operated in the fast-forward mode by making appropriate adjustments in the playback speed of the tape containing the pronunciations of the words to be defined, as its signal is being copied. The signals supplied by the two tapes are fed to an audio mixer, the output of which is recorded on a final master tape suitable for use on a high-speed cassette duplicator. The design and construction of the equipment required for the process just described is now nearly completed, and it will shortly be possible to prepare the materials needed for evaluation.
By happy accident, the cassette

players now supplied to Talking Book readers by the Library of Congress include all of the modifications required for the proper reproduction of the Talking Dictionary.

The Development of an Aural Testing Instrument

In the annual report for 1970-71, a project was described in which the objective is to develop an instrument suitable for use by the individual who acquires by listening the test information that would ordinarily be acquired by reading a printed test form. Acquiring test information by listening to the recorded oral reading of a test is an obvious alternative for those who, for whatever reason, cannot read print.

However, if such a recording is reproduced on conventional equipment (record player, open-reel tape player, or cassette player) the aural reader is handicapped. The individual who acquires his test information by reading a printed test form can easily reread any test item if he is not sure of its meaning. He will typically read a few items once, many items twice, and a few items many times. Furthermore, he can maximize the number of test items he is able to complete by skipping the items that seem difficult to him on first reading, responding to the items that are easy for him, and then returning to the difficult items for more thoughtful consideration. However, if the recorded oral reading of a test is reproduced on conventional equipment, the performance of these operations becomes so inefficient, that the advantages gained by resorting to them are almost, if not completely, counteracted. Returning to a precise location in a recorded tape is a task that must be accomplished by the trial and error process of a successive approximation. It consumes so much time, and becomes so aggravating, particularly when it must be carried out under the time pressure associated with the taking of most tests, that in all likelihood the aural reader will elect to forego the advantages that might be realized by retracing. If the test score he obtains is depressed because he has not had access to operations which contribute to successful test performance and which are accomplished with ease by visual readers, it will not be a valid indication of the ability the test purports to measure. To solve this problem, the laboratory has arranged for the construction of two prototype devices, one by Biotronics, an electronics engineering company in the Louisville area, and one by AEC/Veritas, a research and development company in Galien, Michigan. Each of these devices is designed to be used as an accessory to a conventional cassette player, and little or no modification of the cassette player is required. With the device connected to the cassette player, the aural test taker listens to a cassette on which test items have been recorded. At the end of each test item, the cassette transport is automatically turned off. If he wishes to proceed to the next item, he presses a button that starts the transport again. If he wishes to return to the beginning of that item again, he presses a repeat button and holds it down until he hears a high-pitched tone. Upon its release, he hears the item again, and at its conclusion, the cassette transport is automatically turned off, as before. He may repeat this operation as many times as he wishes. He may retrace any desired amount by holding the repeat button down and by counting high-pitched tones until he arrives at the tone marking the location of the item in which he is interested. If he loses count during this process, he can find his place again by releasing his repeat button when he hears the next tone, and by listening to the number of the test item indexed by that tone. If he wishes to skip ahead, he can press a fast-forward button and listen for the tones that index the beginnings of test items. With the capability provided by this device, the aural test taker can perform the operations that should make aural test taking an attractive alternative for those with visual reading problems.

The two prototype devices now available perform the required functions. Though neither is entirely satisfactory, the experience gained in designing and evaluating them will guide the design of a device that should be adequate for the field evaluation of the utility of aural testing.

Aural Testing in the Public School

In an experiment for which materials are now being prepared, parallel forms of a group test of intelligence will be administered to children in the Louisville Public Schools. They will read one form visually, in the conventional way, and the other form by listening to recorded test questions. The results of this experiment, together with the results of related experiments already completed, will make possible the evaluation of reading by listening as an alternative to visual reading in gathering the kind of information provided by tests of scholastic aptitude and achievement.

The Role of Aural Reading in a Public School Program

Adequate functioning in the program of education offered by our public schools is predicated on the ability to read. In large measure, the child must obtain from printed reading matter the information he needs to succeed in the tasks set for him by teachers. If he cannot read well, his ability to gather this information is impaired, and his performance is adversely affected. We are becoming increasingly aware of a large number of children in public schools who, in spite of persistent efforts at remediation, never learn to read effectively. They do not perform well in school, and it is tempting to conclude that their poor performance and their poor reading ability are both consequences of limited intelligence. This may be a reasonable conclusion in some cases, but experiments performed in this laboratory and elsewhere raise the possibility that some of the children who read ineffectively can listen effectively, and have the ability to succeed in school tasks if they are not required to depend upon visual reading for information.

To explore this possibility, a project has been initiated in collaboration with the Jefferson County School system. Tests of reading and listening comprehension will be administered to all of the children who will be enrolled in the eighth grade at Valley Junior High School for the 1972-73 school year. These test scores will be examined in order to identify a group of children who can be described as poor readers but good listeners, and the children in this group will be given the opportunity to use tape recorded textbooks in some of their courses. Their performance will be compared with the performance of children in a control group, and with their own performance in courses in which tape recorded textbooks were not used.

The Jefferson County School system has provided a grant of $500.00 to be used in initiating this investigation. If initial results are favorable, more adequate funding will be sought from a state or federal source.

The Evaluation of the "Running Outline" as an Aid for Search and Retrieval

This project has been undertaken in collaboration with Mr. Maxwell Kerr of AEC/Veritas, who contributed the concept of the "running outline." He has developed a method of subjecting full text to a kind of scrutiny that permits the rapid identification of crucial words and phrases that form meaningful statements. When these statements are read in sequence, the result is an abstract which exactly parallels the full text, but which has been reduced in length to only one-eighth of the full text. He has shown that suitable abstracts of technical material can be produced, using his method, and that the method can be easily taught to people who are not trained in the area to which the material to be abstracted pertains.

Using the recording techniques employed in the preparation of the Talking Dictionary, an abstract of this sort can be recorded at a speed that will permit its playback in one-eighth of the time required for reproduction of the full recorded text. If the tape containing the abstract is reproduced at one-eighth of the recording speed, and if the resulting signal is mixed with the signal obtained from a full-text tape reproduced at the speed employed during recording, the resulting signal can be copied on the single track of a cassette to produce a display of the same type as that employed in the Talking Dictionary.

Rapid scanning is an important ability of the visual reader that is not shared by the aural reader. This ability permits him to gain a general impression of the contents of a book, and to locate or relocate sections of particular interest to him for more careful reading. When reviewing a book that has already been studied, the ability to scan rapidly permits him to spend his reviewing time efficiently. Using Kerr's method for producing a "running outline," and the recording format developed for use in the Talking Dictionary, the aural reader may be able to realize the advantage of rapid scanning enjoyed by the visual reader. Using a cassette with the appropriate recorded format, and a cassette player with the modifications required for its proper reproduction, the aural reader would start by listening to a recorded book at eight times normal speed. At this speed, he would hear the running abstract, which would be sufficient to give him a good idea of the contents of the book. When he encountered a section he wished to study more carefully, he would reduce his tape speed and listen to the full text.

Funding is now being sought for a project, the objective of which is to evaluate the usefulness to aural readers of recorded text that includes a "running outline." To realize this objective, it will be necessary to provide suitable modified cassette players, train people to prepare "running outlines," record suitable reading matter and prepare it for presentation in the proper format, and provide aural readers with experience in the use of reading matter prepared in this manner. When these tasks have been completed, it will become possible to determine the extent to which the availability of a "running outline" enables the aural reader to realize the advantages of rapid scanning.

The Development of an Aural Reading Instrument

In the last annual report, mention was made of a project in which a comparative analysis of aural reading and visual reading was conducted in order to identify the operations that account for the efficiency of visual reading and which are not ordinarily available to the aural reader. This analysis provided the basis for formulating the functional requirements of a satisfactory aural reading instrument. A written account of this work was made available to Mr. Maxwell Kerr, a design engineer with AEC/Veritas, who was engaged at that time in the development of a record reproducer that would be more suitable than reproducers currently used for the display of recorded oral reading. The prototype reproducer that has been developed at AEC/Veritas under the direction of Mr. Kerr satisfies most of the functional requirements called for in the formulation just mentioned. Consequently, a proposal is now being written for a project to be undertaken by this laboratory, in collaboration with AEC/Veritas, the objective of which is to construct and evaluate an aural reading system based upon record reproducers of the type developed by AEC/Veritas. This project will require the construction of equipment, the preparation of reading matter in suitable recorded form, the training of aural readers in the use of the equipment, and the comparative evaluation of the performance realized by the use of this equipment and by the use of conventional equipment.

The Development of a Print-to-Speech Transducer

In the last annual report, a project was described in which the ultimate objective is the development of a device that recognizes print letter shapes and transduces each recognized character to a unique sound. These sounds are constructed so that when they are reproduced in the same sequence as the printed characters to which they correspond, the result is recognizable speech.

Research in this laboratory has been concerned primarily with the development of a satisfactory speech alphabet. Many problems remain to be solved as far as the optical recognition of characters is concerned, but efforts directed toward the development of an optical character recognizer with sufficient accuracy that will be small enough and cheap enough for inclusion in a practical reading instrument are underway in other laboratories. It now seems likely that when a satisfactory output language has been developed a suitable optical character recognizer will also be available, and it will be technically feasible to construct a lightweight reading machine, no larger than an attache case, and inexpensive enough for individual ownership, the use of which can be mastered with relatively little training.

The PDP-9 computer in the Psychology Department is being used as the major research tool in our development of the output language. It has been equipped with analog-to-digital and digital-to-analog converters and the co-investigator, Mr. Glenn Smith, who is primarily responsible for the daily management of this project, has written programs that make it possible to digitize, store, sample, and reconstruct speech signals. With this software, the computer is used to isolate and shape the discriminable features of speech to arrange them in desired sequences and, by reproducing these sequences, to generate speech that is recorded on tape for subsequent evaluation by listeners.

The initial objective was to define a set of 26 discriminable features corresponding to the 26 letters in the print alphabet, that could serve as characters in a speech alphabet suitable for use in a reading instrument of the sort just described. However, small computers with time-sharing capability can now be purchased at a relatively low cost, and their availability warrants the consideration of a more sophisticated reading system in which a computer examines the output of an optical character recognizer and selects from a complete alphabet, containing all of the discriminable features of speech needed for a faithful rendering of the language, the characters required for the accurate reproduction of the words specified by the output of the optical character recognizer. In a reading system employing a computer for the immediate processing required for transduction from the printed page to accurate speech, the optical character recognizer operated by the reader would be connected to the computer by telephone, and the audible computer output would be transmitted to the reader by telephone. Because this system now seems feasible, the initial objective has been enlarged, and efforts are being directed toward the development of the expanded speech alphabet that would be utilized in a system with computer processing capability.

Progress on this project has been limited by the lack of funds. Since it has not been possible to provide a salary for Mr. Smith, the co-investigator, he has had to accept other jobs in order to make a living, and he has only been able to work on this project in the time that remains. However, Mr. Smith has been appointed as the first Director of Computer Services for the Blind, Inc., a project that will be described at a later point in this report, and the salary associated with this position should provide the security and time he needs for more aggressive development of the speech alphabet and of the reading systems in which it would be utilized.

ACQUIRING INFORMATION BY TOUCH

Investigation of the ability to gather information by touch is a major activity of the laboratory. Included in this category are experiments concerning man's perceptual capacity with respect to dot patterns of the sort represented in the braille code, experiments evaluating various schemes for expanding the braille code, experiments concerning factors that define the effectiveness of tactographic displays, and experiments concerning the haptic perception of form. Experiments in visual perception are also occasionally performed in order to produce data for comparative purposes. A major activity during this year has been the preparation of a progress report for the Office of Education, covering several years of experimentation on tactual perception. This report is nearly completed and will be ready for distribution shortly. Following are accounts of several experiments now in progress.

Identification Thresholds for Moving Braille Characters

In an effort to understand the perceptual basis for the reading of braille, Nolan and Kederis (*Perceptual Factors in Braille Word Recognition*, American Foundation for the Blind Research Series No. 20) have determined the threshold of identification for all the characters in the braille code. To do this, they employed an instrument called a tachistotactometer that controls the time during which dot patterns are exposed. Patterns of pins rise above the display surface of the instrument to the height of a braille dot, remain in position for a preset time during which they press against the fingertip of the subject under examination, and then recede below the display surface again. A psychophysical procedure is followed in determining the minimum time of exposure that is required for the identification of a dot pattern, and the time is regarded as the threshold of identification. The difficulty with this method of presentation is that it only minimally realizes an essential condition of cutaneous stimulation--a condition that is satisfactorily realized when braille is read in the conventional manner. The excitation of cutaneous receptors requires movement of the tissue in which they are embedded. When a subject is stimulated by the dot patterns displayed on a tachistotactometer, tissue is moved by the pins used to form patterns as they rise above the display surface, and as they recede below it again, but not while they are stationary during the time of exposure. On the other hand, when braille is read in the conventional manner, there is continuous movement of the cutaneous tissue in contact with the page as the fingertip passes over the dot patterns in the line of writing, and hence continuous excitation of cutaneous receptors. Thresholds of identification obtained under conditions of stimulation that more closely approximate the conditions of stimulation realized during the reading of braille may prove to be more useful in elaborating an account of the perceptual basis for braille reading than thresholds based upon the relatively static stimulation provided by the tachistotactometer.

In collaboration with John Kilpatrick, a graduate student who conducts research in the laboratory, an experiment is now in progress in which dot patterns are embossed on paper tape. By means of a special tape transport, designed and constructed in the laboratory for this purpose, the tape is made to pass from a supply reel across a display surface to a take-up reel. The subject under examination rests his fingertip on the moving tape, and is stimulated by the dot patterns embossed on the tape as they pass beneath his fingertips.

Tape speed is well regulated and can be varied continuously through a wide range. At the beginning of an examination, tape speed is too fast to permit the identification of any of the dot patterns under test. As the examination proceeds, tape speed is gradually reduced until all of the dot patterns have been identified. The speed at which a dot pattern is first identified is taken as the indication threshold.

When thresholds have been determined in this manner, the same procedure will be followed in determining thresholds of identification for whole words embossed on the moving tape. The data thus obtained will be examined for relationships between threshold for words and threshold for the letters of which those words are composed. The next step will be to determine the speed at which connected prose, embossed on the moving tape, can be read. The data thus obtained will permit a search for relationships between braille reading speed and threshold of identification for letters and words.

Finally, an effort will be made to increase reading rate by giving subjects practice in reading connected prose, presented on moving tape at a speed that is gradually increased as practice continues. According to a current hypothesis, there is a kind of dynamic patterning, involving whole words and phrases, that emerges when the movement between the fingertips of the reader and the line of braille writing occurs at a fast and constant rate. The ability to detect and interpret such patterns enables the reader to read braille at a rate that greatly exceeds the typical braille reading rate, and that compares favorably with the silent visual reading rate. If patterning of the sort required by the hypothesis is a reality, the ability to control the rate at which braille characters move across the fingertip or tips employed for reading, may make it possible to establish the conditions under which braille readers can learn to become aware of and to interpret this patterning.

Reading Rate and the Field of View

The typical silent visual reading rate is nearly three times the typical braille reading rate. A perceptual analysis of the two kinds of reading suggests that this difference is explained by the difference in the amount that can be observed at one time by the visual reader and by the braille reader. The limits of the braille reader's field of view are set by the surface area of the fingertip that is used for sensing braille characters. Because of the size of braille characters in relation to this area, little more than one character can be observed at a time. As a result, when the fingertips are moved across the page, words tend to be perceived a letter at a time, and the reader must spend some of his time in integrating serially perceived letters in order to achieve word percepts. On the other hand, as the visual reader acquires experience, he gradually learns to identify whole words and even phrases. He can do so because his field of view is much larger in relation to the size of characters in the print code, and he can observe many letters at one time.

In order to make the difference upon which this explanation depends more explicit, an experiment has been conducted to determine the number of letters that can be seen during an exposure that is too brief to permit a change of visual fixation. (Douglas Switzer was the experimenter here, and will report its results in his senior thesis.) By means of a tachistoscope, groups containing 3, 5, 7, 9, 11, and 13 letters, chosen at random, were exposed to view for 10 milliseconds. This interval allows enough time for the perception of letters, but there is not enough time for more than one fixation. Subjects were instructed to report all of the letters they saw.

Though the data of this experiment have been collected, the analysis is still in progress, and there are no results to report as yet. However, it is evident from inspection of the data that subjects were able to see and identify several letters at once and if these letters had been arranged in meaningful sequences to form words and phrases, it is a safe inference that the reduction in uncertainty would have permitted their identification as well. Though evaluation of the hypothesis under test must wait the analysis of results, the apparent outcome of the experiment is consistent with this hypothesis.

The Discrimination, Recognition, and Identification by Touch of Shapes that are Random in Three Dimensions

Several experiments have been conducted in this laboratory to explore the ability of subjects to discriminate, recognize, and identify random patterns of dots examined by touch. Although the dot patterns used in these experiments occupied three dimensions, they were varied in only two dimensions, since the height of dots was constant. It can be argued that test patterns of this sort do not permit a thorough exploration of the capacity for haptic perception, since the examination upon which their perception depends produces relatively little of the kinesthetic stimulation that informs haptic perception.

Mr. Richard Baird, a graduate student who conducts research in this laboratory, is currently planning a series of studies, to be reported in his doctoral dissertation, concerning the haptic capacity for perceiving shapes that vary in three dimensions. This series will include studies that permit a comparison of the haptic and visual perception of three-dimensional shapes.

A pilot study, already in progress, is being conducted for the purpose of evaluating and refining experimental materials and procedures. In this experiment, small, polished rocks are the stimulus shapes that vary randomly in three dimensions. These rocks have been painted a uniform color, thus eliminating color as a cue to their identification. A number will be assigned to each rock, and subjects will be taught to identify each rock by its number. One group of subjects will employ only touch in conducting the examination upon which the formation of the association between rocks and numbers depends. A second group will employ only vision and will handle the rocks with tweezers in order to exclude haptic perception. A third group will be allowed to employ both haptic and visual perception. The materials required for the conduct of this experiment have now been prepared, and the collection of data should commence shortly.

The Multisensory Test of Conceptual Ability

Because of the demand value of visual stimulation, there is a high probability that the infant who sees will attend to the visual stimulation in his external environment, and that he will learn to interpret visual stimulation in order to acquire information about his external environment. On the other hand, the stimulation that can be experienced by an infant without sight lacks the demand value of visual stimulation, and as a result, blind infants appear to show considerable variability in the extent to which they consult the stimulation available to them for the information about the external environment they need in order to interact appropriately with it. Many blind children appear to have acquired an adjustment that minimizes attention to external stimulation, and that maximizes attention to internal, self-produced stimulation.

Several years ago, this writer developed, in rudimentary form, a test that was intended to disclose the extent to which blind children would acquire the information contained in the stimulation available to them. This test consisted of a set of 14 blocks that were to be sorted into two groups of seven. Seven unique sorts were possible, depending upon the feature used for classification. They could be sorted in terms of texture (rough or smooth), height (tall or short), shape (round or square), surface detail (the presence or absence of a small indentation in the center of the top surface), color (using blocks of two colors provided partially sighted children with the opportunity to use color as a cue), weight (half of the blocks were conspicuously heavier than the other blocks), and sound (the blocks were hollow, and half of them contained a small bell that rattled when they were picked up).

This test was administered to a small group of blind children in the third grade at the Missouri School for the Blind, and results suggested that the test was eliciting the behavior from which the desired information could be inferred. A preliminary account of this test was published ("A Multisensory test of Conceptual Ability," *The New Outlook for the Blind*, March, 1964, pp. 75-7), but other commitments made it necessary to suspend work on this project before procedures for administering and scoring the test could be developed, and the project became dormant.

In the last two years, this writer has received an increasing number of requests for information about the test itself, and about its cost and availability. The blocks were made available to two graduate students, one at the University of California and one at Washington University in St. Louis, who used the test to gather data reported in their doctoral dissertations.

These expressions of interest have resulted in a decision to reactivate this project. Betty Herz, a volunteer worker in the laboratory, has constructed new blocks that are more satisfactory than earlier blocks in terms of expense of materials, ease of construction, uniformity, and durability. Having developed this prototype version of the test, she can now replicate it without difficulty, and it will soon be possible to provide copies of the test for use by other researchers. Further work in this laboratory on development of the test will proceed as soon as an interested student can be found.

An Improved Method for Constructing Tangible Displays

The investigation of factors affecting the ability to gather, by touch, graphic information displayed in tangible form on a two-dimensional surface has been an enduring interest in the laboratory. Techniques have been developed for producing such displays, and a vacuum-forming machine, by means of which "master displays" can be duplicated on plastic sheets, has been acquired. However, these techniques make heavy demands on patience, skill, and time, and they are limited with respect to the variety of symbols that can be displayed with ease.

John Gill, a researcher at Warwick University, Warwick, England, recently visited this laboratory and described a method he has developed for the construction of tactographic displays that appears to have many advantages over methods now in use. Original composition of the tangible display is done at a computer terminal that includes a visual display unit (VDU), an analog control of the joystick type, and a teletype machine. The information required for the specifications of symbols is stored in the computer. The symbols that may be specified include symbols for points, such as dots, filled and unfilled circles, filled and unfilled triangles, stars, x's, etc., symbols for lines, such as solid lines, dash lines, dotted lines, broad and narrow lines, etc., and symbols for area consisting of a variety of surface textures. The teletype keyboard is used to display these symbols on the face of the VDU, and the joystick is used to position them. Dot patterns corresponding to the dot patterns in the braille code can be added to the display by teletype commands, and positioned by the joystick. When a satisfactory graphic display has been composed in this manner, the information required to specify the composition of the graph is encoded on punched paper tape. This tape is used to control an automatic milling machine that engraves a negative of the graphic display in a sheet of plastic. From this negative, a rubber positive is made which serves as a master for use on a vacuum-forming machine. The end result is a plastic sheet on which the graphic features appear in tangible form.

The advantages of this system include the ease with which graphic displays can be composed, the inexhaustible supply of symbols for point, line, and area to which the composer has access, and the remarkably high quality of the final result. The use of a milling machine provides better control over the formation of tactographic features than has heretofore been possible, and the reduced variability among symbols of the same type permits a more reliable and more finely graded differentiation among symbols of different types.

The equipment required by this method is expensive, and if it were dedicated solely to the production of tactographic materials, the method would probably not be economical. However, the demands on computer capacity are modest, and any general-purpose computer with analog-to-digital conversion may be used. Most computer facilities already include teletype equipment, and many include VDU's. The joystick control device is simple and inexpensive. Automatic milling machines are expensive, but they make minimal demands on operator time, and it is frequently possible to arrange for the donation of their use for this purpose during off-hours. Furthermore, if mechanical engineering skills are available, a special-purpose automatic engraving machine can be constructed at a moderate cost.

John Gill provided several samples of graphs produced by his methods. These graphs have been shown to several experienced blind readers, who praised them for their exceptional quality, and declared them to be the best tactual graphs they had ever examined.

Plans are now underway to implement Gill's method at the University of Louisville. The computer in the Psychology Department, which already includes analog-to-digital conversion, will be used. The teletype machine is available, but it will be necessary to construct a joystick control device, and to acquire a VDU. Gill has agreed to provide all of the necessary software, and to provide a detailed description of all components in the system. A group of volunteer workers who prepare textbooks for use by blind students has expressed a strong interest in the method, and may be able to locate some financial support. John Dressman, a professor on the mechanical engineering faculty in the Speed Scientific School, has offered his assistance in locating an agency willing to donate the use of an automatic milling machine, and has agreed to participate in the implementation of the system. The laboratory already has the vacuum-forming equipment required for the final production step.

If the effort to implement this system is successful, the method it enables will be taught to volunteers who now use more primitive methods in preparing the raised line drawings used by blind college students, and they will be given access to the equipment in order to produce the graphic materials requested by students. By this means, it will be possible to generate a body of user experience that can be consulted for information concerning the relative effectiveness of the method. The system will also be used for demonstration purposes. A description of the system, and an account of our experience with it will be published in appropriate professional journals, and those interested in considering its implementation elsewhere will be invited to visit the laboratory in order to study its construction and operation.

THE PERCEPTUAL BASIS FOR MOBILITY

The perceptual basis for the skill that enables a blind pedestrian to reach his objective independently, safely, comfortably, and gracefully has been one of the laboratory's continuing concerns. For example, experiments have been conducted to evaluate the contributions of the physical characteristics of the cane employed by the blind pedestrian to its effectiveness as a tool for gathering information. The interest in developing techniques for the production of tangible maps is closely related to the interest in the perceptual basis for mobility, because tangible maps constitute a potentially important source of the information needed by the blind pedestrian for orientation and mobility. However, research activities in this area have not received funding as yet, and it has not been possible to sustain an organized program of research.

Recently, an effort was made to formulate a rudimentary theory to account for the mobility of the blind pedestrian. ("Perceptual Basis for Mobility," *American Foundation for the Blind Research Bulletin 23*, 1971, pp. 1-8.) This theory suggests the perceptual operations upon which the blind pedestrian depends in gathering the information he needs, and provides guidelines for a programmatic research effort. The funding required for the implementation for this program is now being sought.

The experiment conducted in this laboratory by Carol McSpadden for her senior thesis affords an example of the kind of research suggested by the theory. The purpose of this experiment was to explore the ability of blind children to acquire a construct of information concerning the relationships among objects in an organized space. To accomplish this, children of both sexes at the Kentucky School for the Blind, who varied in age, degree of visual impairment, and age at onset of blindness, examined a model containing an arrangement of doll furniture. Subsequently, they were shown a similar model without furniture, given a box containing pieces of furniture like those included in the first model, and asked to restore the arrangement of furniture they had previously observed. Their attempts at restoration were photographed, and these photographs were scored for accuracy. The results of the experiment suggested a deficit in the ability to acquire the construct of information needed for restoration that depended, to some extent, upon visual status and intelligence. Though an inadequacy of funding and other resources made it necessary to limit the scope of this study, it served as a useful pilot experiment. The experience gained has informed the planning of a more elaborate experiment to be conducted when resources permit.

OTHER PERCEPTUAL ALTERNATIVES

Though the three areas of listening, touch, and mobility have received major emphasis in the laboratory's research program, other perceptual alternatives have been given some attention. This attention has lead to the initiation of two projects--one completed, and one in progress.

An Attempt to Surmount the Barrier to Communication Imposed by Profound Motor Disability

Teresa is a student at the Cerebral Palsy School in Louisville. Those who work with her are convinced that she is intelligent and aware of the meaning of much that happens in her environment; but it is difficult to be sure of this, because although she can see and hear, her motor disability is so profound that communication is nearly impossible. She is confined to a wheelchair. She cannot speak. She cannot grasp with her hands, and her arm movements are gross and inaccurate.

After discussing her situation with Mary Georganne, the principal of the school, a decision was made to construct a device that might at least enable Teresa to make others aware of some of her needs. Accordingly, a device was constructed that permitted the selective backlighting of 64 transparencies, arranged in eight columns and eight rows. Selection of the transparency to be backlighted was accomplished by operating two switches. The operation of one switch caused the light to advance from column to column in the display, while the operation of the other switch caused the light to advance from row to row. Thus, by switch operations varying from a minimum of one to a maximum of 14, any transparency in the display could be backlighted. An effort was made to design the switches so that they would be compatible with Teresa's limited ability for movement. She could hit the handle of one switch with her left arm, and the handle of the other switch with her right arm.

By operating these switches, Teresa could backlight a picture that had some bearing on her current need. A picture of a glass of water might suggest to others that she was thirsty, a picture of a bed might suggest that she was sleepy, etc. In addition, it was hoped that the device might enable her to take steps leading to the ability to read, by giving her an improved understanding of the relationship between written words and the objects for which they stand. After she had learned to select a pictured object, the written word identifying that object might be added to the transparency, and later, she might discover that she could achieve the same communicative outcome by selecting a transparency that displayed the word only.

Initial experience with the device was quite encouraging. Teresa's smile suggested that she enjoyed using it, perhaps because it gave her the rare opportunity to exercise some control over her environment--to make something happen. However, some time passed before it was possible to make dependable arrangements for training with the device.

During this period, the device was described to June Bigge, a specialist in orthopedic handicaps in the Department of Special Education at San Francisco State College. She was quite impressed with the potential usefulness of the device, and offered to pay expenses if arrangements could be made for a person to bring the device to San Francisco

State College and demonstrate it in a workshop on educational technology for teachers of handicapped children. Ken Daniels, a graduate student in the Department of Psychology of the University of Louisville, agreed to perform this service. Upon his return, he reported that among all of the devices exhibited, this one was generally regarded as the one with the most exciting potential, which report was subsequently confirmed.

This experience prompted an effort to arrange for the small-scale production of the device, so that enough experience could be gained to permit a decision concerning its usefulness. Biotronics has expressed an interest in designing and constructing models suitable for field testing, but this work cannot proceed until money has been found to pay for design and construction.

Meanwhile, the device and its functions were discussed with John Birkimer, a member of the Psychology Department at the University of Louisville. He interested Carole Voll in working with Teresa, and in using the device to improve her ability to communicate. This work has been reported in a senior thesis. Her efforts were largely exploratory, and intended to define more carefully Teresa's readiness for new learning. Teresa continued to enjoy using the device, but efforts to employ it systematically as a teaching aid were frustrated by repeated component failures. Also, it became evident that more attention would have to be given to the design of switches that Teresa could operate dependably and quickly. Her arm movements were so poorly controlled that she frequently missed a switch, or hit the wrong switch. When she had made contact with the switch, she often found it difficult to retract her arm and release the switch. It had been hoped that the exercise afforded by the operation of switches, and the practice in executing the specific movements required to change the display from its present state to an intended state would result in an improvement of controlled arm movement. However, improvement of this sort was not apparent. It appears, in retrospect, that it would have been better to design switches that could be operated by head movements.

Teresa was entertained by the device, and this may have been a worthwhile outcome in its own right. It is doubtful that she learned much from its use, but the information resulting from her experience with it has led to the design of a more sophisticated prototype, and this second generation prototype will be constructed when funding is available.

The Need for Sex Education in Residential Schools for the Blind

In the course of growing up, the seeing child has many opportunities to learn about sexual differences. He continually observes differences in general body conformation, and most children have occasional glimpses of normally concealed body parts. Furthermore, anatomical differences are explicitly shown in pictures to which these children have easy access.

The blind child may have little opportunity to discover such differences. He can explore his own body, but he cannot see the bodies of others, and learning about them by touch is prohibited. Many blind children receive their education in residential schools operated by the states in which they live. In these schools, there has been a tendency to avoid the problems that might result from sexual misconduct by carefully supervised segregation. As a result, the child who spends much of his childhood in a residential school misses the opportunity to learn about sexual differences that is afforded by growing up in a family with brothers and sisters. Of course, the blind child becomes aware of the emphasis on sexuality in our culture, and the combination of curiosity and ignorance frequently leads to the formation of bizarre theories concerning sexual differences.

In recent years, there has been a growing conviction on the part of many educators that blind children, more than most, need adequate sex education. They argue that the blind child's lack of opportunity for the experience that informs his sighted peer, and the misconceptions resulting from this lack of experience, predispose him to sexual maladjustment in adult life. On the strength of this argument, attempts have been made to provide sex education in many residential schools, although no satisfactory way has yet been found to show the blind child what the sighted child can see.

Although a convincing case can be made for the desirability of sex education for blind children, its validity depends, for the most part, on anecdotal evidence. There has been none of the systematic observation that would permit an accurate description of the state of ignorance of blind children concerning sexual differences, and no search for the relationships between such ignorance and the consequences that presumably ensue.

Tom Uhde, a medical student at the University of Louisville, visited the laboratory recently in order to learn about its program of research, and to explore the possibility of participating in a research project involving blind children. Previous work at the School for the Blind had included some counseling of adolescent boys. During his conversations with these boys, he had occasionally encountered some curious deficits in sex knowledge. He discussed his findings with a member of the school faculty, who told him of the need for sex education at the school, and the school's interest in formulating a program of sex education. The curiosity aroused by his experience at the school, and the school's current interest in providing sex education seemed to provide a climate that would be congenial to the investigation of sex knowledge and attitudes in blind children. Accordingly, the following study has been planned.

Uhde will interview males and females ranging in age from prepubescence to young adulthood. During the interview, he will question them about sex anatomy and function, and will explore their attitudes concerning sexual behavior and its regulation. In conducting these interviews, he will follow an interview guide in order to ensure uniformity among those interviewed regarding topics to be explored. He is now preparing this interview guide in consultation with several members of the laboratory staff, and will review it with appropriate members of the school staff before the study is initiated. Interviews will be recorded on tape to facilitate subsequent evaluation. He will be particularly interested in observing misconceptions or false theories concerning sex anatomy and function. The frequency and degree of misconceptions will be examined in relation to such factors as age, sex, visual status, family background, school background, and so forth. If time permits, he will also survey the attitudes of the parents, house parents, and teachers of the students he has interviewed, concerning sex education.

SERVICES PROVIDED BY THE LABORATORY

The laboratory's principal business is the conduct of research. However, an effort has also been made to provide useful services to educators and researchers in its field of interest. These services have included the dissemination of information, the preparation of research materials, the development of equipment and facilities, and consultation with educators concerning the exploitation of perceptual alternatives.

Computer Services for the Blind, Inc.

A recent meeting of the advisory committee of the Sensory Aids Evaluation and Development Center at Massachusetts Institute of Technology, provided the opportunity to visit Kenneth Ingham, a member of the staff of M.I.T.'s Applied Electronics Laboratory. For the past several years, his efforts have been directed toward the development of the ARTS System, (Audio Response Time Sharing), a configuration of computing machinery that has been programmed to provide a variety of services needed by blind persons. These services are delivered by telephone. The input to the system is a typewriter keyboard, connected to the user's telephone. The output of the system is computer-produced speech heard over a loudspeaker, also connected to the user's telephone.

Services provided by the system include dictionary consultation; preparation of letters and other manuscripts; bookkeeping; the mathematical operation provided by a sophisticated electronic calculator; filing, storage, and dissemination of information; computer programming; translation from print to braille; computer-aided instruction; and so forth. This system is now ready for deployment, and Ingham's objective is the establishment of a network of ARTS Systems throughout the country. The ARTS System was described to T. V. Cranmer, Director of Services for the Blind, Bureau of Rehabilitation Services, Kentucky State Department of Education. With his enthusiastic support, an implementation committee was formed for the purpose of bringing the ARTS System to Kentucky. This writer prepared a proposal which was presented to the State of Kentucky. As a result of this proposal, a bill was drafted, and presented to the Kentucky legislature during its 1972 session. The bill, passed by both houses of the legislature and signed by the governor, provides for the establishment of a non-profit public corporation, to be known as Computer Services for the Blind, Inc. (CSB). The purpose of this corporation is to establish and operate the ARTS System for the benefit of blind citizens of Kentucky. The affairs of the corporation are supervised by a Board of Directors, with this writer serving as Chairman. It will begin the conduct of business on July 1, 1972. Governor Ford has provided approximately $171,000 to be used for the purchase of equipment and to pay operating expenses for the first two years. It is expected that, at the end of the second year of operation, the System will have become self-maintaining and will require no further financial assistance from the state. Glenn Smith, a member of the laboratory staff, has been offered the position of Director by the Board, and has accepted the offer. The University of Louisville has agreed to provide, without charge, the space needed to house the CSB staff and the ARTS facility. According to present plans, the installation of computing machinery will begin in September, and the delivery of ARTS services will be possible by January, 1973.

The Development of an Automatic Braille Embosser

The services provided by the ARTS System could be expanded with a braille page embosser that could be operated by a computer at teletype speed. Such an embosser would be welcomed by many blind computer programmers, who now must contend with a computer readout in braille of inferior quality that is produced by a modified printer, or depend upon human assistance. Those volunteers who transcribe material into braille for use by blind students might be able to increase their output substantially by abandoning their braillewriters and operating typewriters that produce punched paper tape as well as typed copy. These tapes, with the addition of some computer processing to cope with the lack of complete correspondence between print and braille, could operate a braille embosser and produce a properly composed braille transcript.

An embosser of the type required for these applications has been developed by the Sensory Aids Evaluation and Development Center at M.I.T., but at a cost of $5,000 per unit, many of its potential beneficiaries must seek other solutions or continue current practices.

The laboratory is collaborating with Biotronics in the development of a braille embosser with the required specifications that can be sold for less than $1,000 and perhaps for as little as $500. A braille embosser in this price range would be cheap enough so that many ARTS users could afford one as a part of their terminal equipment.

The most difficult part of this undertaking, the development of a satisfactory embossing mechanism, is nearly completed. Design of the mechanisms for transporting the embossing head, line indexing of paper, and so forth, poses no engineering problems, and a prototype embosser should be ready for testing within the next few months.

The Center for Rate-Controlled Recordings

The Center for Rate-Controlled Recordings has been a unit of the laboratory since it was founded. The Center for Rate-Controlled Recordings was established to provide a source for time-compressed or expanded speech of high quality at a moderate cost for use in research and education, and to disseminate information concerning time-compressed and expanded speech. During the past year, the Center has met the continuing demand for time-compressed and expanded recordings, and has continued its monthly publication of the *CRCR Newsletter*. Further requests for information have been met through correspondence, telephone conversations, and consulting visits.

The most serious impediment to the useful application of time-compressed and expanded speech has been the lack of suitable compressing equipment at a moderate price. However, efforts to develop moderately priced speech compressors have been underway at many locations. Two new compressors have become commercially available during the past year, and three or four others are on the threshold of commercial availability. Because of the prominent role played by the laboratory in the development of time-compressed and expanded speech, four of the developers of new speech compressors have offered to donate compressors to the laboratory. One compressor, the Varispeech I manufactured by Lexicon and sold for approximately $1,500 has already been received. The Varicom I, manufactured by PKM and sold for approximately $900 is expected shortly. The Cambridge Research and Development Group has developed two integrated circuit chips that incorporate the electronic functions required for speech compression, and is now installing these chips in a cassette recorder supplied by the Center. Compressed Time, Inc. has developed an electromechanical speech compressor with good signal quality that can be made available at moderate price with volume production, and the Center expects to receive one of these compressors as soon as production is underway. Finally, the Center can now provide time-compressed or expanded speech that has been generated by computer processing. The Center is rapidly becoming a compressor museum, and a further expansion of its role in the dissemination of information is to be expected.

Audio-Tutorial Instruction

In audio-tutorial instruction, the objective is to make available to groups of students the advantages ordinarily associated with individual tutoring. This is accomplished by recording on cassette the information that would otherwise be presented during a lecture to a group of students. Careful attention is given to the organization of content, and each cassette is accompanied with a set of written behavioral objectives specifying the behavior on the part of the students that will constitute satisfactory evidence of mastery. Mastery of each unit is required before the student is allowed to proceed to the next unit. Each student progresses through the course at his own rate, and every student who completes the course is assured of a passing grade.

Because of the laboratory's recording facilities, it is ideally suited for the preparation of audio-tutorial instruction that meets professional recording standards. This writer has taken advantage of these facilities in preparing the materials required for the audio-tutorial presentation of the Introductory Course in Psychology at the University of Louisville.

A typical class of blind school children is characterized by extraordinary diversity in readiness for the course of instruction. They show unusual variability in intelligence, prerequisite learning, severity of handicapping conditions, and so forth. As a result, no single instructional experience arranged by a teacher can be expected to be effective for more than a few class members, and the individualization of instruction becomes a necessity. Audio-tutorial instruction offers an attractive solution to this problem, particularly since blind school children have already had considerable experience in reading by listening.

At a recent meeting of the faculty of the Kentucky School for the Blind, this writer described audio-tutorial instruction, discussed its suitability as a method of instruction for blind school children, and offered the assistance of the laboratory in training teachers at Kentucky School for the Blind to prepare and use audio-tutorial materials. There was considerable interest in the possibilities offered by audio-tutorial instruction, and several teachers expressed an intention to avail themselves, during the summer months, of the assistance offered by the laboratory. If this interest leads to action, the next step may be an application for funding to support a collaborative project, involving the laboratory and the Kentucky School for the Blind, to develop the facilities and training needed to incorporate audio-tutorial teaching as a regular component of the school's program of instruction.

As a result of this background in the preparation and use of listening materials, and his interest in audio-tutorial instruction, this writer has been asked to address the Biennial Convention of the Association of Educators of the Visually Handicapped on June 29, 1972, concerning the role of audio-tutorial instruction in the education of blind children. He has also been elected to membership on the Board of the Audio-Tutorial Congress, an international organization serving the interests of those concerned with audio-tutorial instruction.

Consultation

The director of the laboratory is a regular consultant to the research department of the American Foundation for the Blind, concerning psychology, education, and technology, as they relate to blindness. In addition, during the past year, he served as a consultant to the Colorado State Department of Education, the California State Department of Education, and the San Diego School System regarding the preparation and use of time-compressed recordings in educational settings.

The White House Conference Committees

In preparation for the recently concluded White House Conference on Children and Youth, the governor of Kentucky created an action committee and charged it with the responsibility of preparing Kentucky's input to the White House Conference. This writer served as a member of the sub-committee that prepared a report on visually impaired children and youth for this committee. Upon the conclusion of the White House Conference Committee, the members of the sub-committee on visual impairment decided to continue meeting for the purpose of seeking ways to implement the recommendations of the sub-committee. This group, which has come to be known informally as the White House Conference Committee, has met on a monthly basis during the past year. In March, Carol Halliday, the committee's first chairman, resigned, and this writer has served as chairman of the committee since that time.

A METHOD FOR THE PRODUCTION OF TACTUAL MAPS AND DIAGRAMS

J. M. Gill*

Using computer-aided design principles, a system is being developed in the United Kingdom for the production of tactual maps and diagrams for the blind and visually impaired.

The production system composed of the following steps:

1. Input of graphical information from a coordinate table
2. Editing and insertion of text on a visual display unit
3. Negative master produced on an engraving machine
4. Positive copy made using silicone rubber
5. Plastic copies reproduced on a vacuum forming machine.

The map or diagram to be copied is considered as an annotated line drawing. This information can be input from the coordinate table, with the resulting picture simultaneously displayed on a visual display unit.

Editing on the visual display unit permits the insertion or deletion of individual lines, movement of end points of lines, and change of scale. A wide variety of line types (continuous, dotted, dashed, etc.) can be specified from the keyboard. The operator also has control of the height of the lines on the final copies.

A joystick can be used to position standard symbols. Alphanumeric text can be input from the keyboard; the text is automatically converted to grade 1 braille, with a choice of four different cell sizes.

When a satisfactory display is obtained output is requested. This can include output on a digital plotter for future reference, and also magnetic tape or punched paper tape. A map can be stored on a tape and then quickly modified at a later date.

The negative master in laminated plastic, such as Tufnol, is produced on an engraving machine which is either controlled directly from the computer used in the design stages, or from a smaller computer with the data on punched paper tape. A positive copy is produced using silicone rubber; copies, in a plastic called Brailon, are produced on a vacuum forming machine.

At present the system does not include textures, but these can be incorporated when a set of tactually discriminable textures has been identified. No allowance has been made for the partially-sighted reader; the simplest solution is to use black paint to emphasize the outline on the plastic copy.

The main drawback to the system is that it requires an operator with knowledge of what is tactually meaningful to blind people with varying experience of tactile graphics.

The system is still in an early stage of development, hence it is

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*Inter-University Institute of Engineering Control,
University of Warwick, England.

only being used for producing maps and diagrams for research purposes. This work is being carried out jointly with the Blind Mobility Research Unit, (Nottingham) and the Research Center for the Education of the Visually Handicapped, (Birmingham). Current work is concentrated on identifying a set of tactually discriminable line, area, and point symbols.

AUDIO TRANSDUCERS*

Robert W. Gunderson**

Audio transducers find wide application in industry as vibration sources for checking mechanical stresses in aircraft components, electronic circuit elements, etc. They provide various amounts of thrusts, depending upon the load which they are required to "shake." I have not had a great deal of experience with these devices, as to their various sizes, applications, etc., however, I have recently found it necessary to investigate these devices for a different application which I shall describe in this article. First, let us talk about the audio transducers available under the trade name "Electrophonics."

These devices appeared some years ago under the name "Rolen Star," and provided the means for making the walls, ceiling, or the floor of a room act as a sound source or a loudspeaker. The unit is made as a large permanent magnet, provided with a gap which allows the standard voice coil configuration to move back and forth, similar to the conventional permanent magnet speaker. In other words, the assembly is made in the form of a circular magnet, with a cylindrical pole piece at the center. The gap, formed between the outer edges of the center pole stem and the inner edges of the outer yoke assembly, is small, just large enough to allow a voice coil (supported on an insulated bobbin) to move. This voice coil is supported on a plastic cover which has sufficient flexure to provide slight movement of the voice coil in and out of the gap with the application of audio currents. The center of this plastic cover is fitted with a mounting tapped for a 10-24 screw, enabling the unit to be suspended from the underside of the surface to be excited by the transducer. When the current flows through the voice coil in one direction, the field around the winding attracts the magnet, pulling it up toward the under side of the surface to which it is fastened. On the next half cycle of the signal current, the magnet is repelled, causing it to fall, setting the surface in motion and producing the sound output. It is an extremely simple device and its frequency response is quite good, considering the work it does in exciting the floor's members.

The impedance of these units is 8 ohms, and according to the specifications, it will handle up to about 20 watts. Units may be connected in series, providing an input impedance to the transducer bank equal to the sum of the individual impedance, or equal to the impedance of one unit multiplied by the number of units in the series string. On the other hand, they may be connected in parallel, with a resulting impedance equal to the value of one transducer divided by the number of units in the parallel array. It should be obvious, therefore, that series-parallel connections may also be employed, just as you would connect individual moving coil speakers in a distribution system.

Richard Joy, WA2NCX WB6YUB, our deaf-blind ham at the New York Institute for the Education of the

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New York, New York.

Blind, tried to use one of these transducers as a vibrator for copying code. However, Rick preferred his home-grown transducer, fashioned from a discarded p.m. speaker. We next mounted a transducer in the seat of a wooden chair, with the thought that code might be received in a rather different (unconventional) manner, leaving Joy's hands free to operate his equipment. Here again, Joy decided that his brain (as far as copying code is concerned) is in his hands rather than in other parts of the anatomy--the transducer as the receiving element was abandoned. Whether the transducer is superior to the home-built vibrator, or whether his hands are more sensitive than other extremities of his body, is difficult to predict. Once a person is trained in the use of specific apparatus, it is often difficult to switch him to another method. We didn't stop with the idea of using the transducers.

Teaching deaf-blind children requires patience and understanding on the part of the instructors in this field. They are in search of new and improved methods which will make teaching easier, and methods which will make it possible for the deaf-blind student to receive information more readily. Introducing the wonderful world of sound to a person who is hard of hearing is often difficult. Many children resist the idea of wearing earphones so that they might be able to hear. This is a subject in itself and beyond the scope of this paper. However, in an attempt to reach some of our children, we decided that perhaps they might become receptive to sound if they could feel vibrations through their hands, their feet, their spinal column, etc. Accordingly, I set to work and constructed a chair, with transducers mounted in the seat, the wooden back, and one transducer in each of the arms. Switches are provided for disabling any of the transducers so that the various portions of the chair can be excited from the output of an audio amplifier fed from a tuner, a tape recorder, a microphone, etc. Finally, I mounted the chair on a platform, supported on just two of its long edges by heavy timbers to keep it off the floor. This platform or landing was also equipped with a transducer, so that the entire assembly could be excited.

Upon placing some of our more difficult children in the chair, we found that we had reached them--they simply refused to leave it. Further these children now wear earphones and they have become intensely interested in what little sound information they can receive through the system. At present, I am installing earphones in parallel with the vibrating chair elements, enabling the student to wear them to receive the same sounds he receives through other than auditory means. Of course, the earphones will be equipped with attenuators so that they can adjust the level in each ear, apart from the level fed to the vibrating chair.

The chair is driven by a 30-watt amplifier, and the five transducers are connected to a double-pole double-throw switch, fitted with an 8-ohm resistor; one switch-resistor combination for each transducer. Thus, when the switch for a particular transducer is thrown to its "off" position, the transducer is removed from the circuit, although an equivalent 8 ohms is connected in its place. In the circuit arrangement used at present, two transducers are connected in series to give an impedance of 16 ohms. The first pair is then shunted by two more units similarly connected, to yield 8 ohms. This, in turn, is shunted by the remaining 8-ohm unit, and the entire assembly is driven from the 4-ohm output tap on the driving amplifier.

We now have three vibrating chairs, and they have become extremely popular with the deaf-blind boys and girls at the Institute. Recently, the Director asked me to do a paper, describing the project, and asked if I might have some idea as to what we might call these chairs. I suggested "An Asset to Music."

The Rhythm Room is an entire room to be used for teaching various types of auditory stimulation techniques to our deaf-blind students. The floor of this room is fitted with a number of transducers, placed at various locations on the under side of the floor, and excited by means of a high-powered amplifier. Let me tell you something about the design problems encountered with the rhythm floor.

The vibrating portion of the floor measures 10 by 12 feet, and the floor is made of 3/4-inch plywood. It is suspended at its edges, and also by means of a single center-support beam. The original thought was to make the floor of 1/2-inch plywood, but this proved to be too "bouncy" and a change was made to the heavier material. The first experimental platform of 1/2-inch plywood measured 4 by 8 feet and was suspended on an outer supporting frame on which a single transducer in the exact center of the board was mounted and fed audio-frequency power. I decided that I would see how much power would be required to have the student feel vibrations over the entire surface, and decided that the level should not change more than 6 dB (one-fourth the power level at the center) at any point on the floor's surface. The area of this experimental piece of wood is 32 square feet, and four transducers covered this area very well. When it was decided to use heavier wood it was found that the ability of the transducer to "shake" this heavier stock was not as great. It takes about twice as many units for the same amplitude of vibration--one transducer for every 5 square feet.

The vibration levels were checked, using a capacitor microphone and the Hewlett-Packard 400C AC VTVM. I chose 200 cycles as the driving frequency. We are more interested in the low frequencies, inasmuch as these are the tones which provide the timbre or beat (rhythm) which we feel will be of value to the students. The output level appears to fall off rapidly, decreasing at about the square of the frequency. Thus, doubling the frequency yields an output having an amplitude of one-fourth that at 200 cycles. However, by properly equalizing the amplifier, we can obtain a reasonably good characteristic at the output of the floor.

There are 24 transducers on the total floor area of 120 square feet, inasmuch as our complete floor measures 10 by 12 feet. The remainder of the floor area surrounding the suspended portion, supports teaching aids such as a player piano, used as a sound source. This solid portion of the floor is carpeted, while the center portion is stained and varnished. Thus, the student will know when he has moved away from the vibrating portion of the floor. The 24 transducers are all connected in series and then connected to the 200-ohm output on a 100-watt audio amplifier employing a pair of 811A's in class B. Two additional transducers are mounted at the center of each floor section, and these are connected in series to provide an inverse-feedback signal to the input of the amplifier. Further, the voltage developed by shaking these two additional units is used to operate a volume-level meter mounted on the wall of the classroom so that the teacher will have some idea of the level being fed to the vibrating floor.

The rack containing the amplifier and its power supply also holds a tape recorder used to feed different types of program material to the input of the system. In addition, we also have an old General Radio Audio generator. This unit goes up to only 5 kilocycles, and it was incorporated into the design with the thought that it might be useful for teaching hard-of-hearing children the difference between low- and high-frequency sounds. The player piano is fitted with two guitar pickup-type microphones fed to the input of the amplifier for direct pickup from the piano without the need for the tape machine.

When walking into the room, with floor vibrating in accordance with some type of program material, you find that the level is quite high, and it might be well for teacher to wear headphones or some other type of earplug devices to keep the level bearable. The reproduction is quite good, far better than it ought to be considering the large mass of wood being moved by the transducers.

In setting up the floor, I found that it was necessary to get all the series-connected transducers operating in phase. In other words, all magnets must rise and fall together. If they do not, unwanted cancellations occur within the floor structure. It was accomplished by driving the two extra shakers with the amplifiers and connecting all the others in a series-aiding configuration, as evidenced by the fact that the voltages produced by these units when used as generators (shaken by the driving sources) were satisfactory when connected in a proper series configuration. In an attempt to make certain that all transducers were connected in a proper series-aiding arrangement, the leads from the terminal board in the closet which houses the driving equipment, are coded, with different colored wire pairs taken to each transducer. The beginning of the transducer winding was taken as the left side, with the terminal lugs facing up and the mounting stud away from the technician. However, in practice, this did not always work out, and it became necessary to phase the units individually. This might be due to the fact that the magnets were not alike as to their polarity, or the fact that the windings were not always connected to the same lugs--the top might be taken to the left side in one unit and to the right side in the next--we did not open them to find out.

In operating the individual transducers as motors, with the remaining 24 connected as generators, one has to be careful not to burn out an individual unit if more than 20 watts of power is applied. With 24 units connected to a 100-/150-watt amplifier, it appears to be quite unlikely that the units will burn out.

I personally enjoy listening to the sound emanating from the floor, and enjoy it even more if I am standing on the vibrating wood surface. It may well be that one could learn to appreciate high-fidelity sound coming directly from a speaker system along with low-frequency signals transmitted to the feet or seat by conduction of the type described. Plans are being made to install a high-quality speaker system in the same room with the vibrating floor.

EDITOR'S NOTE

We have been fortunate indeed to have secured the permission of the compilers to reproduce this register of research undertakings related to blindness and severe visual impairment for the United Kingdom, compiled by M. J. Tobin, Director of the Research Centre for the Education of the Visually Handicapped, University of Birmingham. We are publishing it in the hope that other countries will consider generating similar registers; and we are considering the possibilities of doing so for the U.S. To be maximally useful, such registers will have to be revised periodically. We solicit your comments and your suggestions about how the community of researchers might best compile an international listing such as that for the U.K.--a listing which has been called for often, and for which a genuine need exists. Though a register is not a substitute for an ongoing effort at "current awareness" in research, it *does* help to meet the need to know what others are doing.

RESEARCH REGISTER*

Relating to the Needs of the Blind and the Partially Sighted

College, University, or Institution	Investigator	Brief Description or Title of Research or Development Project
The University of Aston in Birmingham, Department of Applied Psychology, Birmingham, B4 7ET.	G. W. Ferries, M.A., Lecturer.	Non-verbal communication in relations between sighted and visually-handicapped people.
The University of Birmingham, Research Centre for the Education of the Visually Handicapped, 50 Wellington Road, Edgbaston, Birmingham B15 2EP	M. J. Tobin, Director and Theodore Tylor, Lecturer. S. O. Myers. Mrs. N. Norris. W. R. K. James.	Programmed learning braille project. Vocabulary of the young blind school child. Aims and methods of teaching English to the visually-handicapped child. Science teaching for blind and partially-sighted children of average and below-average ability. Evaluation of the Optacon (OPtical to TActile CONverter) Investigation of former pupils of Condover Hall School for Multi-Handicapped

*Users are asked to report errors, modifications, and additions to: Research Centre for the Education of the Visually Handicapped, 50 Wellington Road, Edgbaston, Birmingham, B15 2EP, England.

College, University, or Institution	Investigator	Brief Description or Title of Research or Development Project
		Blind Adolescents. Observational and other studies of multihandicapped blind children in hospital setting. Cognitive growth in the visually-handicapped child. Visual stimulation for registered blind and partially-sighted children. Evaluation of teaching aids for blind children.
Bristol Eye Hospital.	C. A. Brown, M.D., F.R.C.P., Consultant Ophthalmologist.	Retrolental fibroplasia--early development and late follow-ups.
Brunel University, Department of Production Technol., Kingston Lane, Uxbridge, Middlesex.	J. A. Scott, C. Eng. M. I. Mech. E., M.I.W.S.P., M. Tech: (Research) Candidate.	Investigations into the tactile and kinaesthetic aptitudes of the blind (with the objective of job enlargement).
City of Birmingham College of Education, Westbourne Road, Birmingham 15.	W. R. K. James, Lecturer in Education.	Systems of illustration for visually handicapped.
The City University, Department of Ophthalmic Optics and Visual Science, Cranwood Street, London, E.C. 3.	C. H. Bedwell, F.B.O.A. (hons.) H.D., F.S.M.C., D.C.L.P., D. Orth. Con. Lens. Lecturer in Ophthalmic Clinical Practice.	Research into the visual aspects of reading disability.
J. W. D. Cook, 29 Willow Vale, Fetcham, Leatherhead, Surrey.		Developmental study of visual illusions.
Royal Infirmary, Eye Pavilion, Edinburgh.	C. R. S. Jackson, MA., BM., B.Ch (Oxon.), D.O.M.S., F.R.C.S. (Ed.), Ophthalmic Surgeon.	Partial sightedness. An investigation into its incidence and causes: its social, occupational and educational implications.
	H. J. McPherson, O.B.E., M.B., Ch.B., D.O., Medical Assistant.	Application of visual aids for the visually handicapped.
	Eleanor B. Petrie, B.Sc.(Ed.), M.B., Ch.B., D.P.H., Clinical Assistant.	Associated with above two investigations.

College, University, or Institution	Investigator	Brief Description or Title of Research or Development Project
The University of Essex, Dept. of Electrical Engineering, Colchester, Essex.	R. Aish, M.Des. M. Phil. in Man-Machine Studies. J. H. Edwards, B.Sc., Ph.D. Student.	Design of simplified keyboards for use in testing and training disabled people. Development of an automated electronic visual-field plotter which may be linked to a time-sharing computer.
Guys Hospital, Ophthalmic Department, London, S.E. 1.	P. A. Gardiner, M.D., Research Fellow in Ophthalmology. W. P. Mayles, B.A., M.Sc., Research Physicist. W. L. Mulholland, D.B.O., Research Orthoptist.	Visually-evoked responses applied to visual acuity and field defects.
Hallamshire Hospital, Sheffield.	A. Stanworth, Consultant Ophthalmic Surgeon.	Effect of visual handicaps on the performance of children with other handicaps such as cerebral palsy, and particularly whether correction of visual defects, especially squint, but also refractive errors, produces any beneficial effect.
Hampstead Child Therapy Clinic, 21 Maresfield Gardens, Hampstead, London N.W. 3.	Dorothy Burlingham, Chairman: Study Group on Blind Children.	Regular observation of blind infants in their homes. Day nursery school for older blind children. (Psychoanalytically oriented study of blind children's early development, started 1957.)
Hatfield Polytechnic, Advisory Unit for Computer Based Education, P.O. Box 109, Hatfield, Herts.	W. Tagg, Ph.D.	Development of an on-line computer terminal with braille output.
The University of Keele, Department of Communication, Staffs. ST5 5BG.	D. M. MacKay, Professor of Communication. Mr. G. F. Pick, Junior Research Fellow. Dr. J. P. Wilson, Senior Research Fellow.	Ultrasonic aids for the detection of hazards. Development of an audible obstacle detection device. Obstacle detection by auditory clues: basic work in auditory perception.

College, University or Institution	Investigator	Brief Description or Title of Research or Development Project
Lea Hospital, Stourbridge Road, Bromsgrove, Worcs.	C. Williams, M.Sc., Research Psychologist.	Experimental study of the function of mannerisms in the deaf-blind rubella child.
Liverpool Polytechnic, Faculty of Engineering, Byron Street, Liverpool.	J. Schofield, Senior Lecturer.	Reading aids for spina-bifida children with tunnel vision.
The University of Liverpool, School of Education, Liverpool.	D. J. Thomas, Head of Sub., Dept. of Special Education.	A reading test for visually-handicapped pupils.
London School of Economics, Houghton Street, London, W.C. 2.	J. F. H. Hilbourne, Lecturer in Sociology.	Social factors in delayed presentation for serious and progressive eye conditions.
The University of London: Bedford College Annexe, Peto Place, Marylebone Road, N.W.1.	Margaret Voysey, B.Sc.(Econ.), Research Sociologist.	Sociological aspects of diabetic retinopathy.
Queen Mary College, Mile End Road, E.L.	E. Booth, C. Eng., M.I. Mech. E., Manager: Design Projects Mechl. Dept.	Devices for aiding handicapped people, e.g. compact liquid-level sensor, flame sensor, scales for easy weighing of kitchen requirements.
University College Hospital, Medical School, University Street, W.C.1.	H. Heath, D.Sc., Ph.D., F.R.I.C., Senior Lecturer in Biochemical Pathology.	Research into the cause and prevention of diabetic retinopathy.
The University of Loughborough, Institute for Consumer Ergonomics, Leics.	R. J. Feeney, Assistant Director.	Experimental evaluation of technical aids in industrial inspection tasks for the blind.
Loughborough College of Education, Martin Hall, Loughborough, Leicester LE11 3TN.	J. F. Leedham, M.Ed., Ph.D., Principal Research Lecturer, Educational Technology.	High-intensity illumination of script using closed circuit television.
The University of Manchester, Department of Psychology, Manchester.	B. Hampshire, B.Sc.	Informational studies of braille coding, instruction, and acquisition.
	T. G. Whiston, M.Sc.	Design and production of automatic braille writing apparatus.

College, University, or Institution	Investigator	Brief Description or Title of Research or Development Project
Medical Research Council, Developmental Psychology Unit, Drayton House, Gordon Street, London, W.C.1.	B. Hermelin, Ph.D., Research Psychologist.	Left- and right-handed reading of braille.
	N. O'Connor, Ph.D.	Information processing in blind children.
The University of Nottingham: Blind Mobility Research Unit, Department of Psychology, Nottingham NG7 2RD.	J. D. Armstrong, B.Sc., Ph.D., Research Fellow.	Development of evaluation techniques for mobility aids. Evaluation of displays for a simple clear-path mobility aid.
	G. Delafield, B.A., Research Student.	Investigation of personality and social factors affected by guide dog training.
	D. J. Gaseley, B.Sc., Research Student.	Mobility problems of the deaf-blind.
	A. D. Hayes, Ph.D., B.Sc., M.Inst.P., Research Fellow.	Design of electronic guidance systems. Electro-tactile stimulations. Hearing aids for deaf-blind.
	G. James, B.Ed., Research Student.	Evaluation of computer produced tactile maps and diagrams.
Child Development Research Unit, Department of Psychology, Nottingham NG7 2RD.	Joan A. Head, M.A., Research Officer.	The use of toys and play materials in the amelioration of handicap (including visually-handicapped children).
	Kay Mogford, B.Sc., Research Officer.	Associated with above investigation.
	Cathy Urwin, B.Sc., M.A. Course.	Project in learning of an aiming task, using tactile feedback, and exploratory work on localization of sound in the blind child.
Department of Electrical and Electronic Engineering, Nottingham, NG 7 2RD.	R. L. Beurle, B.Sc., Ph.D., Professor in Electronic Engineering.	Investigation of the possibilities of pulsed stereophonic-ultrasonic environmental sensors.
	A. J. Crawford, B.Sc., Ph.D., Postdoctoral Research Fellow.	
	J. R. Rudlin, B.Sc., Ph.D. Student.	
School of Education, Nottingham, NG7 2RD.	D. M. Deakin, M.Phil. Student.	Blindness in children: the effect of impoverished opportunities for reading.

College, University, or Institution	Investigator	Brief Description or Title of Research or Development Project
Nuffield Laboratory of Ophthalmology, Walton Street, Oxford, OX2 6AW.	L. R. Croft, Ph.D., Research Officer. J. J. Harding, Ph.D., Departmental Research Assistant. R. van Heyningen, M.A., D. Phil., Senior Research Officer. A. Pirie, M.A., Ph.D., Margaret Ogilvie's Reader in Ophthalmology.	Study of the lens in relation to cataract formation.
Institute of Psychiatry, M.R.C. Neurological Prostheses Unit, De Crespieny Park, London S.E.5.	G. S. Brindley, Hon. Director. P. E. K. Donaldson, M.A., M.I.E.E.	Development of an implantable visual prosthesis. Visual Prosthesis.
Royal College of Surgeons, Lincoln's Inn Field, London.	Professor D. W. Hill.	Vascular causes of eye disease.
Royal Eye Hospital, St. George's Circus, London, S.E.5.	A. I. Friedmann.	Genetic causes of disease. Instrumentation and applications of methods of examination of the visual fields to a variety of diseases.
St. Thomas' Hospital, London, S.E. 1.	M. D. Sanders, Consultant Ophthalmologist.	Study of septo-optic dysplasia. Congenital blindness with neurological malformations.
The University of Sheffield, Institute of Education, Sheffield.	Edith M. Richardson, Lecturer in Educational Psychology.	The development of spatial concepts in blind children. At present working on: animistic thought in blind, deaf, sighted children.
The University of Stirling: Department of Psychology.	Helen E. Ross, Ph.D., Lecturer.	Orientation of divers in low-visibility water.
Department of Sociology.	B. M. Valencia, Ph.D., Lecturer.	Self-organized groups of the handicapped. A study of welfare organizations set up by handicapped people.

College, University, or Institution	Investigator	Brief Description or Title of Research or Development Project
The University of Sussex, Laboratory of Experimental Psychology, Falmer, Brighton, Sussex.	A. M. Uttley, B.Sc., Ph.D., Research Professor.	Auditory reading aids for the blind (supported by St. Dunstan's).
	M. Clowes, B.Sc., Ph.D., Senior Research Fellow.	Study of visual perception and intelligence using artificial intelligence techniques.
M. T. Swanston, 2 Derwent Close, Cove, Farnborough, Hunts.	-	Psychophysics of visual search.
The University of Warwick, Department of Engineering Science, Coventry, CV4 7AL.	P. W. Davall, B.Sc., Ph.D. Student.	Increasing the information rate of talking books by time slicing of individual phonemes.
	J. M. Gill, M.Sc., Ph.D. Student.	Computer production of tactile maps and diagrams.

CALL FOR PAPERS

Dr. Chittranjan N. Daftuar, Editor of the journal *Behaviorometric*, P. O. Gaya R. S., Maharani Road, Gaya (Bihar), India, informs us that he is planning a special issue of the journal for December 1973 on the general theme of "Problems of Human Factors Engineering." According to Dr. Daftuar, the ". . . special issue intends to be as broad-based as possible. We wish to include such papers as would highlight the broad spectrum of human factors within a single cover. . . you can imagine the special issue of this journal turning in(to) a textbook, giving a feel for all possible areas of the field. There is no specific point of focus. Both empirical and philosophical papers will be welcomed."

Papers which arrive too late for inclusion in the special issue will be published in subsequent issues of the journal.

Dr. Daftuar would be happy to answer questions concerning the suitability of a particular paper for his journal's special issue.

THE NATIONAL RESEARCH INSTITUTE OF SPECIAL EDUCATION*

Raison d'être of the Institute

In Japan, special education has recently undergone considerable development in terms of the number of special schools and special classes. However, there are still many problems to investigate--such as curricula and teaching methods for various specific handicaps.

There is also a growing need for special education for the severely and/or multiply handicapped, the emotionally handicapped, the speech handicapped, and others to whom insufficient consideration has been given.

In response to such needs, the Ministry of Education has established an independent research institute to fulfill a triple function:

1. Applied research in the whole field of special education integrating the knowledge and techniques of medicine, psychology, education, and technology.

2. Collecting research information and providing it to universities, colleges, and relevant research institutes.

3. Conducting regular systematic inservice training for teachers of special education.

Following preparations since 1967, the Institute was founded in October, 1971 as one of the institutes directly governed by the Ministry of Education.

Activities

1. Research (started in October 1971). The Institute carries out research directly applicable to educational contents and teaching methods in special education in areas such as medicine, psychology, education, and technology.

2. Information Service and Promotion of Research Activities (partly started in April 1972).

   a. The Institute provides services such as collecting, processing, and offering research information, data, and materials internationally.

   b. The Institute promotes research activities by cooperating with institutes, universities, and colleges in Japan and abroad, and holding seminars on special education.

3. Inservice Training for Teachers (started in 1972). Long-term training of 12 months, and short-term training of three months, is provided to improve the quality of teaching in the field of special education.

4. Child Guidance Clinic (started in 1972). As one of the practical research programs, the Institute provides counseling for handicapped children and their parents, and educational guidance based on a comprehensive diagnosis.

5. School for the Handicapped (scheduled to open in April 1973). The school will accept severely- and/or multiply-handicapped children. The School will aim at developing curricula and teaching methods for such handicapped children with whom

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*The National Research Institute of Special Education (NRISE)
2360, Nobi, Yokosuka,
Kanagawa pref. Japan.

educational guidance is particularly difficult.

Organization

1. Board of Counsellors. An advisory organ to the Director of the Institute. The Board consists of 20 members, prominent in research and special education.

2. Internal Organization.

   a. Planning Division

      (1) Coordination and general planning of work of the various departments.

      (2) Planning and arrangements for cooperation with research institutes, universities, and other relevant organizations in Japan and abroad.

   b. Department of the Visually Handicapped

      Section I: Education for the blind.

      Section II: Education for the partially sighted.

   c. Department of the Speech and Hearing Handicapped

      Section I: Education for the deaf.

      Section II: Education for the hard of hearing.

      Section III: Education for the speech handicapped.

   d. Department of the Mentally Retarded

      Section I: Education for the Severely- or moderately-mentally retarded.

      Section II: Education for the mildly-mentally retarded.

   e. Department of the Physically Handicapped

      Section I: Education for the crippled and disabled.

      Section II: Education for the delicate and chronically ill.

   f. Department of the Emotionally Disturbed

      Section I: Education for the emotionally disturbed.

   g. Department of the Multiply Handicapped

      Section I: Education for the visually and hearing impaired, with or without other handicaps.

      Section II: Education for the mentally retarded with visually and/or hearing impairment, with or without additional handicaps.

   h. Department of Educational Technology

      Section I: Research and development of teaching machines and/or training appliances and apparatus for the education of handicapped children.

In addition to the above, each department performs the following functions:

1. To collect materials on special education.

2. To cooperate, upon request, with various institutions of related interests in Japan and abroad.

3. To promote research activities through lectures and seminars.

Name: Audible Vu Meter

Source: Mr. Richard G. Allen
Associate Branch Manager
Electronics Systems
CBS Laboratories
High Ridge Road
Stamford, Connecticut 06905

Availability: one-off working unit

A Vu Meter adopted to provide an auditory signal instead of a visual one in monitoring audio program levels. The main features of the instrument are:

1. Indication of level by means of an audio tone. Gated when a threshold is exceeded or can be made continuous, if desired.
2. A step-variable attenuator which permits sensitivity to vary from -10 VU in 2-dB steps.
3. A balanced, bridging input.
4. The frequency of the gated tone is voltage variable to give an audible indication of how much the signal exceeds the threshold.
5. Switchable ballistics--either standard VU meter ballistics or fast-rise time-to-yield true-peak information.
6. Stereo capability--dual inputs and switch to select Left, Right, or "OR" function of the pair.

Name: Battery Tester

Source: American Foundation for the Blind
15 West 16th Street
New York, New York 10011

Availability: Experimental prototype

The device gives an aural indication of dry battery condition.

Name: Braille Teaching-Machine

Source: Prof. IR. Roelf G. Boiten
Laboratorium voor Werktuigkundige meet-en Regeltechniek
Technishe Hogeschool
Stevinweg 1
Delft, The Netherlands

Availability: Experimental prototype

The device consists of the following components: A cassette player and four-track stereo tape, the outer tracks used for sound recording, the inner ones for digital signals; a braille printer, powered by electric motor, which prints on Kraft paper tape moving from right to left; a standard-braille keyboard, logical circuits to generate the required commands.

There are four basic modes of interaction with the learner.

1. Instructional mode, in which instructions or explanations are given verbally from the voice track of the tape only.
2. Demonstration: oral instructions are given and a character or word is presented. The digital track of the tape fills the register, stops the tape, and activates the printer to emboss the characters in the register.
3. Command mode: oral instruction to print a character or word is given and the register filled with the first character required. The learner tries to write the character, using the keyboard. His action is checked against the contents of the register by the comparator component. If correct, the character is printed. If not, an oral correction and command to try again is given. Once the correct character has been printed, the process is repeated for the next one.
4. Conversational mode: a word is printed and the learner asked to read it. He shows his ability to do so by reproducing the word on the keyboard. Errors are handled as in the command mode.

Name: Braille Typewriter

Source: Association Valentin Haüy
3 a 9 Rue Duroc
Paris 7, France

Availability: Pre-production prototype

Name: Currency Recognition Device

Source: Theodor D. Sterling
Department of Applied Mathematics and Computer Science
Washington University
St. Louis, Missouri 63130

Availability: Experimental prototype

Device for personal use in discriminating paper currency of various denominations.

Name: "Digi Tac" (Tactile Digital Readout)

Source: American Foundation for the Blind
15 West 16th Street
New York, New York 10011

Availability: Experimental Prototype

A tactile binary-coded decimal readout for use with any device having a numerical readout. The tactile output for each digit is in the form of from zero to four pins representing binary numbers. The system is somewhat analogous to braille and may result in more rapid and accurate readings instruments such as counters, calculators, gauges, meters, or a transducer/meter combination.

Name: Discon 201

Source: Josef Penska
"ELPO" United Establishments of Electronic Measuring Equipment
Bialobrzeska 53
Warsaw, Poland

Availability: From "ELPO"

The device converts into braille the output of digital measurement instruments. It can function in conjunction with digital volt and ammeters, digital ohmmeters, digital capacitance meters, frequency meters, rev counters, reaction time meters, counters, quartz crystal clocks phase meters, and electronic calculators.

The DISCON 201 converter can operate with the following inputs: Code: - BCD 1, 2, 4, 8, or BCD 1, 2, 2, 4 (30-point connector: "Telfa" (Poland); decimal (75-point connector: "Continental 75-20").

The input signals are converted to the code which controls points of the digital braille indicators. The converter has seven digital braille indicators, or six plus a polarity sign, and can indicate six decimal points. The display delay is 0.2 sec.

Name: Dual Signal Guidance System

Source: Selim A. Mahas
P.O. Box 7257
Beirut, Lebanon

Availability: Experimental prototype

The system enables a blind person to follow a previously laid track. It consists of an audio-generator, an audio-amplifier, a loop of single-core insulated wire, 100 yards or more in length, and a cane equipped with a receiver, amplifier, loudspeaker, and control switch. The wire, laid one or two inches below ground surface, provides the track, which is detected by swinging the cane in small scanning movements. The blind person follows the track by keeping to the path over which the sound signal picked up by the cane is clearest. (U.S. patent 3,495,213.)

Name: Electronic Cane

Source: Polish Union for the Blind
Polski Zwiazek Niewidomych
Zarzad Glowny
Warsaw, Poland

Availability: Laboratory prototype

Capacitance variation of a high-frequency oscillator contained within cane which changes frequency upon approaching an obstacle.

Name: Electron Tube Tester

Source: Polish Union for the Blind
Polski Zwiazek Niewidomych
Zarzad Glowny
Warsaw, Poland

Availability: Laboratory prototype

For studying receiving tubes, voltage stabilizers, thyratrons and other tubes of relatively low-power output and testing tube conditions. Instrument can measure anode current, screen current, isolation resistance between anodes, and other tube elements. Will indicate breaks in filament, state of the vacuum atmosphere of tube, etc. External "index current" can be connected to anode, cathode, or screen, and permits simultaneous examination of all relevant tube characteristics.

Name: Guidance System for the Blind

Source: R. C. Richards
P.O. Box U
Ventura, California 93001

Availability: Experimental prototype

The system consists of:

1. A traffic signal GO activator, which senses and emits a wave when the signal in the desired direction is "go".
2. A guidance strip, which can be easily placed in the pavement, sidewalk or under a carpet.
3. A cane which picks up the traffic GO signal information and is sensitive to the guidance strip.

This unit is powered by four ordinary penlight cells. As an alternative to the cane a hand-held unit which can sense the GO signal has also been developed.

Name: Hear-a-Lite

Source: Dr. Iben Browning
Thomas Bede Foundation
5510 Domingo Road, N.E.
Albuquerque, New Mexico 87110

Availability: Experimental prototype

A small light sensor which consists of a photocell, an electronic circuit for generation of a tone, a battery, and an earphone. Depending on the amount of light impinging on the photocell the tone heard is a high pitch for more light and a low pitch for less light. The Hear-a-Lite is sensitive to a wide range of light intensity.

Name: IBM Card-Reading Instrument for the Blind (with Light-Identifier)

Source: Ezra Shapir, Research Consultant
IBM Research and Demonstration Center for the Blind and Otherwise Handicapped
Jewish Institute for the Blind
Jerusalem, Israel

Availability: Experimental prototype

The instrument consists of electronic components. It has horizontal- and vertical-braille scales and a movable wheel block on the vertical scale. Columns are located in relation to the horizontal scale. The position of card holes within a column are located by the position of the screw index on the wheel block, in relation to the vertical-braille scale. A buzz signal emitted by the Light-Identifier indicates the presence of a card hole. The Light-Identifier can be removed from the card reader and used for locating the position of lights on computer panels.

Name: Infra-Code

Source: University of Zagreb
Yugoslavia
and
John E. Medaris Co.
Infra-Code Center
5014 Dolecarlia Drive
Bethesda, Maryland

Availability: from John E. Medaris Co.

Device for tactual presentation of sound vibrations, consisting of a microphone, processing unit, and oscillator. The oscillator is strapped against the skin of the user (on the wrist) and produces vibrations which correspond in their variety to the sounds spoken into the microphone. In addition to its use in speech training, the device appears to sensitize some deaf persons to sound vibrations to a point at which they can detect them without the instrument. Several oscillators can be connected to a single central unit, permitting group training.

Name: Laser Print Scanning Device

Source: Dr. Sam L. Sparks
Director
Sensory Engineering Laboratory
17505 - 68th N.E.
Bothell, Washington 98011

Availability: Experimental prototype

Pen shaped device emits a narrow laser beam. When the beam is reflected from white paper it activates a reed in the side of the device, which vibrates against the user's finger. There is no signal when black print is encountered. The user traces the outline of letters on the basis of this on-off signaling.

Name: Laser Spectacles

Source: J. Malvern Benjamin, Jr., President
Bionic Industries, Inc.
Bala Cynwyd, Pennsylvania

Availability: Experimental prototype

Laser beams are emitted from sources fitted on eyeglass frames. Objects in the user's path are detected when laser light is reflected from them, and sensed by the receptors of the device. The beams may be aimed at ground and head level, with a different output signal for each. The signal to the user may be either auditory or tactual. (U.S. patent 3,654,477.)

Name: Mechanical System for Speech Compression

Source: Mr. Clarence Lundy
3512 Stancrest
Glendale, California 91208

Availability: Experimental prototype

A modification of a standard tape recorder. Compression is achieved by alternately and very rapidly starting and stopping the tape on a tape recorder while it is copying a signal supplied to another tape recorder.

Name: Miniature Pocket Bridge

Source: Polish Union for the Blind
Polski Zwiazek Niewidomych
Zerzad Glowny
Warsaw, Poland

Availability: Laboratory prototype

Based on same principle as Resistance and Capacitance Measurement Bridge, with half-wave rectifier for resistance and capacitance measurements.

Name: Opticron

Source: Mr. Zaid Diaz Gandia
CSI Processing Corporation
Commercial Scientific and Industrial Data Processing and Systems Analysis Services
218 Del Parque Street
Santurce, Puerto Rico

Availability: Experimental prototype

Device for presentation of visual images in tactile form. It consists of a camera or diode array feeding a control mechanism and an amplifier and processor. The latter feeds into an image projector which interfaces with the blind user. The image is presented to the skin of the back by electrical stimulation. The present model has a 1600-point display which uses a maximum current of 5 milliampere. The magnitude of the current is used to indicate degrees of gray. The subjects are trained to respond to very low levels of stimulation through operant conditioning.

Name: Pitch Detector with Tactile Display

Source: T. R. Willemain
Department of Electrical Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

Availability: Experimental prototype

Voiced speech is detected by means of throat microphone, amplified, processed and quantized into eight channels. The first seven channels correspond to bandwidths of about 20 Hz; the eighth corresponds to all pitch frequencies above 240 Hz. Counts in each channel are recorded for analysis of a speaker's pitch distribution. Speech input can be sampled for various durations between 50 and 400 ms. and immediately displayed for 50 ms. The tactile display to the fingers employs either two or three solenoid pokers, indicating "high," "low," and (optionally) "ok." Switching circuits allow the experimenter to assign counts in any channel to any tactor, enabling him to vary the display parameters.

Name: Resistance and Capacitance Measurement Bridge

Source: Polish Union for the Blind
Polski Zwiazek Niewidomych
Zarzad Glowny
Warsaw, Poland

Availability: Laboratory prototype

Bridge equilibrium is signaled by an acoustic signal. Measured quantities are read on a plastic meter face suitably brailled.

Name: "Seeing Aid"

Source: Forrest M. Mims
6901 Zuni SE A-12
Albuquerque, New Mexico 87108

Availability: Experimental prototype

An active infrared mobility aid mounted on spectacle frames. The device detects objects up to 15 feet away by means of a beam of modulated near infrared radiation. The beam of radiation is emitted by a light-emitting diode installed in a tube on one side of the eyeglasses and reflections from objects intersecting it are sensed by a receiver similarly housed on the opposite side. The information output to the user is a tone heard through a thin plastic tube inserted in one ear. The device weighs three ounces and has no additional parts. It is intended as a supplement to the cane or dog, not as a substitute for them. Developmental Seeing Aids intended for experimental evaluation are available for $250.00.

Name: Sound Reader

Source: Vojislav Djurdjevic et al.
"Boris Kidric" Nuclear Institute
Belgrade, (Vinca), Yugoslavia

Availability: Experimental prototype

Sound is recorded on paper in a manner similar to that used in making sound films. The decoder used for reading resembles a fountain pen in shape and operates by a combination of optics and electronics. By moving the reader along the impressed sound, the optically printed lines are transmitted to a photo-electronic detector, whose signals are intensified and then transmitted to a loudspeaker (transistor or radio set).

Name: Tactile Television

Source: Henry Boll, Ph.D.
Bell Laboratories
Murray Hill, New Jersey

Availability: Experimental prototype

The device translates visual images into tactile displays consisting of air-jet patterns. One model is worn on the head, hat-shaped and self-contained. The air-jets impinge upon the forehead and power is supplied from batteries. Two sets of transducers are employed, one converting light to electrical impulses, the other converting these to jets of air. Two lenses are used, one giving a central "vision" analogous to that of the fovea, the other wide-angled, as in peripheral vision. There are the same number of mosaic elements for both lenses, so that one can shift between central and peripheral "vision." A chest worn model has also been developed.

Name: Tactile Writing Board

Source: Professor D. R. Taylor
Department of Mathematics
University of Houston
Cullen Boulevard
Houston, Texas 77004

Availability: Experimental prototype

The device provides a 17" x 24" surface on which to write or draw. Raised lines are produced immediately by means of a stylus.

Name: Universal Resistance, Current, and Capacity Meter

Source: Polish Union for the Blind
Polski Zwiazek Niewidomych
Zarzad Glowny
Warsaw, Poland

Availability: Laboratory prototype

Voltage range:	100 mv to 1000 V, ac and dc.
Current range:	1 mA to 6 A, ac and dc.
Resistance range:	10 m ohms to 10M ohms.
Accuracy:	+ or -4 percent, all scales.

Name: Varispeech Machine

Source: Lexicon, Inc.
60 Turner Street
Waltham, Massachusetts 02154

Availability: from Lexicon, Inc.

Tape recorder for time compression and expansion through electronic signal processing. The voice signal is converted to a digital format and entered into a small, special-purpose computer. The computer converts the voice to a second digital format, correcting it for pitch, and finally to an analog representation, without loss of intelligibility or speaker identification. The recording medium is Phillips audio tape cassette, at standard cassette speed. The playback speed is continuously adjustable from 1/2 to 2.5 times the recording speed.

Name: Visotoner

Source: Mauch Laboratories, Inc.
305 Dryden Road
Dayton, Ohio 45439

Availability: Laboratory prototype

Personal reading machine of the optophone type; it contains a vertical column of nine photocells, an optical system, and electronic circuits for the generation of a different tone for each photocell when it scans a black area. Each letter when scanned thus produces a characteristic sound pattern which corresponds to the configuration of black areas in its inkprint form. The device has a variable-magnification optical system adaptable for use with various type sizes. It is powered by battery and equipped with earphones.

Name: Visotactor

Source: Mauch Laboratories, Inc.
305 Dryden Road
Dayton, Ohio 45439

Availability: Laboratory prototype

A "tactile optophone," operating on the same principle as the Visotoner, but with output to the user in the form of tactual stimulation of the fingers instead of sound. The device comes in more than one model, with variations in the array of sensors and stimulators.

Name: Cognodictor

Source: Mauch Laboratories, Inc.
305 Dryden Road
Dayton, Ohio 45439

Availability: Experimental prototype

Personal reading machine with spelled speech output. The Visotactor constitutes the sensor probe of the system. Letters are identified by the "Two-Dimensional Multiple Snapshot" character recognition technique, which can handle most commonly used type fonts. A "Contracted Spelled Speech" output is being developed for the machine.

Name: Digitactor

Source: Mauch Laboratories, Inc.
305 Dryden Road
Dayton, Ohio 45439

Availability: Experimental prototype

Dual-purpose reading aid. Used alone it will serve as a direct translation reading machine, with tactile output to the fingers of the scanning hand. The device will also generate electrical signals suitable for being fed into either a personally-owned recognition machine (Cognodictor) or a central library computer with machine-speech output.

Name: Stereotoner

Source: Mauch Laboratories, Inc.
3035 Dryden Road
Dayton, Ohio 45439

Availability: Pre-production prototype

The device translates letter shapes into stereophonic sound patterns. Its control box is 4-1/2" x 5" x 1-1/2" in size and contains the circuitry and a rechargeable D size battery. The box also contains storage space for the other two components, the earphones and hand-held probe. The miniature camera of the probe has a zooming range of 10:1 which enables it to handle a wide range of letter sizes. Provisions are also made for monaural reading, and for reading of italics, and white-on-black print.

Aids for Children. ICTA Information Center, Fack S-161 03, Bromma 3, Sweden, April 1972. (Technical aids for physically handicapped children except defects of vision, hard of hearing, orthosis and prosthesis.)

Apple, M. M. "Kinesic Training for the Blind," *Education of the Visually Handicapped*, May, 1972, Vol. 4, pp. 55-60.

Baer, J. A., and J. W. Hill. *Optical-to-Tactile Image Conversion for the Blind.* Menlo Park, California: Stanford Research Institute, June 1972. (Final report covering the period 17 May 1970 to 30 June 1972, prepared for Social and Rehabilitation Service Office of Research Demonstration and Training, Washington, D.C. Contract SRS 70-42 and Grant 14-P-55296/9-02.)

Chess, S., S. J. Korn, and P. B. Fernandez. *Psychiatric Disorders of Children with Congenital Rubella.* New York: Brunner/Mazel, 1972.

Coursey, T. P., D. L. McGowan, and L. E. Apple. "Night Viewing Goggles for Night-Blind Travelers," *Bulletin of Prosthetics Research*, Spring 1972, Vol. 10 (17), pp. 191-4.

Freiberger, H. (ed.). "Sensory Aids," *Bulletin of Prosthetics Research*, Spring 1972, Vol. 10 (17), pp. 248-72.

Graham, M. D. (ed.). *Science and Blindness: Retrospective and Prospective.* New York: American Foundation for the Blind, 1972. (Edited version of the American Foundation for the Blind 50th Anniversary International Symposium on Science and Blindness, held in New York City in October 1971.)

Dinnage, R. *The Handicapped Child: Research Review.* Vol. 2. London: Longmans in association with the National Children's Bureau, 1972.

Davis, J. H., and P. A. B. Radcliffe. "An Analog Data Storage System for a Reading Machine for Blind Readers," *IEEE Transactions on Biomedical Engineering*, November 1972, BME-19 (6), pp. 415-21. (A limited number of reprints are available from IPIS upon request.)

Forbes, J. "Braille Translation: The Computer Aids the Blind," *Mitre Matrix*, April 1972, Vol. 5(2), pp. 22-31.

Genensky, S. M., H. E. Petersen, H. L. Moshin, R. W. Clewett, and R. I. Yoshimura. *Advances in Closed-Circuit TV Systems for the Partially Sighted.* Santa Monica, California: Rand Corp., 1972. (A final report prepared under Research Grant [Project No. 14-P 55285/9] from Social and Rehabilitation Service, U.S. Department of Health, Education, and Welfare.)

Hatfield, E. M. "Blindness in Infants and Young Children," *The Sight-Saving Review*, Summer 1972, Vol. 42(2), pp. 69-89.

Hearing Sensitivity and Related Medical Findings Among Children: United States. Vital and Health Statistics, DHEW Pub. No. (HSM) 72-1046, Series 11, No. 114, Public Health Service. Washington, U.S. Government Printing Office, March 1972.

Lauer, H. "Sensory Aids for the Blind: Are they Automatic Bonus or Needed Tools?" *Education of the Visually Handicapped*, December 1971, Vol. 3(4), pp. 111-15.

Metfessel, M., and C. Lovell. "Guidelines for Developing an Alphabet to Synthesize Spelled Speech," *Bulletin of Prosthetics Research*, Spring 1972, Vol. 10 (17), pp. 154-76.

Methods for the Early Detection of Potentially Blinding Eye Conditions. Copenhagen, Denmark:

Regional Office for Europe, World Health Organization. Report on a Working Group, Copenhagen, 7-11 December 1970. (A limited number of copies are available for persons officially or professionally concerned with this field of study from the WHO Regional Office for Europe, Copenhagen.)

Morris, J. E., and C. Y. Nolan. "Bibliography on Tests and Testing of the Blind, 1971." Louisville, Kentucky: American Printing House for the Blind, Educational Research, Development, and Reference Group.

Morris, J. E., and C. Y. Nolan. *Bibliography of Research on the Visually Handicapped, 1953-1971.* Louisville, Kentucky: American Printing House for the Blind, Educational Research, Development, and Reference Group.

Newman, G. (CHM). *Evaluation of Sensory Aids for the Visually Handicapped*. Washington, D.C.: Academy of Sciences, 1972. (A report on a conference sponsored by the Subcommittee on Sensory Aids Committee on Prosthetics Research and Development of the Division of Engineering National Research Council, held at the National Academy of Sciences, Washington, D.C. on November 11-12, 1971.)

Nolan, C. Y., and J. E. Morris. *Bibliography of Research on Large Type Reading, 1971.* Louisville, Kentucky: American Printing House for the Blind, Educational Research, Development, and Reference Group.

Nolan, C. Y., J. E. Morris, and C. J. Kederis. *Bibliography of Research on Braille, 1971.* Louisville, Kentucky: American Printing House for the Blind, Educational Research, Development, and Reference Group.

Optacon Newsletter, November 1972, Issue No. 3. Stanford, California: Optacon Project, Applied Electronics Laboratory, Stanford University.

The following appeared in the *Bulletin of Prosthetics Research*, BPR 10-17, Spring 1972, p. 286:

"Sensory-Aids Excerpts from BPR 10-17 on Tape Cassettes," include the following items:

Articles

Milton Metfessel and Constance Lovell. "Guidelines for Developing an Alphabet to Synthesize Spelled Speech."
Louise Sloan. "Optical Magnification for Subnormal Vision: Historical Survey."
Thomas P. Coursey, David L. McGowan, and Loyal E. Apple. "Night Viewing Goggles for Night-Blind Travelers."

Highlights of Other VA Research Programs

Howard Freiberger (ed.): Sensory Aids.

Notes and News

Excerpts from BPR Available on Tape Cassettes:
The Stereotoner
1972 Conference on Speech Communication and Processing
New Pamphlets on Blindness
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Sloan, L. "Optical Magnification for Subnormal Vision: Historical Survey," *Bulletin of Prosthetics Research*, Spring 1972, Vol. 10(17), pp. 177-90. (*Journal of the Optical Society of America*, February 1972, Vol. 62(2), pp. 162-8.

Sylvestre, N., and C. Daurat-Hmeljak. "Quelques aspects de la construction du nombre chez l'enfant deficient visuel." ("Some Aspects of the Construction of Numbers in the Partially Sighted Child.") *Revue de Neuropsychiatrie infantile*, 1972, Vol. 20(3-4), pp. 323-33.

Tuttle, D. W. "A Comparison of Three Reading Media for the Blind," *Education of the Visually Handicapped*, May 1972, Vol. 4(2), pp. 40-4.