American Foundation for the Blind

Research Bulletin 27

APRIL 1974

Contents


EX
LIBRIS
AMERICAN FOUNDATION
FOR THE BLIND INC.

American Foundation for the Blind

Research Bulletin 27

APRIL 1974

The *Research Bulletin* is a publication of the International Research Information Service (Leslie L. Clark, Director), American Foundation for the Blind, 15 West 16th Street, New York, New York 10011 USA.

Published irregularly twice a year, the *Research Bulletin* may be purchased for $1.50 per copy. Subscriptions for four issues are $6.00.

Articles in the *Research Bulletin* are abstracted in *Excerpta Medica, Psychological Abstracts*, and *Rehabilitation Literature* and by the Swedish Institute for the Handicapped and the Institute for Scientific Information of the U.S.S.R. Academy of Sciences.

Manuscripts and other material to be considered for publication in the *Research Bulletin* should be submitted in duplicate to the editor-in-chief. All correspondence concerning manuscripts, editorial policy, and further information about research reported in the journal should also be directed to the editor-in-chief. A set of guidelines for contributors is available on request.

All correspondence concerning subscriptions and orders for back issues should be sent to the Publications Division of the American Foundation for the Blind. Printed in the United States of America.

CONTENTS

In Memoriam

Samuel J. Mason

Cecil H. Green Professor of Electrical Engineering

Associate Director, Research Laboratory of Electronics,
Massachusetts Institute of Technology

1921 - 1974

TACTUAL ORIENTATION PERFORMANCE OF BLIND CHILDREN IN DIFFERENT GRADE LEVELS

Edward P. Berlá*

Errors of directional orientation have serious implication for map reading skills and the application of information derived from maps for subsequent mobility behavior. Research and practical experience with the blind suggest that they are subject to significant errors in directional orientation. Worchel (1951) investigated blind subjects' ability to follow a prescribed path and found their performance to be poor when compared to blindfolded sighted subjects performing the same task. The blind subjects' poor performance was primarily due to angular deviations from the correct direction. Cratty, et al. (1968) found that blind subjects veer about 36 degrees for every 100 feet traveled when required to walk a straight path.

Spatial orientation is currently a topic of interest within the general psychological literature as well (Howard and Templeton, 1966). One focal point of interest is the degree to which subjects can determine the orientation of a shape. Ghent (1960) and Ghent and Bernstein (1961) found that normal children show considerable consistency in visually identifying the phenomenal orientation of both real and nonsense shapes. For example, different children are consistent in calling an unfamiliar shape "upside down" based upon certain distinctive features of the shape. However, for a similar task performed tactually, Pick, Klein and Pick (1967) found that both blind and sighted (blindfolded) children were inconsistent in identifying the phenomenal orientation of a series of shapes, while sighted children performing visually were consistent.

A second focal point of interest concerns the effects of orientation on both the visual and tactual discrimination and/or recognition of a shape. For vision, it has been found that children and adults are able to recognize both familiar and unfamiliar shapes more accurately or quickly when a shape is presented in one specific orientation of several possible orientations (Braine, 1965; Fitts, Weinstein, Rappaport, Anderson and Leonard, 1956). For tactual perception it has been found, at least for adult sighted (blindfolded) subjects, that the tactual recognition of an unfamiliar shape is no better in one orientation than it is in any other (Warm and Foulke, 1968). Other research has shown that for both visual and tactual shape discrimination, it is easier to discriminate two identical shapes when they are both oriented in the same direction than when they are oriented differentially (Warm, Clark and Foulke, 1970). However, research by Goodnow (1969) and Pick and Pick (1966) has shown that, visually, a change in shape is discriminated more easily than a change in the orientation of a shape, but tactually the reverse is true. This finding at first may seem inconsistent with the previous research on the tactual perception of phenomenal orientation. However, the fact that children can discriminate the orientation of a shape more easily tactually than visually could stem from either of two diametrically opposed hypotheses. First, if two identical shapes are presented to a subject, with one of the shapes rotated 180 degrees with respect to the other, the subject could recognize that of the two shapes presented to them one of them is "upside down and thus call the shapes different because of the differences in

*American Printing House for the Blind.

orientation. However, a second hypothesis that seems more likely, at least for blind children, is that the subjects may not in fact recognize that the tactual shapes are identical with one rotated. Instead they may perceive them as completely different shapes without detecting the fact that the shapes differ only in orientation. For these reasons, the present study was conducted to determine more directly the ability of blind subjects to detect and manipulate the orientation of tactual shapes. It seemed important to verify whether a young blind child has the concept of the orientation of a shape in space and the extent to which blind children of different grades make errors of directional orientation. Whether or not blind children can utilize orientation cues and with what degree of accuracy is of practical importance in utilizing directional orientation cues on mobility maps, general reference maps, and diagrams.

In the present study, blind children from different grade levels were presented with a tactual shape in one orientation for inspection. Following an inspection period the shape was rotated and the subject was asked to reorient the shape to its original position. In addition, the complexity of the stimuli was varied over three levels to determine if the complexity of the stimulus affects orientation performance. Nonmeaningful stimuli were used instead of real objects in order to reduce any effects experience in using the objects might have played in orientation performance.

METHODS

Subjects

The subjects were 72 braille readers of both sexes enrolled in schools for the blind. Eighteen subjects from each of grades two, four, six, and eight participated in the study. The means and standard deviations for the ages within each grade are as follows: Grade Two $\bar{x}$ age = 9.04, *SD* = 1.19; Grade Four $\bar{x}$ age = 10.94, *SD* = 1.09; Grade Six $\bar{x}$ age = 14.19, *SD* = 1.96; Grade Eight $\bar{x}$ age = 16.46, *SD* = 1.72. The schools participating in this research were the Georgia Academy for the Blind, Lavelle School for the Blind, Tennessee School for the Blind, and the West Virginia School for the Blind.

Materials

Three sets of metric figures were constructed from three levels of complexity. Metric figures are constructed by specific rules as detailed by Alluisi (1960), Baker and Alluisi (1962), and Fitts, et al., (1956). The metric figures employed here were constructed by drawing circles having 3, 4, and 5 equally spaced radii, respectively. The radii were then divided into 3, 4, and 5 equal segments, respectively. Then, using a table of random numbers, radial heights were sampled and these points were connected to form geometric shapes having 3, 4, and 5 sides which constituted the three levels of complexity. Figure 1 illustrates the metric figures employed. Ten geometric shapes from each level of complexity were used. Of the 10 shapes, 9 had one or more unequal sides, while one figure from each complexity level was equal-sided, thus forming a perfect triangle, a perfect square, and a perfect pentagon. Each shape was constructed by inscribing the shape within the bounds of a circle having a radius of 1-3/4 inches resulting in figures which had a maximum diameter of 3-1/2 inches. A template was made of each form and used to cut each shape from 1/4-inch masonite. The figures were presented on a circular board which had a rotatable wheel in the center. The wheel had a radius of 4 inches and the circular board had a radius of 8 inches. Around the outer edge of the rotatable wheel, affixed to the circular board, was a scale which enabled the experimenter to measure the amount of rotation in degrees. Figure 2 is a schematic representation of the apparatus. The apparatus was secured to a table top by suction cups on the bottom of the circular board.

Experimental Design

The design consisted of four variables which included grade levels, experimental and control conditions, complexity, and degree of rotation.

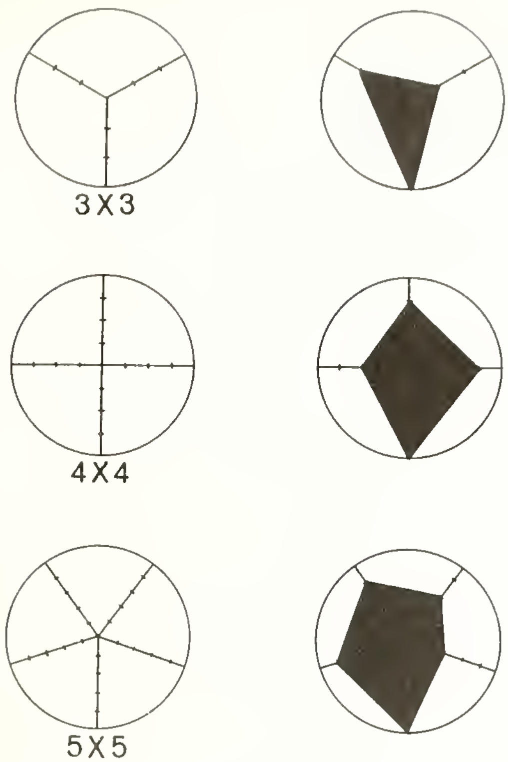


Figure 1. Matrices Used to Construct Stimulus Figures at Three Different Levels of Complexity.

The effect of grade level was a between-subjects variable while the effects due to the experimental vs. control conditions, complexity, and degree of rotation were within-subjects variables. For each session, for each complexity level, each subject was given 12 trials which consisted of reorienting each of the nine geometric forms having unequal sides (experimental condition) and three trials reorienting the equal-sided figures (control condition). The logic underlying the control condition was that since the shapes were all constructed to have equal length sides there were no distinctive cues to differentiate one corner or one side from any other side. Consequently, after the subject inspected the shape and the experimenter rotated it, there was no distinctive feature or frame of reference available to the subject with which to reorient the figure to its original position. Thus the subject's response could vary from 0° (if by chance the subject reorients the shape to its original position) to 180° (if by chance the subject reorients the shape upside down). If the subject's performance was governed completely by chance, the average degree of error should be halfway between the two extreme scores (0° to 180°) or 90°. The control condition thus generated an empirical baseline and an estimate of the mean and variability against which to determine statistically whether performance in the experimental conditions was above chance level. The order of presenting the three levels of complexity was blocked and counterbalanced so that a given subject was presented with one of six possible permuted orders of three levels of complexity. An equal number of subjects was assigned randomly to each of the six orders. The equal-sided control figures were randomly interspersed between successive trials of the experimental figures except for the restriction that no control figure was given first within any block and no two control figures followed each other successively.

Procedure

At the beginning of each session the subjects were given three practice trials to familiarize them with the task. Each subject was told that he would be presented with a shape on a round wheel and that he had to inspect the shape and remember its location. The experimenter turned the wheel around and asked

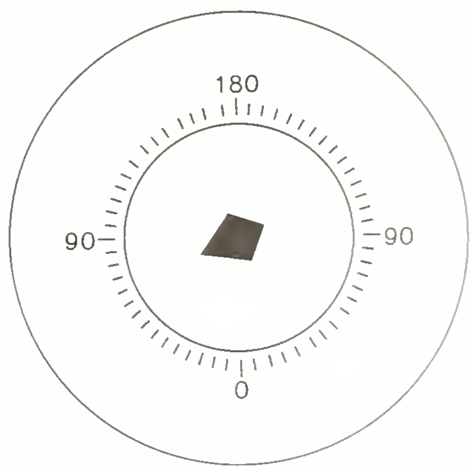


Figure 2. Schematic Representation of the Apparatus.

the subject to return the shape to its original position. Each subject was also informed that the examiner was timing each trial to determine how quickly he could inspect the figure and how quickly he could return the figure to its original position. Each trial consisted of presenting one shape on the rotatable wheel for inspection, as soon as the subject removed his hands, the wheel was rotated a predetermined number of degrees (90, 180, 270). The subject was then asked to return the figure to its original position by rotating the shape. For both the inspection phase and the reorientation phase, latency was measured from the time the subject placed his hands on the shape to the time he removed them. The amount of error was measured from absolute zero to the nearest degree. The subject's errors were not corrected and no information was given during the trials.

RESULTS

Every subject participated in both an experimental condition in which he was asked to reorient unequal-sided figures, and a control condition in which he was asked to reorient equal-sided figures. The mean level of accuracy and the standard deviations in degrees of error as a function of grade level for both the experimental and control conditions are shown in Table 1. Also shown is the theoretical baseline for reorienting tactual figures if it is assumed either that the subjects had no ability to reorient the figures or if there were no cues with which to orient the figures.

Given these assumptions, the expectation is that the subjects will show an average error of 90 degrees. Table 1 shows that the mean error of the control condition

TABLE 1

Mean Level of Error (In Degrees) as a Function of Grade Level for Experimental and Control Conditions

Grade Level		2	4	6	8
	$\bar{x}$	58.37	46.73	40.09	30.49
Experimental	*SD*	16.85	15.38	16.86	16.42
	n	18	18	18	18
	$\bar{x}$	76.21	88.36	84.84	83.51
Control	*SD*	14.85	18.36	16.84	18.94
	n	18	18	18	18
	$\bar{x}$	90.00	90.00	90.00	90.00
Theoretical	*SD*	-	-	-	-
	n	-	-	-	-

approximated the theoretical baseline. One main question was whether subjects at each grade level could reorient figures at better than chance levels. To answer this question a-priori *t* tests for simple main effects were performed comparing each subject's performance in the experimental condition with his performance in the control condition using the *MS* error for conditions X subjects/groups as the error term. All of the comparisons of the experimental conditions with the control conditions for grades two, four, six, and eight were significant (*MS* error = 243.31; $df = 1/68$; $p < 0.01$). The respective *t* values were: 3.43, 8.01, 8.61, 10.20.

A separate analysis of variance was performed on the accuracy data only for the experimental condition in order to evaluate the effects due to grade level, complexity, and degree of orientation of the tactual figures on orientation performance. The only significant effect was differences between grade levels ($F = 9.19$; $df = 3/68$; $p < 0.01$) which showed that performance improved steadily from grades two through eight. The complexity and absolute orientation of the tactual figures and all other interactions had no effect on the reorientation performance. A summary of the analysis of variance is shown in Table 2.

TABLE 2

Analysis of Variance for Degrees of Error in the Experimental Condition

Source	*df*	*SS*	*MS*	F
Total	647	668323.54		
Between subjects	71	231038.87		
Grades	3	66663.51	22221.17	9.19*
Error	68	164375.36	2417.28	
Within subjects	576	437284.67		
Complexity	2	3484.56	1742.28	2.30
Grade X complexity	6	4121.16	686.86	< 1
Error	136	103155.96	758.49	
Orientation	2	4281.89	2140.95	2.37
Grade X orientation	6	3712.51	618.75	< 1
Error	136	122702.90	902.23	
Complexity X orientation	4	2174.12	543.53	< 1
Grade X complexity X orientation	12	2380.38	198.36	< 1
Error	272	191271.16	703.20	

*$p < 0.01$

Analyses of variance were performed on reciprocals of the latency data using only the experimental conditions. One analysis was performed on the inspection phase data and a separate analysis was performed on the reorientation test phase. Separate analyses were performed because the task for inspection consisted of an exploration of the tactual figure, while during the test phase the subject not only had to explore the figure but also was required to rotate the figure back to its original position. To compare the performance of these two phases in terms of task time would have been misleading since the conditions were not comparable.

The analysis for the inspection phase showed that complexity had a significant effect on task time (F = 19.98; df = 2/136; $p < 0.01$). As shown in Table 3, as complexity increased task time increased. The least complex figures resulted in the fastest task time while the most complex figures resulted in the longest task time with figures of intermediate complexity falling between these two. No other variables or their interactions were significant. A summary of the analysis of variance is shown in Table 4.

A 3-way analysis of variance was performed on the reciprocals of the latency data for the reorientation test phase. This analysis showed that complexity had a significant effect on task time (F = 20.68; df = 2/136; $p < 0.01$). As shown in Table 5 the lowest level of complexity had the fastest task times while intermediate levels of complexity had the longest task times. The most complex figures had latency scores between the longest and intermediate levels of complexity. No other variables or their interactions were significant. Table 5 is a summary of the analysis of variance.

Post hoc tests on the transformed data using Tukey's *HSD* procedure (Kirk, 1969, p. 306) showed that for both inspection and reorientation test phases the only significant effects for the latency data were those between 3-sided and 4-sided figures and between 3-sided and 5-sided figures respectively: MS error inspection = 0.005085; HSD = 8.85, df = 3/136, $p < 0.01$; HSD = 5.52, $p < 0.01$; MS error test = 0.004492; HSD = 8.46; df = 3/136, $p < 0.01$; HSD = 7.13, $p < 0.01$. Thus, for both the inspection and test phases, 4-sided figures were not significantly different from 5-sided figures using latency as the measure of performance.

TABLE 3

Mean Task Times (In Seconds) as a Function of Stimulus Complexity for the Experimental Condition during Inspection and Test Phases

Complexity (Sides)		3	4	5
Inspection	$\bar{x}$	5.83	6.86	7.46
	SD	2.74	3.27	3.65
Test	$\bar{x}$	6.45	8.26	7.99
	SD	2.69	3.63	3.85

TABLE 4

Analysis of Variance of Mean Task Time for Inspection

Phase Using a Reciprocal Transformation

Source	*df*	*SS*	*MS*	*F*
Total	647	5.200049		
Between subjects	71	3.519599		
Grades	3	0.129601	0.043200	< 1
Error	68	3.389997	0.049853	
Within subjects	576	1.680450		
Complexity	2	0.203217	0.101608	19.98*
Grade X complexity	6	0.019547	0.003258	< 1
Error	136	0.691555	0.005085	
Orientation	2	0.004687	0.002343	1.41
Grade X orientation	6	0.005642	0.000940	< 1
Error	136	0.226718	0.001667	
Complexity X orientation	4	0.005880	0.001470	< 1
Grade X complexity X orientation	12	0.018073	0.001506	< 1
Error	272	0.505129	0.001857	

*$p < 0.01$

DISCUSSION

The results seem quite clear with respect to the orientation ability of blind children. The accuracy of performance was a linear function of experience (grade level). Even at the earliest grade level sampled (grade two), the subjects showed above chance performance indicating that they had some knowledge and ability to utilize a frame of reference, and thus were able to reorient the tactual figures.

However, from a qualitative standpoint their overall performance was poor. Even at the eighth-grade level, the subjects were averaging 30+° of error with a *SD* of 16+°. The obvious conclusion is that the blind subjects do have the concept of the orientation of a tactual figure in space, but their performance is poor. The large errors in directional orientation performance found in the present task are consistent with previous research (Cratty, 1968; Worchel, 1951). It is apparent that the difficulty blind children have in directional orientation is a pervasive one which extends even to such simple tasks as the one used here. Since errors decreased steadily over grade levels, it would appear that performance could be improved considerably with training.

TABLE 5

Analysis of Variance of Mean Task Time for Reorientation Test Phase Using a Reciprocal Transformation

Source	*df*	*SS*	*MS*	*F*
Total	647	3.386165		
Between subjects	71	1.724638		
Grades	3	0.102143	0.034048	1.43
Error	68	1.622495	0.023860	
Within subjects	576	1.661526		
Complexity	2	0.185808	0.092904	20.68*
Grades X complexity	6	0.006566	0.001094	< 1
Error	136	0.610855	0.004492	
Orientation	2	0.006967	0.003483	1.83
Grade X orientation	6	0.011042	0.001840	< 1
Error	136	0.258380	0.001899	
Complexity X orientation	4	0.005225	0.001306	< 1
Grade X complexity X orientation	12	0.025478	0.002123	1.05
Error	272	0.551204	0.002026	< 1

*$p < 0.01$

The performance of the task by the subjects could be characterized as one in which at least one distinctive feature of the stimulus is located during the inspection phase and coded in relation to a frame of reference. Then, during the test phase the figure is explored in an attempt to relocate the distinctive feature and this distinctive feature is used to rotate the figure back to its original position with respect to the frame of reference. This characterization suggests why the complexity of the stimulus figure had no effect on the accuracy of reorientation. If it is assumed that there is an increase in the number of distinctive features as the complexity (as defined here) of the stimulus increases, then the subjects' task is merely to choose one distinctive feature (one corner or one side) with which to determine the figure's absolute orientation. During the test phase, the subject only needed to find this distinctive feature ignoring all of the others, and reorient the figure using only the one distinctive feature. Thus, as long as a stimulus has one unique feature, the task can be performed with the same level of accuracy regardless of the total number of distinctive features.

However, complexity did have an effect on performance in terms of task time. It took longer to inspect and reorient 4- and 5-sided figures than 3-sided figures. If task time is viewed as a measure of information gaining rather than information processing, then increasing the complexity (sides and angles) results in a more difficult search task in terms of increasing the time needed to choose and then relocate a distinctive feature for the reorientation phase.

Observations of the subjects performing the task indicated that the older subjects were more systematic and careful in choosing distinctive features of the shapes during the inspection phase than were the younger subjects. During the reorientation phase many of the older subjects would rotate the figures several times until they located the specific distinctive feature(s) they needed to reorient the shape. However, younger subjects' exploration of the shapes was less systematic and complete. Many of the younger subjects seemed to choose distinctive features "impulsively" and then would have difficulty relocating the same distinctive feature during the reorientation phase. Often it seemed that the younger subjects never did find the distinctive feature they were searching for and seemingly reoriented the shape using a different (incorrect) distinctive feature. Thus the behaviors of both the older and younger subjects suggest that a major difficulty in identifying a tactual shape on the basis of its orientation may be due to errors in perceiving one or more distinctive features of a shape as being identical to the distinctive features of the same shape presented in a different orientation. It appears that older subjects, while still making errors, are better at identifying and locating distinctive features of a shape than younger subjects and this may be the major reason their performance is superior to younger subjects. However, the results of the present study suggest that further research is needed to investigate other factors important to the orientation of shapes in space. The minimum requirement to orient a shape in space is not only the distinctive features of a shape but also a specific frame of reference. In the present study no specific frame of reference was designated in advance, consequently the subjects had to use their own phenomenal frame of reference. For example, the subjects may have used the relative directional location of the distinctive features of the shapes with respect to the sides or midline of the body or hand. A subsequent study is needed to determine the relative contribution of easily accessible distinctive features and specific frames of reference in directional orientation performance of tactual shapes in space.

SUMMARY

The effects of stimulus complexity (3-, 4-, and 5-sided figures) and degree of rotation (90°, 180°, 270°) on tactual figural orientation performance were investigated with 72 blind children in grades two, four, six, and eight. The overall quality of performance was poor, but the subjects in all grade levels were able to orient tactual figures at above-chance levels with accuracy of performance increasing significantly as grade level increased. Complexity and degree of rotation had no effect on accuracy of performance, but increasing levels of complexity significantly increased task time. Differences in tactual search patterns appeared to be responsible for the differences in accuracy across grades.

Acknowledgments

The author extends his appreciation to John Siems for his assistance in the data analysis and Ken Coy for making the stimulus material.

REFERENCES

Alluisi, E. A. On the use of information measures in studies of form perception. *Perceptual & Motor Skills*, 1960, 11, 195-203.

Baker, E. J. & Alluisi, E. A. Information handling aspects of visual and auditory form perception. *Journal of Engineering Psychology*, 1962, 1, 159-179.

Braine, L. G. Age changes in mode of perceiving geometric forms. *Psychonomic Science*, 1965, 2, 155-156.

Cratty, B., Peterson, C., Harris, J., & Schoner, R. The development of perceptual-motor abilities in blind children and adolescents. *New Outlook for the Blind*, 1968, 62, 111-117.

Fitts, P. M., Weinstein, M., Rappaport, M., Anderson, N., & Leonard, J. A. Stimulus correlates of visual pattern recognition: A probability appraoch. *Journal of Experimental Psychology*, 1956, 51, 1-11.

Ghent, L. Recognition by children of realistic figures presented in various orientations. *Canadian Journal of Psychology*, 1960, 14, 249-256.

Ghent, L., & Bernstein, L. Influence of the orientation of geometric forms on their recognition by children. *Perceptual and Motor Skills*, 1961, 12, 95-101.

Goodnow, J. Eye and hand: Differential sampling of form and orientation properties. *Neuropsychologia*, 1969, 7, 365-373.

Howard, I. P., & Templeton, W. B. *Human spatial orientation.* New York: Wiley, 1966.

Kirk, R. E. *Experimental design: Procedures for the behavioral sciences.* Belmont, Calif.: Brooks/Cole, 1969.

Pick, H. L., Klein, R. E., & Pick, A. D. Visual and tactual identification of form orientation. *Journal of Experimental Child Psychology*, 1967, 4, 391-397.

Pick, A. D. & Pick, H. L., Jr. A developmental study of tactual discrimination in blind and sighted children and adults. *Psychonomic Science*, 1966, 6, 367-368.

Warm, J., Clark, J., & Foulke, E. Effects of differential spatial orientation on tactual pattern recognition. *Perceptual & Motor Skills*, 1970, 31, 87-94.

Warm, J., & Foulke, E. Effects of orientation and redundancy on tactual perception of form. *Perceptual & Motor Skills*, 1968, 27, 83-89.

Worchel, P. Space perception and orientation in the blind. *Psychological Monographs*. Washington, D.C.: American Psychological Association, 1951, 65 (332).

SENSORY AIDS PROGRESS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT) SENSORY AIDS EVALUATION AND DEVELOPMENT CENTER

George Dalrymple*

Editor's Note: The following description of the research and development progress involving three of the devices for which the MIT Sensory Aids Center is best known was adapted from a report to the Center's sponsors, and covers the period, approximately to the end of 1972 (including some anticipated developments through part of 1973). The report is of more than usual interest, we think, since it is in part an historical narrative *cum* substantive description of what difficulties have been met in the program, and what solutions or compromises were made to achieve hoped-for results. To those involved in sensory-aids research and development, the conduct of work may seem over the years to have the character of little more than a series of chaotic but interlocking events in which frustrating delays, muddle-headed commentary on one's work by others, and unforeseen and uncontrollable delays in one's plans, form a constant and unremitting source of frustration in the path of useful accomplishment. We think it is astonishing that Mr. Dalrymple can ignore all these diversions and convey in a compactly telescoped description all the freshness of discovery and excitement of accomplishment that these devices represent. One is also struck by the achievements of the many users who were an integral and important part of the development of the systems, most especially of Braillemboss.

Similarly, in the description of the TAC-COM system for communicating with the blind and the deaf-blind, Mr. Russell has given us a refreshing and disarmingly skilled look at the complexities that arise in the application of a very simple idea: the utilization of an induction-loop RF receiver system to convey coded signals.

Because these pieces offer a unique view of the inner workings of sensory aids development, we are pleased to publish them, and hope that our readers will find them both informative and--*mirabile dictu*!--entertaining, as we did.

As Mr. Dalrymple points out in a note on the personnel involved in his original report, the staff of the Center during the period covered by the report included Vito A. Proscia, Research Associate and Director of the Center, until April 1972, when he left to become Vice President, Sales & Training, Telesensory Systems, Inc., manufacturers of the Optacon, in Palo Alto, California; Mr. Dalrymple, the present Acting Director of the Center; Nancy Brower, secretary until August 1970; Evelyn Welch, secretary from August 1970 through June 1972; Susan Sokalner, secretary at the present moment; Norman J. Berube, Senior Technician. Additional work was done for the Center by Lindsay Russell, consulting electrical engineer; and Murray Burnstine, consulting mechanical engineer.

The Center was founded in 1964 with John Kenneth Dupress as Director. Mr. Dupress' convictions and vigor profoundly influenced the Center along with the entire international effort relating science to blindness. He served until his death in December 1967. Professor Robert W. Mann was faculty sponsor in augmenting the Center and has served since as Chairman of the Steering Committee.

---

*Acting Director.

INTRODUCTION

The MIT Sensory Aids Evaluation and Development Center (SAEDC) has been exploring three devices to enhance the communication capability of the blind and deaf-blind. The first is the Braillemboss, a braille page printer, or braille-producing Teletype. The second is TAC-COM, a wireless communication and paging system for the deaf-blind. The third is the Pathsounder, a device that communicates to the blind traveler a blockage of the path ahead.

The Braillemboss has been demonstrated in two basic ways; one, an output device for a computer; the other, as a braille production device. There is some overlap in these functions--for example, when the Braillemboss is used as the output device for a computer-braille translation system.

The most significant use of the Braillemboss is as a tool in routine day-to-day employment. It has been used as the communication link from a computer to professional computer programmers; it has been used to give customer-service personnel access to computer data; and it has been used as a newswire printer to give a blind television newscaster access to that service.

The Braillemboss has been used also in small-scale braille publishing activities: several pamphlets, a chapter of a book, and a book. One pamphlet was published in a cooperative effort with the National Braille Press; two other pamphlets are SAEDC Technical Description Sheets. The book chapter was done in cooperation with Technology Community Association and the MIT libraries on behalf of the blind students at MIT and other colleges in the Boston area. The complete book was embossed for the Library of Congress.

The Braillemboss was selected by the national IR-100 Industrial Research contest as one of the 100 most innovative and significant "products" produced in America in 1972.

TAC-COM is a wireless communicator for the deaf-blind. Each user carries a small receiving unit that vibrates when signalled by (wireless) inductive coupling. The system is effective in an area defined by signal loops connected to a fixed-station transmitter. Two installations are presently in use--one at the National Center for Deaf-Blind Youths and Adults, New Hyde Park, Long Island; and one at the SAEDC, Building 31 of the Massachusetts Institute of Technology.

BRAILLEMBOSS

The Braillemboss (Figs. 1 and 2) operates in a fashion similar to a Teletype, i.e., it converts coded electrical signals into embossed braille. The Braillemboss is constructed as an output device only, and when used in an interactive role it must be used in conjunction with a device containing an appropriate keyboard.

The Braillemboss is the product of a long range MIT program involving the efforts of many MIT people (1, 2). Students, faculty, engineers working in the Mechanical Engineering Department, Sensory Aids Evaluation and Development Center, and the Draper (Instrumentation) Laboratories were all involved. The development was supported at various times by the Office of Vocational Rehabilitation, Vocational Rehabilitation Administration, Social Rehabilitation Administration and the Social and Rehabilitation Service of the Department of Health, Education, and Welfare, and by the John A. Hartford Foundation (3, 4, 5, 6, 7, 8, 9, 10).

The Braillemboss' earliest beginning was in a design engineering course (2.671), as a result of a series of lunch-time seminars called "Sensory Aids Discussions," chaired by John K. Dupress. These seminars brought together members of the MIT community, some of those who have worked with the blind, and members of the blind community, to explore the ways technology can help the blind. Initial senior theses by Lichtman and Eglinton were written on the design of a braille printer and of a typewriter input device for it (11, 12).

The first operational braille embosser was built by Kennedy as a Master's thesis (13, 14). This model was refined further, and six units were built at the SAEDC. Two of these units were loaned to users; three were used by students for additional thesis projects; and one was retained at SAEDC. The SAEDC unit later served as a test bed for the changes incorporated into the Braillemboss.

The three student-project braille embossers were built into braille telecommunication terminals by Armstrong for a Master's thesis (15). One of the terminals was then incorporated in a computer-based Grade II braille transcription system by Greiner for his Master's thesis project and saw limited use at Perkins School for the Blind (16). The other two units were used in design improvement projects by Scott and by Sturgis (17, 18).

The SAEDC engineers and technicians, in conjunction with an engineer and design draftsman of the Draper Laboratory, reexamined the design and made changes to improve its reliability and accuracy, and to reduce its cost of manufacture. As a part of this effort 20 Braillembosses were constructed.

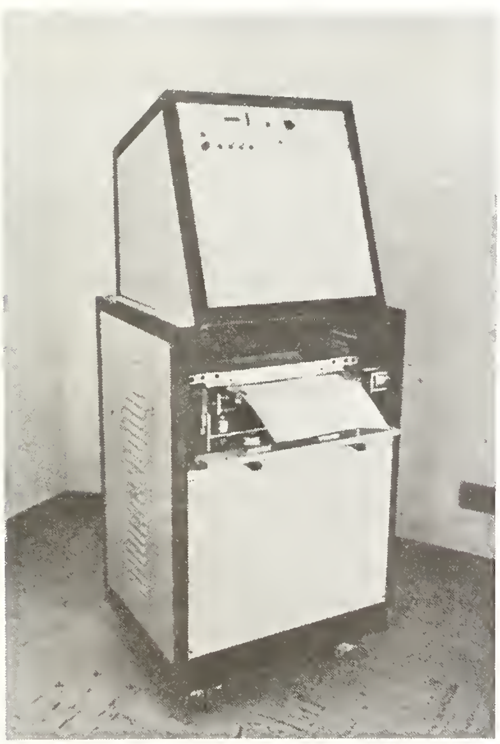


Figure 1. Model 3 Braillemboss

Figure 2. Model 4 Braillemboss

As the Braillemboss is presently configured it uses "brailler code" as its input data (19). This code is an 8-level or 8-bit code; that is, there are eight yes-no elements or bits-per-character or data word. This code was designed to have maximum correspondence to the braille cell. If the eighth level (machine function) is a zero (no), then the first six levels are embossed in braille; i.e., level 1 data becomes dot 1; level 2, dot 2, and so on through level 6, dot 6. If the machine function is a 1 (yes), then the codes in levels 1 through 7 determine the machine function to be performed; these are (a) space, (b) new line (carriage return), (c) new page, and (d) line feed.

The Braillemboss was built to use the existing "standard" brailler code for braille equipment. It was recognized early in the development of the Brailleemboss that maximum flexibility had to be built into the device, as it was expected that uses for the Braillemboss other than remote production of literary braille via computer would be found. Provision was made in the Braillemboss for interface units to adapt it to the desired applications. The flexibility would not be needed when large numbers of Braillembosses are built for any given application, as the control electronics can be optimized for the data transmission code used.

For most of the present applications of the Braillemboss three data transmission codes are used: (1) 5-level newswire (TTY); (2) 7-level EBCDIC, and (3) 8-level Teletype (ASCII). The most common interface unit uses ASCII data transmission code, and has input conversion equipment to permit the Braillemboss to operate in parallel with all of the present 8-level Teletypes: Models 33, 35, 37, and 38, regardless of version, whether Receive Only (RO), Keyboard Send-Receive (KSR), or Automatic Send-Receive (ASR).

An interface unit for newswire (TTY) has seen service at a TV station. This interface unit includes a time buffer and format control circuitry to provide clear format material. An interface unit has been built also for EBCDIC, the code used by IBM for its remote terminals. Preliminary testing of this unit is complete, but it has not seen field service.

Conventional English braille, either letter-for-letter Grade I or highly contracted Grade II forms are not directly usable with computers, as many of the symbols used in the ASCII or EBDIC character set are simply not defined in braille: several characters are ambiguous, i.e., "(" and ")" use the same braille symbol. Further, numbers are not directly defined in braille, but use a number sign before the letters "a" through "j" to represent the numbers 1 through 9 and 0.

A new braille system was defined for use with the Braillemboss. Each symbol in the Fortran character set has a unique braille symbol defined in this system by computer programmers. This code, called "one-cell" braille, uses the same pattern for the alphabet. It takes advantage of the pattern in defining braille, using the identical pattern for the numbers, defining the same bit arrangement as "a" through "j," but using the lower four dots in the cell, while "a" through "j" use the upper four dots of the cell. Then, the most important symbols in the Fortran character set: =, +, -, *, /, (, and) are assigned the least ambiguous braille cells. Finally, the remaining characters used in the ASCII (Teletype) characters set are arbitrarily assigned the remaining braille characters. This one-cell braille has a one-to-one correspondence between each printing character of the ASCII character set used in Teletypes and the 63 possible printing characters in the braille cell. This allows any system based upon the ASCII transmission code to transmit Grade II braille, since each braille symbol has a printing ASCII code to represent it. One-cell braille has also been defined with the 5-level code, with not all braille symbols represented. One-cell braille is also defined for the 7-level EBDIC, but with only 62 printing characters.

Interface units have been built for one-cell braille containing translators for each of these three codes. There have been special features included in some of these interface units, such as a data-controlled on/off switch, and with a time buffer and format-control circuitry for newswire use.

Time-shared Computer Programmer Terminal

The Braillemboss is presently being used by programmers and system analysis with time-shared computers at a U.S. government agency, two companies, three universities, and a residential school for the blind. At each of these installations the Braillemboss is connected to a Teletype such that both the Braillemboss and the Teletype page printer produce the received material simultaneously.

This form of interconnection was selected for two reasons. First, it insures that the installation will not be restricted to blind users, but can also be used by the sighted; this provides maximum flexibility and usefulness of the terminal. Second, it limits the amount of special equipment at the terminal that must be maintained differently from equipment used regularly; it also reduces the complexity of the Braillemboss.

Sensory Aids Evaluation and Development Center Installation

The first Braillemboss built (Serial No. 10) was connected to a Model 35 Teletype at the SAEDC and was first used by a graduate student in his ergometric studies. The terminal was used chiefly with CTSS, a time-shared computer system at MIT based on an IBM 7090 computer. This particular Braillemboss is not presently in use, but could be up-graded easily and put back in regular service if desired. Two Braillembosses (Serial Nos. 26 and 27) have been and are being maintained on line at the Center for use of MIT students and for computer braille experiments and demonstrations.

John Morrison, NASA/DOT, Cambridge, Massachusetts

The first Braillemboss in the field was installed at NASA Electronic Research Center (ERC) in Cambridge. The Braillemboss and Teletype were installed in Dr. Morrison's office during October 1969 (Fig. 3).

ERC was disbanded in June of 1970 and the facility was transferred to the Department of Transportation. Dr. Morrison transferred to the Department of Transportation's (DOT) Transportation Research Center. In October of 1970 the Massachusetts Commission for the Blind purchased one Braillemboss for Dr. Morrison's use, and the DOT installed a Model 33 Teletype. At that time the SRS-supported equipment was removed.

Appendices 1 and 2 are Dr. Morrison's written reports on his use of the Braillemboss. It should be noted that the last service call, except for lubrication, was in early 1971 to install a convenience switch

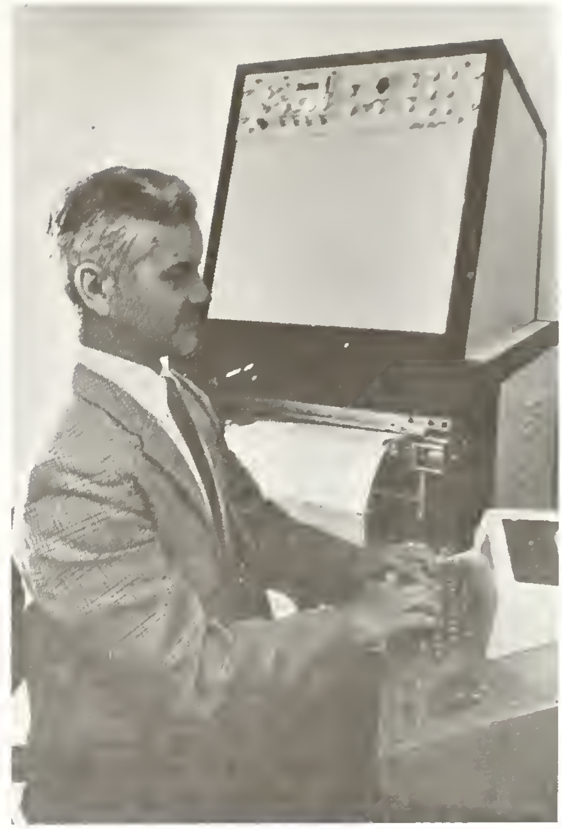


Figure 3. John Morrison at Brailemboss Terminal.

and to adjust the electronic timing to eliminate the occasional random dropping of characters. The Braillemboss and Teletype have been moved at least twice, by DOT and by telephone personnel, without assistance from the Center.

Programming Course, Perkins School for the Blind, Watertown, Massachusetts

For several years the Perkins School for the Blind has offered a course in computer programming for students in the upper school during their junior and senior year (20). The object of the course was best expressed by Benjamin F. Smith in a report to "The Blind in Computer Programming, an International Conference" describing the reasons for use of a time-shared computer:

> ". . . we concluded that this computer plan offered considerable promise as a tool in the

classroom of some of the subject areas in our senior high-school department. We felt that the application of the computer to classes in mathematics and science would be particularly effective both as a means of greater efficiency in the learning process and also as a means of motivating our students to greater interest and effort.

"Finally, since it had already been well demonstrated that blind people can be highly successful vocationally as computer programmers, we concluded that we should give our students experience on the computer with a view to exploring both vocational interests and vocational aptitude." (21)

An MIT Braillemboss was transferred to Perkins and was connected to a Teletype previously rented by Perkins. The initial time-sharing computer service was provided by General Electric. (A Babson College Hewlett-Packard Model 2000C time-shared computer system presently is used.)

The Perkins students are taught both how to use a time-shared computer and how to program with programming language. During the 1972-73 school year there were seven students, including five braille users, in Computer I, and five students, including four braille users, in Computer II. The computer terminal room is now left open during certain afternoons and evenings each week for use of both students and members of a computer club.

The Braillemboss has operated reliably and efficiently, with only two service calls in the period March 1970 through January 1973. Its performance and student acceptance of it has demonstrated that a reliable, maintenance-free braille terminal is an essential adjunct to teaching blind students computer programming via a time-shared computer.

Alan Downing, Systems Programmer, Honeywell Information System (HIS), Cambridge, Massachusetts

Alan Downing exemplifies the importance of an interactive braille terminal to a motivated, intelligent blind student or computer professional. During his junior year at MIT (1970-71) Downing took an introductory course in Fortran programming. He was not content to have other students read his output or proofread his input. He arranged with the SAEDC, therefore, to use one of the Braillemboss terminals at the Center as his terminal, and arranged with the Department offering the course to support his use of the IBM 360/67 time-shared computer at the MIT Computation Center. This proved satisfactory and was continued during his senior year.

Downing obtained summer employment at Intermetrics, Inc., a "software house," contingent upon a braille terminal being available to him at their office. The SAEDC then agreed to loan him the terminal shown in Fig. 4 until a cooperative agreement could be reached with the Massachusetts Commission for the Blind (MCB). The MCB, through an arrangement similar to Dr. Morrison's, underwrote the transfer of a Braillemboss for Downing's use. A new Braillemboss was installed for his use and the temporary Braillemboss returned to the Center.

During his senior year Downing continued employemtn at Intermetrics on a two-day-a-week basis, and upon graduation he was offered full-time employment. He decided, however, that he would rather work on development of the operating system of a large scale computer, and obtained employment at HIS. The Braillemboss was moved to his new location and has continued to give good service.

Donald Keeping, Supervisor, Programming Course for the Blind, University of Manitoba, Winnipeg, Manitoba

This Braillemboss was procured through a grant from the Canadian National Research Council for use of teachers and students

Figure 4. Alan Dowling at Prototype Braillemboss Terminal

in the Programming Course for the Blind. The Braillemboss was shipped during October 1971 and was installed by University of Manitoba personnel during November. At the present time the Braillemboss is used only by Keeping, as all of the present students, while legally blind, have sufficient vision so as not to require braille.

The Braillemboss is used with a Teletype as a terminal on an IBM 360/65 system using Time Sharing Option (TSO). Keeping estimates that he uses it 4 or 5 hours per week, chiefly before and after normal working hours and on weekends.

It is also being used in a small-scale program to generate French braille for a group in Toronto. The programming associated with transcribing Grade I French braille is comparable to transcribing English into Grade I braille, and is much simpler than Grade II English braille.

The University of Manitoba experience is summarized in a letter from Donald Keeping to Vito Proscia:

> "As you know, we have recently installed here at the University of Manitoba an MIT Braillemboss. Outside of a few minor mechanical problems, we have found the system quite satisfactory. We have here a suite of conversational mode programs which are excellent on such a device." (22)

<u>Terry Hicks, Programmer, Bristol Engine Division, Rolls Royce (1971), Bristol BS12 7QE Great Britain</u>

A Braillemboss was transferred during March 1972 to Rolls Royce, Ltd. for use by Terry Hicks, a blind programmer in their Bristol Engine Division. A letter from Dennis C. Boston, Head of Mathematical Services Department, to Milton D. Graham of the American Foundation for the Blind, describing their use of the Braillemboss is appended (see Appendix 3). This Braillemboss was converted to 117-V, 50-Hz power, and was tested on 50-Hz line at the Maynard Plant of the Digital Equipment Company (DEC). Since the Braillemboss is being used on the DEC PDP-10 computer at Rolls Royce, DEC crated, shipped, and installed the Braillemboss.

<u>Phillip Hall, Worcester Polytechnical Institute (WPI), Worcester Area Collegiate Computation Center (WACCC), Worcester, Massachusetts</u>

Through a cooperative agreement negotiated by the SAEDC between the MCB and the New Hampshire Division of Blind Services, a Braillemboss owned by MCB has been loaned to WACCC. It is presently being used by Phillip Hall, a blind student at WPI from New Hampshire. The Braillemboss was installed by the staff of the SAEDC and is located in the terminal/keypunch room at WACCC. It is connected to one of the four Teletype terminals of the PDP-10 located in the main Center. This terminal is available to any of the users of the WACCC PDP-10, but it is the only one usable by Hall. He does not have absolute priority to this terminal, but must wait his turn when all the terminals are in use. When a terminal becomes free, the user of the Teletype/Braillemboss terminal is asked to move to another terminal so that Hall can use the Braillemboss.

For the second semester of the 1972-73 academic year Holy Cross College is planning to install a new Teletype unit in the terminal/keypunch room at WACCC for the use of a blind student. The Braillemboss will be reconnected to this Teletype. This will give blind students a terminal that will give them absolute priority over all other users.

The WACCC serves a consortium of colleges and universities in the Worcester area. There are approximately 10 blind students in these colleges and WACCC is expecting five or six of them to make use of the Teletype/Braillemboss terminal during the second semester this year. (It should be noted that Holy Cross is not now a member of the consortium.)

Customer Service Computer Terminal

In the past several years the computer has become an important part of many nontechnical jobs. One of these is customer service. Inquiries can be about an account or about organizational policies. Another potential job area is the making and confirming of reservations for airlines, hotels, motels, rental cars, etc. In many of these jobs contact with the public is via telephone. Some special equipment is required for a blind person to fill these jobs. Perhaps most important he must have access to a computer output. The Braillemboss is capable of being used as an output device with essentially any computer used in the customer service field. In certain cases telephone indicators may be required. The typical working blind person either has most of the additional equipment required, or it is regularly supplied to him by existing rehabilitation agencies.

Jack McSpadden, Taxpayer Service Representative (TSR), Internal Revenue Service (IRS), District Office, Little Rock, Arkansas

The IRS has employed many blind persons as TSRs whose function is to assist the public in obtaining information on the tax codes and tax rules and regulations, and to answer questions concerning taxpayer records. Presently most of the some 40 braille-using Taxpayer Service Representatives are limited to answering questions only on the tax code, rules, and regulations--unless they have sighted help to obtain the required data on taxpayer accounts.

In certain regions the taxpayer records are now available on the Integrated Data Retrieval System (IDRS), a large, regionally based computer. Each district office in a region with IDRS has Cathode Ray Tube (television-like) displays, on which lines of data are displayed for a sighted TSR. Each office also has a Receive Only (RO) Teletype to provide a "hard" copy, one that can be saved when needed.

A Braillemboss was connected to the RO Teletype so that a braille copy and an inkprint copy can be made when requested (see Fig. 5). McSpadden, a blind TSR in the Little Rock office, now has access to the braille equivalent of the other TSRs' hard copy in the office. His access to the data is only slightly slower than other TSRs when they are not using hard copy.

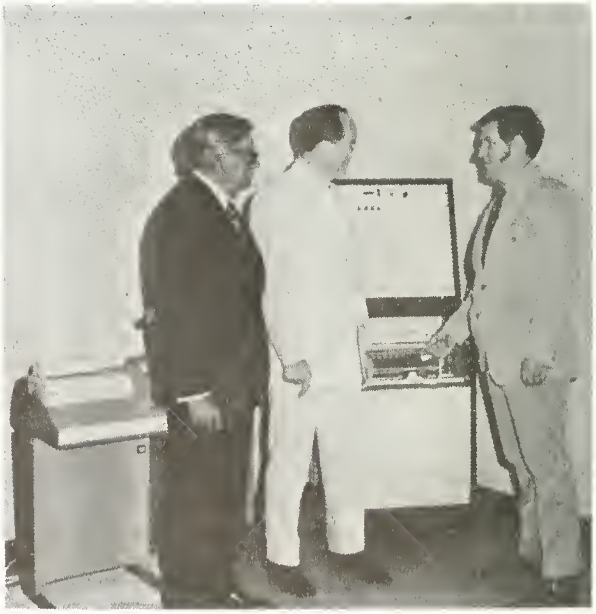


Figure 5. Jack McSpadden Showing Braillemboss to J. M. Walker, IRS Commissioner and A. W. Brisbin, Regional Commissioner.

McSpadden is an enthusiastic Braillemboss user. He is reported by his supervisor to be performing all his duties essentially as do the other TSRs in that District office. It should be noted the Braillemboss has removed the restriction of needing sighted help, or of limiting McSpadden's services to answering only tax code questions.

Newswire

A serious handicap to the blind performing as radio or television newscasters is the lack of usable direct braille copy of newswire services. The Braillemboss, with a suitable interface unit, has demonstrated that it can provide this copy. To develop and demonstrate this capability several steps were undertaken.

The first was to produce newswire braille in non-real time, to determine the utility of the braille copy, and to explore the system before a final design was fixed.

The initial step to demonstrate program feasibility required that the following be available: a newswire service with a tape reperforator, a 5-level TTY code to one-cell braille translator, a paper-tape reader, and a Braillemboss.

The first items were available for a limited period at Electronic System Laboratory (ESL), a part of the Department of Electrical Engineering. (The Laboratory was performing some studies on computer storage and retrieval of news, sponsored by the American Newspaper Publisher Association.) A United Press International (UPI) newsprinter and reperforator was also available which could produce 5-level punched paper tape for our use.

The SAEDC had all the remaining necessary equipment, with the exception of the translator. The translator was designed and fabricated by the staff engineer, and was installed in one of the MIT Braillembosses located at the Center. A pilot program was then initiated; punched tapes were acquired from ESL, brought to the Center, and translated into braille via the Braillemboss system.

The braille material produced by this method was distributed to three blind readers for examination and use. Approximately five hours of newswire services (produced on a daily basis), were converted into braille each day. The conversion of the newswire-service information into braille took approximately three hours running time. The pilot study was performed during May and June of 1970, and terminated when the UPI reperforator service was discontinued at ESL.

The next step was taken when Paul Caputo of Westfield, Massachusetts obtained a job as a television newscaster at WWLP-TV (Channel 22) in Springfield, Massachusetts, with the provision that the Massachusetts Commission for the Blind would obtain newswire braille for his use (Fig. 6). A Braillemboss was installed at WWLP-TV during May 1971.

The interface unit for this installation had to be significantly different from that used previously for the news demonstration. In the first news demonstration, punched paper tape was used as a convenience, but it also served as a timing buffer to accommodate the carriage return time of the Braillemboss. Using

Figure 6. Paul Caputo Reading Braillembossed UPI Newswire Copy.

this method in an operational system is not desirable, since paper tape is yet another expendable item, and the system would require a tape reader and tape punch. Furthermore, full reel of paper tape lasts only five or six hours, while a box of braille paper lasts several days; this complicates the operation and requires much more attention by the user than is reasonable.

To simplify the system, an integrated-circuit storage system was designed and built to provide the necessary timing buffer, thus eliminating the need for the intermediary paper tape. Two shift registers are used, both 128 words long with eight bits-per-word. While one register is being loaded from the newswire the other register is used to drive the Braillemboss. When the register being loaded is full, the system interchanges the registers. Sufficient time generally exists to unload a register into the Braillemboss while the other register is being loaded.

Included in the interface unit are format control circuits. A space counter and line-control circuits are used to divide the 72-character line of the Teleprinter at a space near the 38-cell length of the Braillemboss line. This generally eliminates dividing words randomly at the end of the line. Paging-control circuits were included also to prevent embossing on the perforations.

This newswire Braillemboss installation was accomplished, as noted, as a cooperative program with the Massachusetts Commission for the Blind. The Center adapted a Braillemboss to the UPI newswire by designing and constructing the interface unit. The MCB supplied funds for the necessary hardware.

Unfortunately Caputo's relationship with WWLP-TV ended during October 1972. But the Braillemboss performed well during the period and provided him with excellent braille copy that he could read rapidly and accurately while on camera.

There is some dropping of characters in the timing buffer used in the newswire interface unit when a long series of short lines are received. Computer memory technology developments since the newswire interface unit was designed should permit significantly better buffer performance for approximately the same cost as the original buffer.

Interactive Grade II Braille Production

A computer program for Grade II braille transcription (DOTSYS III) was written by the Mitre Corporation under contract to the SAEDC (23). (This contract was supported from a multi-sponsored MIT account.) The program is written in COBOL (*CO*mmon *B*usiness *O*riented *L*anguage) so that it can be transferred from one suitably equipped computer to another with few changes (24, 25, 26).

Additions have been made to DOTSYS III to use the Braillemboss as an output device. This modified program is stored in the time-shared computer of Interactive Data Corporation, in Waltham, Massachusetts, a commercial computer facility.

A Teletype, connected by telephone line, is used as the input/output device of the computer. The Braillemboss is connected via an interface unit to the Teletype. The material to be brailled is typed into the computer, where a data file is created. This file can be proofread and corrections made. Then, with a single command, the material is translated by the computer and brailled on the Braillemboss.

The initial interface units did not include a computer-controlled brailler on/off switch so that they could be used with the computer translation program. A redesign of the Model 33/35 interface unit permits the Braillemboss to be used as a time-shared computer terminal for a blind programmer, or by throwing a switch, to be used as the braille output unit for DOTSY III. All interface units now have this modification.

National Braille Press (NBP) Demonstration

The first substantial use of DOTSY III by the SAEDC was the brailling of an IRS publication for a client of NBP in December 1971. The material to be brailled was typed into the computer, using the necessary format controls, thereby forming the input file. The input typing was done by personnel of both NBP and the SAEDC. As sections of the input file were completed, these sections were individually translated, brailled, and proofread. Typographical errors in the input file were corrected, and small changes were made in the translation table of the program to remove program braille errors. After the input file was completed and all known errors corrected, the entire publication was translated, embossed by the Braillemboss, bound by NBP and delivered to their client.

The system shown in Fig. 7 was demonstrated to a large group of possible employers and workers for the blind on January 31, 1972. An employee of NBP produced several pages of braille. Following the typing and correction of the input file the remote computer translated the material which was then brailled on the Braillemboss.

In Darkness

On January 5, 1972, Howe Press of Perkins School for the Blind issued a purchase order ". . . to do a single copy at MIT of the novel *In Darkness* using a paper tape prepared by computer, and to provide Howe Press with a paper tape to drive the stereograph machine. . . ." Scheduling commitments with the NBP demonstration delayed start of this work until February 1, 1972. The same steps were employed in the translation as at NBP, including two proofreadings, except that a punched tape was prepared while a copy was being produced by the Braillemboss. (The proofreading was performed by NBP personnel under a purchase order arrangement on a "time available" basis.)

Figure 7. Janet Fields Examining Braille Produced on Braillemboss at National Braille Press.

The unbound braille copy was delivered to Howe Press on April 12, 1972. The SAEDC staff worked with Howe Press personnel in testing, adjusting, and repairing the APH paper tape-driven stereotype. The SAEDC staff then operated the stereograph and otherwise assisted in producing the embossed zinc plates for press-run braille production. (The stereotype's reliability could be improved upon by replacing the relay control system with solid-state logic as used in the Braillemboss.)

The experience gained by the regular staff of the SAEDC, supplemented by proofreaders, has demonstrated that the existing computer program and equipment can produce computer translated braille. It cannot be done efficiently, however, unless the work is performed by an organization fully and completely committed to braille production. The overall national production and timely availability of braille would be improved if several regional computer braille production facilities were established to supplement the work presently being done by The American Printing House, the many volunteer agencies, and the braille libraries. These regional facilities could be new organizations or extensions of existing braille agencies (27).

Technical Description Sheets (TDS)

Two sets of TDS have been translated by *DOTSY III* and stored in punched paper tape form so that copies can be produced on demand.

The first was TDS No. 2, "The Braillemboss, A Braille Page Printer," (see Appendix 5). In inkprint it is two full single-spaced typewritten pages; in braille it is six plus pages. A typist with some previous experience typing in material for DOTSYS spent approximately an hour typing the material, proof reading, and correcting the input file that was produced. It then took 20 minutes of terminal time to translate and braille the material.

A total time of 80 minutes was required for a person familiar with the DOTSYS format control convention (see Appendix 6, TDS No. 11) to produce this report. It was not necessary for that person to know Grade II braille, however, a user should have enough knowledge of braille to check for obvious operator, computer transmission, or terminal error.

The TDS No. 1, "Folding Canes," (28) has also been translated by DOTSYS III. Slightly shorter than TDS No. 2, it is five and one-half braille pages long and took 45 minutes to produce.

Both TDS are available in braille on request from SAEDC.

"The Social Beaver"

The SAEDC, in conjunction with Technology Community Association (TCA), the MIT Libraries, and the Howe Press has embossed 25 copies of "The Social Beaver," a chapter of HoToGAMIT (How To Get Around MIT). HoToGAMIT is a paperback student guide to MIT and the Boston area. The chapter entitled "The Social Beaver" is a guide to enjoying oneself in and around Boston, and is applicable to all, not just MIT, students.

Through a fortunate set of circumstances, catalyzed by Steve Shladover of TCA, this braille volume was made possible. Lindsay Russell volunteered to produce the braille-coded punched paper tape necessary to produce the copies of braille economically on the Braillemboss.

The Braillemboss had been used previously to produce braille materials from manually-prepared punched paper tape. This punched tape was prepared by a professional braillist using a modified Perkins Braillewriter connected to a paper tape punch.

The Center has a special Teletype, modified by Telephone Pioneer Raymond Morrison, which produces braille-coded punched paper tape directly from its keyboard. This Teletype contains all Grade II braille symbols in its character set.*

Bertha Kasetta of the Howe Press, and two blind young people presently or formerly MIT students, proofread the material. The book was then brailled on the Braillemboss operated by TCA volunteers under the direction of the Center Staff.

The MIT Libraries undertook the distribution of copies of the finished volume to other universities and colleges in the Boston area. A copy has been given to each blind student at MIT. The libraries also underwrote the cost of binding the volumes by the Howe Press.

Rehabilitation Agency: Arkansas Enterprises for the Blind, Little Rock, Arkansas

A Braillemboss was made available to Arkansas Enterprises for the Blind (AEB) to be used in their rehabilitation and training programs. It was installed during September 1972. AEB has obtained a minicomputer and paper tape equipment to be used with the Braillemboss.

AEB's applications include training of IRS/TSR students on the IDRS system. They will also use the Braillemboss to train other students in computer interaction. The minicomputer can be used both as a simulator of the larger IRS/IDRS or as a small computer for actual operating and programming experience by other AEB trainees.

Another AEB application of the Braillemboss is the braille duplication

---

*This Teletype is similar in concept, but different in detail, to the Tyco brailler developed by Woodcock (29).

of instructional materials. A paper-tape punch/Perkins Braillewriter combination was borrowed from Howe Press to support this effort. The Howe Press equipment was used by an expert braillist to produce a punched paper tape which is then used to operate the Braillemboss to produce as many braille copies as desired. This same paper-tape equipment was used at an earlier time by MIT to produce a pamphlet for Perkins upper school students to establish the accuracy of reproduction by the Braillemboss.

TAC-COM*

Introduction

TAC-COM (for "*tac*tile *com*munication") is the name given a system of signaling to deaf, blind, and most importantly, *deaf and blind* persons. The focal device of the system is the TAC-COM pocket receiver (Fig. 8); a six-ounce instrument which vibrates in response to a radio signal. Carried on the person (in a shirt pocket typically) the receiver functions as a pager, not unlike the pocket pagers

Figure 8. TAC-COM Receivers, Front and Rear View.

*This section written by Mr. Lindsay Russell.

in common use by physicians in a hospital, or executives in an office building. Instead of beeping in response to a call, however, the TAC-COM receiver vibrates. Held in the hand, when it is activated it feels rather like an electric toothbrush while running.

Two purposes established the initial scope of the TAC-COM project, both related to needs of the deaf-blind: to develop something to serve as a fire alarm and also as a doorbell.

The financial support for this project came from two sources: an initial purchase of hardware by the National Center for Deaf-Blind Youths and Adults* with a view toward fulfilling the above two needs; later, support over a three-year period by the Social and Rehabilitation Service of the United States Department of Health, Education and Welfare, with the objective of augmenting and broadening the usefulness of TAC-COM beyond this initial limited scope.

Background

To summon a person who is both deaf and blind, to alert him that there is a fire, that he is wanted elsewhere, or to signal that a particular moment has come ("end of lunch hour") is not an easy thing, unless one is close enough to touch him. A person who is blind, but hears normally, can be alerted in the usual auditory ways: doorbell, fire gong, even by calling out to him. A deaf person, if he has sight, can be signaled visually by turning a light on or off, or in any other way that will catch his eye. For the deaf-blind, there seems to have long been a need for some scheme that could call a person from a distance without needing either his eye or his ear. Many techniques have been used, such as stamping on the floor or starting an electric fan

*Referred to subsequently in this report as the "National Center," it is located at 105 Fifth Avenue, New Hyde Park, New York, and administered by the Industrial Home for the Blind, Brooklyn, New York.

(to create an air current), but they have obvious limitations in range and dependability.

Although it is this double handicap to which TAC-COM is primarily addressed, there come to mind ways in which a person afflicted with deafness or blindness alone could make use of a vibratory signaler. A deaf person can be alerted by turning on a lamp, but only if it is assured that he will be looking where the light can be seen--a difficult requirement when he is outdoors. A nonauditory signal could be useful to a blind person under many circumstances one could envision: when a sound-maker would embarrass him, annoy others nearby, drown out other sounds he must hear, etc. Thus, while the needs of the deaf-blind are the main objective of TAC-COM and its (by now) many adjuncts, there has been attention given that potential benefits to those with either single handicap do not pass by us unheeded.

Technical Description

Radio-frequency induction is the basic technique of the TAC-COM system. This is not true radio communication; indeed, it is a form of signaling that historically antedates radio. The transmitted signal is a 25-kHz alternating magnetic field, set up by energizing one or more loop antennas placed typically on the walls of the building or rooms to be covered. Figure 9 shows the transmitter proper, an all solid state unit housed in the kind of cabinet used for audio amplifiers or small public address systems.

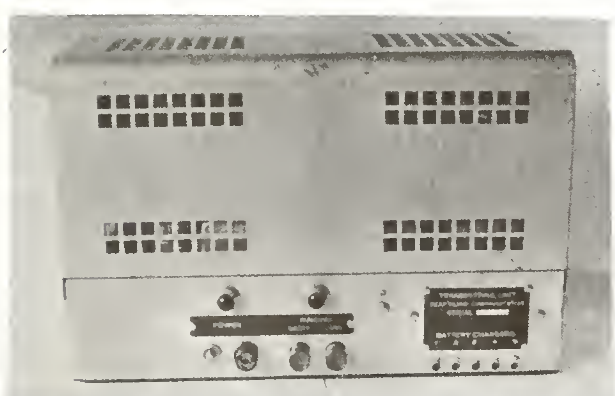


Figure 9. TAC-COM Transmitter

Creation of the ringing field is accomplished by pressing a button on the front of the transmitter. "Short Ring" is a momentary-contact pushbutton; "Long Ring" evokes an activation of fixed duration, typically set at five seconds. The latter feature is primarily for insurance against missed calls due to an overbrief button push on the part of the caller. Pushbuttons at other locations can be wired to terminals on the back of the transmitter so that it can be activated from a remote location if more convenient.

Five small jacks on the front of the transmitter are outlets for recharging batteries within the TAC-COM receivers. This is done each night; thus, five receivers can be recharged simultaneously.

Receiver

Specifications of the TAC-COM pocket receiver are:

Weight	6.3 ounces
Size (approx.)	2-1/2" x 7/8" x 5"
Battery	Four Burgess CD-3 or equivalent
Ringing time	45 minutes, starting fully charged
Listening time	150 hours, starting fully charged

"Listening" means the quiescent situation in which the receiver is switched on to respond to a call, but is not actually being called. There is very low battery drain, as compared with "ringing," hence the many hours of use when the receiver is on but not activated.

The components are all housed in a small aluminum case, except for the loopstick receiving antenna which is potted in silicone rubber at the bottom. When the transmitter is activated and a ringing field established, a weak 25-kHz signal is induced in this loopstick. It is amplified by circuits within the receiver, detected, and if above a certain minimum threshold, energizes a tiny electric motor within the instrument. Vibration is generated by a tiny eccentric on the motor shaft. The mechanical inertia is low, and the vibration starts and stops within milliseconds of the starting and stopping of the ringing field.

Transmitting Loop Antenna

All installations to date make use of transmitting loops in vertical planes, so that the magnetic field lines will be substantially horizontally oriented in the service area. The receiver loopstick will normally be oriented more or less horizontally too, for example, in the pocket of a sitting or standing person, so that its alignment is appropriate for the exciting field. If this exciting field were generated by a single-loop antenna, however, a null direction would exist at which the loopstick, though horizontal, would be perpendicular to the magnetic flux lines. (Anyone who has rotated a transistor radio in his hands will have observed corresponding nulls that it, too, exhibits in certain directions.)

To avoid the risk of missed calls due to a user's possible unfavorable orientation while being paged, a second loop is used, also connected to the same transmitter, but whose exciting current is in time quadrature with that of the first loop, and whose physical placement is at right angles. This arrangement effects essentially null-free coverage, since the null direction of one loop's field will be nearly at the maximum of the other's, and the time quadrature relating the two will prevent destructive interference at intermediate angles.

Why Magnetic Induction?

A word or two ought to be said about the choice of this low-frequency induction scheme, especially considering that there are true radio systems as alternatives. For example, why not use Citizen's Band channels, or possibly even private frequencies of one's own assigned by the Government?

Easily the most negative feature of the induction system chosen is the need for transmitting loops; for strong coverage, the wires comprising them must run the length and breadth of the coverage area. Whether this factor makes the installation of a TAC-COM system troublesome and expensive depends on the building involved, whether the wires must be totally out of sight, and so on. There are ways of avoiding some of these problems, about which more will be said in the next few pages.

The positive features are technical simplicity and freedom from radio interference problems (false rings, etc.). The receiver uses only five transistors, and its simple circuit lends itself to substantial further miniaturization, should such be sought. The noise level at its detector is more than 50 dB below the signal present upon receiving a ringing signal; the transmitter, with only several watts output, provides considerable "overkill." In short, there is a high strength or safety factor in this system; only the most rare and unlikely circumstances could be envisioned in which it would interfere with or suffer interference from other radio services.

Installations to Date

TAC-COM signaling systems have been installed in:

1. The MIT Sensory Aids Center at 292 Main Street, Cambridge, Massachusetts;

2. The MIT Sensory Aids Center at 77 Massachusetts Avenue (Building 31), Cambridge, Massachusetts;

3. The Headquarters of the National Center for Deaf-Blind Youths and Adults, New Hyde Park, New York (30);

(4) The apartment of a deaf-blind National Center staff member at Kew Gardens, New York.

The MIT Installations

The TAC-COM installations at MIT (two, because the Sensory Aids Center moved from its old to its new location in 1971) were set up not only to prove out the system in an initial way, but to gain the experience of many months of continuous operation--a designer's life-test, so to speak. Both installations were accomplished without difficulty; the coverage area in each case was about 4000 square feet, and was null-free. The one transmitter involved has run about three years without breakdown. It can be keyed (to page receivers in the area) by pressing a button either at the Director's desk or at that of his secretary. One staff member has for several years made it a habit to keep a receiver in his pocket at all times while at work; to gain him a secondary benefit (besides the main one of life-testing the equipment involved), the transmitter has been wired to the Center's telephone switchboard to signal incoming calls, and to an "electric doormat" to signal that someone has entered the front door. Since the reception area and switchboard are unattended at off-hours, the arrangement permits him to work in remote areas of the Center without missing incoming calls or visitors.

The New Hyde Park Installation

This TAC-COM system was installed at National Center Headquarters and put in operation in July, 1970. A semi-institutional setting wherein a number of deaf-blind clients are served in various rehabilitative and sheltered work programs, it has been here at the National Center that the bulk of experience has been gained with the kinds of handicapped people TAC-COM is designed to serve.

The system is in use at this Center as a fire or evacuation alarm (initially for testing and demonstration, but now in real use) and has been wired to a time clock to signal each hour's rest break and return to work. The system has functioned as it was designed to, although a number of problems have turned up. The main difficulties and their solutions are summarized in the following sections.

Vibration amplitude. Many clients find a severe startle factor in the TAC-COM stimulus. This is not surprising. Experience suggests that a person deprived of one or more senses is startled by a relatively minor stimulus in a remaining sense, especially when the stimulus onset is sudden. Thus, the TAC-COM vibration, which seemed just adequate to its designers for reliable detection through a layer or two of clothing, was excessive to most deaf-blind people, and many objected to wearing the early receivers for that reason. The problem is easily corrected by reducing the rotor mass eccentricity in the receiver's motor. A number of receivers were recently so modified on a trial basis for the National Center by MIT.

Inadequate pocket retention. A second problem was that receivers dropped out of users' pockets with considerable frequency, sometimes being damaged on striking the floor and needing subsequent repair. (The early units had pocket clips more suitable for securing a pencil than a six ounce receiver.) The retaining method was improved a little by cementing abrasive patches to press against the pocket wall, but even the improved units had only marginal retention. On the assumption that each receiver would probably get dropped sooner or later anyway, more rugged mounting means were arranged for the batteries and motor inside; these were the components that generally were dislodged by a bad fall. Each receiver returned to MIT for repair was sent back not only fixed, but with more secure internal construction. The problem, then, while not solved completely on a hard-and-fast basis, was considerably alleviated. Further work should include a stronger clip yet, perhaps even special pockets sewn on the clothing of users for whom nothing else will work, perhaps mounting on a belt, or other similar strategem. Finally, miniaturization of the receiver would make the task of retaining the receiver in place easier no matter what the scheme of mounting.

Installation of loops. A third TAC-COM problem is the nuisance factor (and possible cost) of installing the transmitting loop antennas. The number of loops needed and their placement depend on the geometry of the service area, and it is not feasible at present to prepare a universal manual of instructions. The magnetic flux paths are not straight lines, but curve away at some distance from a loop, so that for the moment engineering judgment is needed to prescribe installation for a particular setting. For this reason, and with a limited number of installations envisioned at present, it has seemed a wise policy for the Sensory Aids Center at MIT to examine each setting and suggest an antenna arrangement. A way has been found to simplify the loop requirement now, described later (see Horizontal Loop).

Miscellaneous improvements. Several items of more minor nature were suggested by National Center personnel, improvements which would diminish nuisance value and result in greater convenience to deaf-blind users.

One would be a "short-stop" button on the receiver: pressing it during a ring would terminate or abort the remainder of that ring. A time-clock signal, for example, might last ten seconds; the user who "got the message" during the first second could press the "short-stop" button and not be subject to nine seconds' additional vibration.

Also desirable: a more convenient recharging method than connecting the small charging plug to the receiver. Perhaps the electric toothbrush scheme could be used: the receiver would merely be dropped into a slot or receptacle and recharged by magnetic induction; no connections would be needed.

Kew Gardens (Apartment) Installation

A "doorbell" installation was put in use on a test basis at the apartment of a National Center deaf-blind staff member. The transmitter was placed atop a refrigerator in the kitchen, and two loops were affixed to kitchen walls at right angles. The coverage was adequate in most of the two-bedroom apartment, although just marginal at extreme ends of the furthest rooms. The loop arrangement was responsible for the marginality; it was a compromise which avoided time-consuming work of an electrician in snaking wires through walls, etc. The transmitter was actuated by the apartment front-door intercom "beeper" by means of a sound switch (described later) placed against the tiny intercom loudspeaker in the user's living room. Results of this TAC-COM set-up were reported to be satisfactory; it was taken down, however, when the user moved to a new location.

Ancillary TAC-COM Devices

A considerable part of the SRS-supported TAC-COM work was a study of ways to augment TAC-COM's usefulness beyond the simple paging or calling function. A number of techniques were studied and devices designed to that end; many of the studies resulted in working hardware, and some of this hardware was placed into service with deaf-blind clients (at the National Center) during the period of the contract. These subsidiary studies are described as follows.

Standby Battery

An emergency stand-by battery pack was developed for the 115-V transmitter so that it could continue to run in the event of ac power failure. If the TAC-COM system were used as an emergency or fire alarm, it is apparent that the very circumstances that might call most urgently for activation of the alarm could be accompanied by a failure of ac power; hence the need for the battery pack.

The stand-by pack is "retrofittable" into existing transmitters; that is, the pack fits entirely into the present transmitter cabinet. The battery, a set of nickel cadmium cells, is kept on trickle charge under normal conditions, so that they are always fully charged. A sensing relay responds to failure of the main power, and within a second, throws the battery on to the transmitter's internal dc bus to supply energy if a ring is called for. The battery will provide 30 minutes of ringing, enough, obviously, to warn of an emergency.

Long-playing Battery

Something quite separate, and not to be confused with the above, is a small rechargeable battery pack not much bigger than a TAC-COM receiver. It is typically kept in one pocket, and the receiver in another, with a tiny cable running between them. Its function is to give the receiver a substantially longer ringing time than the 45 minutes it normally gets from a full charge on its own internal battery. The reason is that sometimes a receiver is used for many hours a day in situations involving much ringing, and if operated on its own battery alone, would run down long before the day ended. An example of such use is in training deaf-blind clients to walk a straight line (correcting veering tendency) in which the trainer signals to him when he veers via the TAC-COM, by keying a hand sender (described below).

Hand Sender

The hand sender (Fig. 10) is a short-range (about 3 feet) battery-operated transmitter. One of its uses is to demonstrate the TAC-COM system to visitors or to handicapped persons. One hands such a person a

Figure 10. TAC-COM Hand Sender

receiver, then makes it ring by pressing a signal button on the hand-held sender several feet away. The advantage of the short range, of course, is that one does not ring all the receivers in the area, as would happen if the main transmitter were keyed. Thus, a rehabilitation counselor can work with a particular client in an institutional setting, make use of the short-range TAC-COM feature for some purpose or other, and not disturb other clients by making their instruments ring too.

End-of-Line Signal

Another specific use for the short-range signal is to create a vibratory equivalent to the "end-of-line" bell on a typewriter. The typist wears the TAC-COM receiver in the usual way, with the hand sender placed on the table alongside the typewriter with a small cable connecting the two. As he approaches the end of a line, the instant the typewriter warning bell rings, the hand sender is keyed for about one-half second, so that the pocket receiver gives a brief burst. Although the typist can neither hear the bell nor see the line he types, he gets the warning anyway, and need not keep stopping to feel the carriage position relative to the end of the line. The complete system is shown in Fig. 11.

The typewriter must have a tiny switch installed at the bell hammer, and a small connector on the back of the machine, so that the hand sender can be connected or disconnected. The typewriter is not encumbered in any way when the new feature is not is use. So far as can be ascertained, most makes of machines can be equipped with the bell switch; and, more important, so can a Perkins braillewriter. One such Perkins machine was furnished to a deaf-blind braille user for trial.

Selective Ringing

The TAC-COM system at present is an "all ring" system: receivers are identical, and all respond in unison when the 25-kHz activation field is present. One can envision

Figure 11. Vito Proscia Using TAC-COM End-of-Line Indicator on a Perkins Braillewriter.

circumstances in which it might be desirable to signal one receiver or another out of a group; paging one particular individual without disturbing any others. A brief study was made of ways to achieve selective ringing. A straightforward way would be to tune receivers in the area to different frequencies, and to modify the transmitter for multi-frequency operation. Subcarrier or tone modulation schemes would be another way.

The selective ringing problem was studied briefly on a theoretical basis. The conclusion was that it would cause considerable complication of present equipment, but is nonetheless quite feasible. No hardware was built. No user or using agency, to our knowledge, felt a need for incorporating this feature into existing programs, while hardware for other TAC-COM ancillaries, such as the sound switch, *was* needed. First hardware priority was given where a need existed.

Sound Switch

The sound switch (Fig. 12) is a microphonic device connected to the 115-V transmitter, to cause the keying of the transmitter in response to ambient sound. One can demonstrate its function to a visitor holding a pocket receiver by giving a loud whistle; the receiver will vibrate for the duration of the whistle. The sound of the whistle is picked up, causing the transmitter to be keyed, thus activating receivers in the area.

Useful sound switch applications are probably obvious. The device can be placed near a telephone to signal its ringing to a deaf-blind person. The same can be done with a doorbell. No electrical connections need be made, a fact that can be surprisingly advantageous. In the case of the Kew Gardens installation described earlier, for example, the usual city apartment situation was found: a street entrance with a row of intercom buttons to "beep" each unit, and the apartment in question some flights up. It would have been a costly task for an electrician to run secondary lines down to the street entry, install a special button, etc., to say nothing of getting the landlord's permission to do so. As an easier solution, a sound switch was strapped across the livingroom intercom speaker to pick up a visitor's "beep," and no connections had to be made to the existing building wiring.

Further uses might include picking up the buzz of a kitchen timer, or the cry of an infant waking in the night (the sound switch could be suspended over the crib). The sensitivity can be varied over a wide

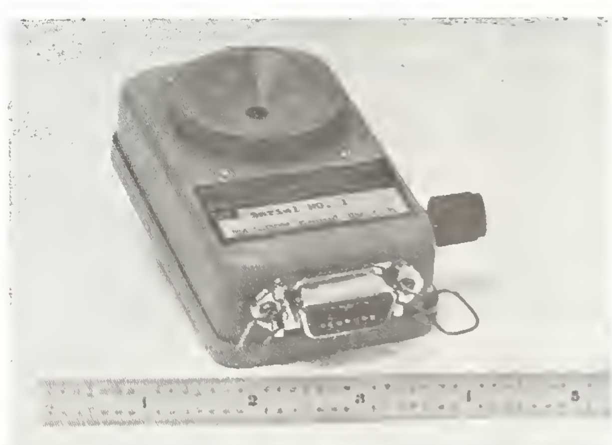


Figure 12. TAC-COM Sound Switch.

range, to make the switch respond only to loud near-by sounds or, if wanted, to much fainter sounds. In fact, the sensitivity can be increased to the point where it will key the transmitter intermittently from the sounds of a radio playing in the same room.

Light Probe

A corresponding device, used to detect ambient light instead of sound, was designed and a breadboard constructed. This unit ought to be thought of as a TAC-COM-like instrument, because it has a vibratory display; but beyond that, it has no direct connection to the design of either the receiver or transmitter. It is, in fact, a totally self-contained unit, resembling a small flashlight. Instead of casting light it responds to light: aim it at a source of light and it vibrates like a TAC-COM receiver; aim it where there is no light and it is still. It embodies a lens, phototransistor, solid-state amplifying circuitry, and a vibration motor.

The light probe could be used by a deaf-blind person to ascertain whether lights were on or off in a room, whether a pilot lamp glowed to show that an appliance was turned on, and so forth. Also, it might have application in travel, permitting one to home in on a front door light at night, etc.

Horizontal Loop

When it became apparent that a simpler antenna would be a worthwhile system improvement, a modified pocket receiver was designed whose loopstick was oriented vertically (Fig. 13). The loopstick is held in a bulge or "blister" on its front.

With this kind of receiver the transmitting antenna can be a single loop in the horizontal plane; it would run around the perimeter of the area to be covered (which could be quite large, some acres, in fact), going up and over doors; and it need not run across floors in the interior, a bothersome point with the present system.

Figure 13. TAC-COM for Use with Horizontal Loop.

This new system would have been used at the outset, were it not for concern that the receiver design would have been complicated, and its shape slightly less advantageous for pocket carrying. Also it was thought that the original system would give the user somewhat more latitude in bending or stooping, where the receiver could depart many degrees from the vertical and still have little risk of missed calls.

These problems seem not to be so troublesome as originally thought, and the new system now seems preferable; it is a step in the right direction. If and when more TAC-COM systems are installed, the one-horizontal-loop arrangement will probably be recommended for its simplicity.

Signaling Codes

Just as a bell or buzzer can be used for simple messages, "go to the door," it can also be used to convey information of much greater scope, by using, for example, Morse code. A similar extension of the TAC-COM system has always seemed an exciting possibility: the receiver responds swiftly to keyed signals, and the transmission of Morse code, albeit at a slow rate, should be possible by simply connecting a telegrapher's key to the transmitter. Thus one could communicate with a deaf-blind person at a distance, something not readily feasible at present, so far as is known.* With a sound switch appropriately placed near a telephone receiver, Morse code could be sent to a deaf-blind person at his home via telephone.

At least the beginnings of coded signaling are now in view: clients at the National Center distinguish the long slow ring, for the hourly rest break, from the rapid short rings of a fire drill. Also, visitors to the deaf-blind apartment dweller would identify themselves at the door by individual codes, e.g., two shorts, one long, etc. At the Sensory Aids Center a bread board has been made of an all solid-state code-keyer with which, by pressing a button, various ten-element sequences of dots and dashes can be initiated.

How useful such techniques might ultimately be is now known. To view the matter conservatively, a Morse code signaling system might find little usefulness to most deaf-blind persons; indeed, on the basis of conversations with rehabilitation workers, there seem not to be many deaf-blind people who have learned Morse code. But the personal communications barrier is the dominant result of this tragic double impairment, and anything that might help penetrate this barrier must have potential value.

PATHSOUNDERS**

Approximately three years ago five Pathsounders (Fig. 14), ultrasonic mobility aids (31), were purchased under Contracts SAV 1057-67, et al., predecessors to the current SRS contracts at SAEDC (30).

Figure 14. Pathsounder.

A follow-on effort has continued on the evaluation of these devices. This has involved minimal expenditure, simply that needed for maintenance, responding to inquiries, and occasional acts of assistance to users and their instructors. The follow-on seems to have been highly worthwhile though, and has required only a small fraction of SAEDC effort. The following is a brief summary of the status of each Pathsounder, with mention of the school or agency concerned.

The first unit is in use by a young totally blinded and partially deafened woman who suffered an attack of meningitis. The rehabilitation counselor, in overseeing cane travel instruction for this client, requested a Pathsounder because of the difficulty she was having in bumping into above-the-waist objects, and because of her inability to localize objects by sound. She reported the instrument most helpful and her lessons ended. She now retains it on long term loan. (Vision Center, Columbus, Ohio.)

---

*It is understood that experimental systems directed toward this end do exist, notably one proposed by Bell Telephone Company.

**This section was written by George Dalrymple.

The second unit has been used in an effort to effect some limited travel independence for a fifteen-year-old boy blind from birth and confined to a wheelchair by cerebral palsy. The Pathsounder and appropriate training have got him "on his feet" to a modest extent, and his instructor reports encouragement. (Ohio State School for the Blind, Columbus, Ohio.)

The third Pathsounder is in use by a blind Brooklyn resident, a cane-traveler who, according to the agency concerned, was trained with it, found it helpful in walking to work in a city environment, was allowed to retain it, and continues to use it. (The Jewish Guild for the Blind, New York, New York.)

The fourth Pathsounder is in use by a twenty-one-year-old girl totally blind from birth and confined to a wheelchair by cerebral palsy. She graduated from a residential school where she was given Pathsounder training; because of her travel progress the staff elected to have her retain an instrument, and she is now reported to be traveling independently and effectively in her new environment. (The Oak Hill School, Hartford, Connecticut.)

The fifth Pathsounder has been on loan to a college for use by teachers-in-training in its orientation and mobility program. A rather thorough evaluation of the device's effectiveness was performed by several students--in particular, on the effectiveness of easing a cane traveler's course through fairly dense pedestrian traffic in downtown city areas. The results were favorable and, in fact, most encouraging; their publication by the investigators is anticipated. (University of Pittsburgh, Pittsburgh, Pennsylvania.)

All five SRS-owned Pathsounders continue to be beneficially employed, and the productive liaison between this Center and the schools and agencies involved should be evident.

APPENDIX 1

Evaluation of the MIT Automatic Brailler

January 15, 1970

The MIT Brailler has been located in my office in NASA's Electronic Research Center in Cambridge, Mass. for three months. The Brailler is connected to a teletypewriter which is, in turn, connected by a telephone line, to a Digital Equipment Corp. PDP-10, a digital computer. I share this office with one other person.

I am blind; my office mate is not. Both of us are Ph.D., Aerospace engineers, employed by NASA to pursue research in the application of orbital mechanics to the determination of the motion of earth satellite. The teletypewriter has been used exclusively by us.

I have been involved in this type of work for ten years. By the nature of the work, it has been essential to program the results of my research on a computer for purposes of verification of the accuracy of the calculations, evaluation of the methods employed and investigation of possible applications. As is not unusual, I have called in programmers to carry out the actual programming and running of the results on a computer. I have had to rely on others to at least scan the numerical output in order to keep abreast of progress. The whole procedure has been quite unsatisfactory. The effort, time, cost, red tape, and the inefficiency of the procedures have led, in practice, to laying aside possible fruitful avenues for investigation.

With the advent of time-sharing capability, the situation has been completely altered. A scientist can now have direct access to the computer and almost zero turn-around time. However, for a blind scientist the time-sharing capability of computers is absolutely useless without a braille output device to reproduce the teletype output. It was my good fortune that, when the time-sharing facility became available to me, almost simultaneously, the MIT Brailler was put at my disposal for evaluation purposes.

From a purely personal point of view, I cannot emphasize enough the almost unanticipated boost in morale the Brailler has afforded me. For the first time, I have access to the computer directly and, for the first time, I can read the results of my labor. It is no exaggeration for me to say that, for the past three months, I have spent just about every waking moment either sitting at the Brailler and teletypewriter or preparing my next numerical experiment. Needless to say, I have not nearly exhausted the backlog, built up during the past ten years, of possible uses for the computer.

From the point of view of a productive worker, my contribution to the in-house effort has kept pace with my colleagues, which would not have been the case had I not had the Brialler at my disposal. I consider it an indispensable instrument for my work. Should I be deprived of its use, my value to my employer would suffer commensurately.

In my opinion, every possible effort should be made to ensure the development and further refinement of the MIT Brailler and its availability to all blind persons who can demonstrate a legitimate use for it. The potential uses for the Brailler are by no means limited to my particular applications. The least that can be said is that whatever is available to a sighted person through a teletypewriter is available to a blind person through the addition of a Brailler. This capability alone is sufficient to justify the development of the Brailler.

The MIT Brailler does have some shortcomings, but they do not nearly cancel its advantages. One difficulty with the present design, and one which will take some ingenuity to eliminate, is the dropping of a character at the end of a line. This defect has been more of an annoyance to me, rather than a hindrance, since properly formatting the output circumvents line-overlap. Noise is another annoyance which can probably only be ameliorated under the present design. Some aspects of the Brailler which can be improved are: size of the machine, manner of presentation of the brailled material as it issues from the machine, and reliability.

John Morrison

Dr. Morrison wrote this report directly into the PDP-10 computer using a teletype and Braillemboss. A text-editor program, TECO (Text Editor and COrrection) was used to correct, insert, delete, and modify the report as necessary. Dr. Morrison then used an auxiliary program to set up the format of the report for the line length of the Braillemboss. Following Dr. Morrison's directions a teletype at the SAEDC was attached via a telephone to the computer and the report requested. The report was printed on the teletype directly from the computer's memory. This copy was retyped from the teletype copy without further editing.

George F. Dalrymple

APPENDIX 2

Semi-Annual Review

Date: February 20, 1971

To: Massachusetts Commission for the Blind

From: John Morrison
Department of Transportation
Transportation Systems Center

Subject: Operation and application of MIT-SAEDC's Embosser.

At this installation, the Braille Embosser is connected to a Teletypewriter (Mod. 33). This remote terminal can, at present, access by conventional (voice channel) telephone lines, either a PDP-10 computer (located in the building) or the Government Services Administration's computer center located in Atlanta, Ga. This latter facility is accessed by a local call to the Boston GSA office; then via leased lines through New York and Washington to Atlanta. The computer in Atlanta is a General Electric 440 Time-share system.

The remote terminal is in nowise limited in its use as a conventional Teletype by having the Braille Embosser attached to it. It is, as a matter of fact, not only used by myself, but by two or three other sighted persons. For the most part, I use the terminal to perform three functions.

The first of these--and by far the most important--is to input scientific programsinto the computer and to output the results calculated by the computer. The Brailler is essential in both stages. The terminal produces a braille copy of my program, along with any errors in the program that the computer can find. This permits me to have a permanent copy of the program for future use and to make any necessary corrections. The output, of course, is most important since it contains the reason for doing the work in the first place.

The second use of the Brailler (and the Teletype) is to obtain copies (Braille and print) of manuals and shared library programs which are contained in storage in the computer systems. This facility has been especially helpful to me in learning how to use the GSA computer.

Finally, one of the computer programs (which happens to be available on both computers) is of particular interest to me for reasons other than mathematical or engineering. This program, called Runoff, was devised to assist in the preparation of reports. I write a report in braille; type it into the computer, including instructions or titling, centering, paragraphing, footnoting, etc. I get back a braille copy of just the report (without the instructions) and a typed copy in which my instructions for formatting have been carried out. From the Braille copy, I can find my inevitable typing errors. Others can review the typed copy for modifications are then made, by Teletype input, in the computer. The computer then outputs the corrected report as a final copy or draft version. This report is being generated in this fashion. I may decide to make some alterations in the print punctuation as a concession to the braille reader to counterbalance the many concessions made to the print reader.

Regarding the performance of the Brailler itself, there are four remarks:

1. Through some circuit change, the Brailler is now able to line-feed without dropping a character at the end of a line. This is a marked improvement.

2. I have requested that line-feed signals from the Teletype be interpreted by the Brailler as a space. This modification has not been made. A line-feed which does not occur at the end of a braille line always means a wasted line of braille paper. (This report is being typed in single space for that very reason.) Since a Teletype line is about double the length of the Braille line, about

one-third of a braille page is empty. This is an extravagance which should be avoided.

3. The Brailler misses characters in what appears to be a random fashion. The cause has not as yet been precisely pinned down.

4. A convenience switch has not yet been provided for disabling the Brailler while non-essential material is being typed out on the Teletype.

APPENDIX 3

ROLLS-ROYCE LIMITED

P.O. Box 3, Filton,
Bristol BS12 7QE

August 1, 1972

Engineering Computing Centre
RCP/DCB/6005

American Foundation for the Blind, Inc.
15 West 16th Street
New York, N. Y. 10011

. . . You will be very pleased to hear that the Braillemboss has been an unqualified success. Terry Hicks is delighted with it and by its help is a fully contributing, and very capable, member of our programming team.

We have no need to make any concessions as to the type of programming work we ask Terry to undertake, though in practice we avoid giving him jobs involving unusually large quantities of output, not because Terry would be unable to cope but because the difference in speed between the Braillemboss and a standard line printer would involve his taking rather longer than others.

It has been a great source of satisfaction to us to see such a successful outcome and we have many people to thank, not least yourself.

Terry Tate, whose enthusiastic and industrious guidance of Terry Hicks has been the most significant single factor in this enterprise, would like to see more blind people exposed to this type of environment. To this end we are considering the possibility of training others, though the form and extent of this will have to be carefully thought out and be ultimately approved by our Divisional Directors who, I should add, have gone out of their way to support us in this venture.

Dennis C. Boston

APPENDIX 4

Folding Canes

May 4, 1971

SAEDC Technical Description
Sheet No. 1

Since its inception, the Sensory Aids Evaluation and Development Center has been concerned with examining and developing devices to enhance the mobility of the blind. These devices have included the Pathsounder, straight line travel indicators, compasses, the folding cane, and other devices. Early investigations established the following criteria which must be met by a folding cane.

1. The weight of the cane cannot exceed one pound.

2. The folded cane must fit into a coat pocket (5" x 10" x 5/8").

3. Aside from collision damage, the cane must survive 5,000 fold extend cycles, based on one year of use by an active blind traveler.

4. The assembled unit must provide a handle and tip with similar "feel" and sound generation capabilities as those experienced by current long cane users.

5. While the extended cane length cannot be changed by the user, the design must include provisions for supplying the cane assembly in two-inch increments of length over the range of 36 to 70 inches.

6. Opening and closing input forces cannot exceed the capabilities of women and children.

7. Opening, closing, locking, and storing procedures, must be compatible with "one-hand" operation.

8. The overall design must be simple. Fabrication of component parts should not require specialized techniques, select fitting or assembly.

9. A realistic mass-market price goal was estimated at under $10.00 each.[1]

Each of the then known available folding canes were examined and several tested. None met all of the requirements, especially that of feel and durability. Earlier work at MIT had produced a design concept, a central-steel-cable compressing conical joints, which showed promise of meeting most of the requirements. Work on canes using this concept produced the "aluminum-tube, swaged-joint, central-steel-cable folding cane."

During the conference for mobility trainers and technologists,[2] the Center was urged by several of the attendees to distribute the swaged-tube central-steel-cable crook handle folding cane in its present configuration for evaluation purposes to appropriate agencies and persons.

An evaluation involving approximately 100 canes was performed. The evaluation used qualified mobility instructors to interact between the Center and each subject. The mobility instructors recruited the subjects and determined the cane length and the tip desired by each subject. The cane and a data package was sent to an instructor for each subject. The data package included both instructions and the data

---

[1]Final report to the VRA from SAEDC, Oct. 31, 1965.

[2]Proceedings, Conference for Mobility Trainers and Technologists, SAEDC, MIT, Dec. 14, 15, 1967.

collecting questionnaires. The instructor taught the subject how to assemble and disassemble the cane and at the appropriate times administered questionnaires. A pretest questionnaire was used to determine the subject's regular cane, travel skill, and travel habits, while the post-test questionnaire recorded his use, likes, and dislikes of the cane.

The cane was well received and thought by most to have characteristics similar to their regular cane. Two problems reported were namely the large size of the crook and both the small diameter and surface of the grip.[3]

Continuing work on folding cane development during the evaluation produced a straight handle cane using the same principles as the crook handle cane.[4] Several usable but different prototypes for a straight handle cane were made. Each of the prototype canes overcame the difficulties discovered during the crook handle cane evaluation while retaining its desirable characteristics.

At this stage in the straight-handled cane development, it was realized that this cane met the important above requirements and that it should be made commercially available. A search was then conducted for both a manufacturer and an appropriate agency to assist by providing the tooling and initial production costs. The Northwest Foundation for the Blind through the Center provided a small subsidy to HYCOR,[5] a local aerospace company who agreed to make and offer for sale the straight handle cane for $12.00.

With the introduction of the cable cane by HYCOR, the Center's work in folding canes has been brought to a successful conclusion. The work on the folding cane has demonstrated the essential requirements of providing a new and useful appliance for the blind, from the realization of the need, to the development of a viable concept, to the practical design, to its test and evaluation, and to the appliance commercial marketing.

The support of the Center during the folding cane work was by the Vocational Rehabilitation Administration and the Social Rehabilitation Administration of the Department of Health, Education, and Welfare.

---

[3] Final Report to SRS from SAEDC, 1970.

[4] Annual Report to SRS from SAEDC, 1967.

[5] HYCOR, North Woburn Industrial Park, Woburn, Mass. 01801.

APPENDIX 5

Braillemboss, A Braille Page Printer

August 4, 1970

SAEDC Technical Description
Sheet No. 2

The MIT Braillemboss[1] is a braille page printer designed to emboss braille at similar or faster rates than teletypes. The Braillemboss accepts electrical braille-coded signals from a variety of sources and in turn produces braille pages. When operating continuously, it produces a page of braille every 1.6 to 2.0 minutes.

The Braillemboss lines are 38 cells long. Each page has 28 lines with 25 lines for braille and 3 blank lines for the top and bottom margin. The paper used by the Braillemboss is 100-pound-basis manila fan-folded sprocket-drive paper. When the sheets are separated and the sprocket-drive strips are removed at the perforations, each sheet is a standard 11" x 11-1/2".

The heart of the Braillemboss is the embossing heads, each head contains six embossing pins in the braille cell configuration and an interposer pin beneath each embossing pin. These heads are fastened to a chain and so arranged that one head is always supported under the platen, a steel female die containing 38 braille cells.

Each embossing pin is spring loaded upward. If an interposer pin is held in, then the corresponding embossing pin produces a dot when struck by the platen. If the interposer pin is out, the corresponding spring-loaded embossing pin is merely forced down by the platen and no dot is made.

Each interposer pin is controlled by a selector bar. There are six selector bars, one for each dot, with three on each side of the head. Each selector bar is parallel to the head support track and is controlled by a solenoid (250 mA @ 40 volts). When a solenoid is energized, the corresponding interposer pin in the active head is held in.

The heads are positioned by both a support track and a tooth that engages the escapement rack. The tooth is held against the rack by a spring driven by a torque motor. This combination supplies a constant force to keep the tooth engaged.

The escapement rack is composed of two one-half pitch racks displaced by one pitch length. The rack shuttles back and forth at right angles to the head track and is driven by an eccentric. Each time the rack moves from one side to the other the head advances one cell. When the active head is in the last cell location, it closes an end-of-line switch used in the Carriage Return logic.

The platen is supported by two pivoted arms and driven by cranks at both ends of the cycle shaft. The rack is also driven by an eccentric geared at one-half speed to the cycle shaft. The cycle shaft is driven by a 1/20 horsepower motor through a cycle clutch. Each time the cycle clutch solenoid is pulsed, the cycle shaft makes one revolution. The platen goes through one cycle, from top to emboss position, and back to top, while the rack moves from one side to the other side each time the cycle shaft revolves.

The fan-fold sprocket-drive paper is supported by two paper tractors mounted close to the head track and platen but on the output side. The paper tractors are driven by a Ledex Digimotor. Each time the Digimotor is pulsed (5 amps @ 40 volts), it advances the paper on braille line.

[1]MIT Braillemboss Specifications. SAEDC August 1969 with latest revision.

A page register is also a part of the paper drive and provides one switch closure-per-page to enable a new page command to be accurately executed.

The emboss sequence is as follows. The electronics determine from the signals that a braille cell is to be embossed. The cycle clutch is pulsed and the appropriate selector bars are energized. The embossing is performed as the platen reaches the bottom of its excursion, the selector bars are released and the head is advanced as the platen reaches the half-way point on its upward travel. The space sequence is identical except that selector bars are not energized. When the active head is in the last (38th) cell, at the time the selector bars are released, an automatic line feed signal is generated. This provides an automatic carriage return at the end of the line. The paper is advanced and the next head becomes the active head in the first cell position.

The Carriage Return function is controlled by a flip-flop. When the Carriage Return flip-flop is set, a self-clocking series of cycle-clutch pulses are generated and the heads are stepped around. The automatic-line-feed signal when in the last cell resets the flip-flop and stops the heads such that the active head is in the first cell location. The Line Feed signal pulses the line feed Digimotor.

The End-of-Page function is also controlled by a flip-flop. When the End-of-Page flip-flop is set, a self-clocking series of line feed pulses are generated to step the paper. When the paper is stepped to the first line position on a page, the page register switch resets the End-of-Page flip-flop.

The electrical signals for the Braillemboss are derived from three principal sources, manual (including a keyboard), a paper-tape reader,[2] or a translator.[3] The manual modes are used primarily for test or limited addition to braille from other sources. The translator allows other devices such as Model 27 or 35 teletypes, an IBM 2741, a card reader or similar devices to supply the electrical signals. A three connector adaptor has been made to permit paper tapes in other codes than brailler codes to drive the embosser through the appropriate translator.

---

[2]Friden Model SP-2 Paper Tape Reader.

[3]One-Cell Translators, Braillemboss Interface Units. SAEDC, TDS No. 8.

Interactive Braille
Remote Computer Translated Grade 2 Braille

September 7, 1972

Technical Description
Sheet No. 11

A person with typing skills but with a minimum knowledge of Braille can produce a high quality Grade 2 Braille with ease and dispatch, using the Interactive Braille System. The necessary components of the system are:

1. A time-sharing computer with DOTSYS3 stored in it.

2. A teletype or other time-sharing computer terminal.

3. A Braillemboss attached to the teletype.

It is not necessary for the computer to be located at the same place as the terminal and Braillemboss.

The Braillemboss is a Braille page printer[1,2] used to produce the output. DOTSYS3 is a version of DOTSYS III modified to use the Braillemboss[3] as output unit.

The material to be brailled is typed into the computer and stored in a data file. The material is typed in almost as it is written in normal inkprint. The teletype has only upper case so a control character is required to tell DOTSYS3 when to capitalize. A single equal sign (=) is typed preceding each word to be initial capitalized, two equal signs before each word to indicate that the word is solid capitals. Most punctuation is typed in directly.

Additional format control characters are required to tell the program when to start paragraphs, when the typist demands a new line to start not in the regular progression of text. Other format control symbols are used to indicate headings and titles. The most used symbols and format controls are listed on a single sheet (see below).

Some training is necessary for the typist to learn to create and manipulate the data files in the computer. This training can be accomplished in a few hours using manuals prepared by the time-sharing computer people.

After the input file is created, proofread and corrected if necessary, the computer is told by a single typed in command to produce the Braille. The computer translates the material and will either store the Braille to produce multiple copies or the computer can immediately output the Braille to produce only one copy.

This is essentially the system used at the National Braille Press and demonstrated there on January 31, 1972.

This Interactive Braille System is designed to be used in places where skilled Braille transcribers are not available, such as in a public school system with a few blind students enrolled. It can also be used in an agency environment to supplement the existing skilled transcribers or to free them from

---

[1]Braillemboss, A Braille Page Printer, SAEDC TDS #2, August 4, 1970.

[2]Final Report to John A. Hartford Foundation, "Development of a High-speed Brailler System for More Rapid and Extensive Production of Informational Material for the Blind," SAEDC, September 29, 1970.

[3]Gerhart, Millen, and Sullivan, "DOTSYS III, A Portable Program for Grade II Braille Translation," MITRE MTR 2119, May 14, 1971.

the relatively simple literary Grade 2 Braille to more specialized Braille which is more demanding of their skills.

Braille Control and Format Codes
DOTSYS III on IDC 360/67 with Teletype and Braillemboss Terminal (029 Keypunch)

Capitalization
= for initial capital of following word
== for all capitals of following word

Italics (Shift 0 TTY)

underscore (_) before each word for one, two or three words

two underscores before four or more word italics, and

one underscore before last word

Ordering Italics, Capitals, Accent, Delineator

Force possible illegal contraction
/_ before and _/ after letters

Prevent contraction
$/ within the letters to be contracted

Quotes
" may be used for both left and right if no quotes within a quote is used
$" for left double quote within a quote
$"R for right double quote within a quote
$' for inner opening quote
$'R for inner closing quote

Accent Mark
](Shift M) TTY (12, 11, 0, 5, 8, Keypunch)*

---

*To obtain accent control symbol on keypunch hold down Mult Punch key and strike &, -, 0, 5, and 8 keys before releasing. The Mult Punch key automatically places keypunch to numbers mode. Do not release the Mult Punch Key until all 5 keys are struck.

Brackets
< for a left bracket[
> for a right bracket]

Short Syllable Sign $SV

Long Syllable Sign $LV

End of Poetry Foot Sign $FT

Caesura Sign $CS

Null Symbols
$/ Null replacement symbol generally used to prevent contraction

Forced Blanks $B

Termination Symbol $T

Paragraph $P

New Line $L

Skip Multiple Line $Slnnb (2 digits + blank) skip nn

New Page $PG

Tabs
one tab $TAnnb (start at position nn)
multiple $STABmLnn (set tab m at position nn)
L for left justification, R for right justification
D for decimal justification
$#m before each item to be tabulated

Titles
$TLS before and
$TLE after each title
produces centered title on each numbered page

Heading
$HDS before and
$HDE after for centered one line headings

Poetry
$PTYS before and
$PTYE after all poetry text

Octal Braille
$OCTaabbccdd for 4 codes
Allows individual braille cells to be inputed
arrangement
dot 1 = 10, dot 2 = 20, dot 3 = 40
dot 4 = 1, dot 5 = 2, dot 6 = 4

Computer Braille
$CPBxxxx will print 4 codes each represented by graphic x in the computer braille code (ASCII to one-cell)

Letter Sign +

Self Checking: The symbol $SCON$/$/$/$/$/ is used to turn self-checking on and $SCOFF is used to turn self-checking off. Delineator is ^ (circumflex, Shift N) on TTY, or | (vertical bar) on keypunch.

REFERENCES

1. Mann, R. W., Enhancing the availability of braille. *Proceedings of the International Congress on Technology and Blindness*, New York: American Foundation for the Blind, June 1962, 409-426.

2. Dupress, J. K., Baumann, D. M. B., & Mann, R. W. *Towards making braille as accessible as print*, Cambridge, Mass.: MIT Report No. DSR 70249, June 1968.

3. *Evaluation report on work in progress on sensory aids and prosthetics*, Engineering Projects Laboratory Report 8768-3, Cambridge, Mass.: MIT, October 1962.

4. *Evaluation report on work in progress on sensory aids and prosthetics*, Engineering Projects Laboratory Report 9211-2, Cambridge, Mass.: MIT, April 1964.

5. *Final report to vocational rehabilitation dministration, Department of Health, Education, and Welfare, Contract SAV-1036-65*, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, October 1965.

6. *Final report to vocational rehabilitation administration, Department of Health, Education, and Welfare, Contract SAV-1045-66*, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, April 1967.

7. *Annual report to social rehabilitation administration, Department of Health, Education, and Welfare, Contract SAV-1057-67*, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, November 1967.

8. *Final report to social rehabilitation administration, Department of Health, Education, and Welfare, Contract SAV-1057-67*, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, April 1969.

9. *Final report to social rehabilitation administration, Department of Health, Education, and Welfare, Contract SRS-69-41*, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, December 1970.

10. *Development of a high-speed brailler system for more rapid and extensive production of informational material for the blind*, Final Report to the John A. Hartford Foundation, Inc., SAEDC, Cambridge, Mass.: MIT, September 29, 1970.

11. Lichtman, S. A. *The design of a high-speed slave brailler for a braille converter device.* Thesis (SB), Department of Mechanical Engineering, MIT, May 1961.

12. Eglinton, D. G. *Preliminary design of the mechanical to electrical coding conversion for a typewriter to braille converter.* Thesis (SB), Department of Mechanical Engineering, MIT, May 1961.

13. Kennedy, D. W. *A high-speed braille embossing system* - 3 Volumes. Thesis (SM), Department of Mechanical Engineering, MIT, May 1963.

14. Maskrey, R. H., *Design and construction of a braille keyboard for the high-speed electric brailler.* Thesis (SB), Department of Mechanical Engineering, MIT, May 1963.

15. Armstrong, A. E. *A braille telecommunication terminal.* Thesis (SM), Department of Mechanical Engineering, MIT, June 1965.

16. Greiner, W. E. *Development of a braille system for classroom use.* Thesis (SM), Department of Mechanical Engineering, MIT, March 1968.

17. Scott, D. B., Jr. *System for the production of braille.* Thesis (SM), Department of Mechanical Engineering, MIT, June 1969.

18. Sturgis, R. H., Jr., *Design modifications of the M.E. brailler.* Thesis (SM), Department of Mechanical Engineering, MIT, May 1969.

19. *Conference on automatic data processing and the various braille codes*, Cambridge, Mass.: MIT, March 17, 18, 1961.

20. Smith, Benjamin F., Perkins experiment with computer produced braille, and Waterhouse, Edward J., Perkins enters the computer age, *The Lantern*, Vol. 37, No. 3, March 1968.

21. *Proceedings of the blind in computer programming, An international conference*, Cleveland, October 9-11, 1969, ACM Newsletter, Special Issue, July 1970.

22. Keeping, Donald, personal communication to Vito Proscia, December 15, 1971.

23. Gerhart, W. R., Millen, J. K., & Sullivan, J. E. *DOTSYS III, A portable program for Grade II braille translation*, MTR-2119, Bedford, Mass.: The MITRE Corporation, 1969.

24. Millen, J. K. *Choice of COBOL for braille translation*, MTR-1743, Bedford, Mass.: The MITRE Corporation, 1970.

25. Millen, J. K., *DOTSYS II: User's guide and transfer and maintenance manual*, MTR-1853, Bedford, Mass.: The MITRE Corporation, 1970.

26. Millen, J. K., *DOTSYS II: Finite-state syntax-directed braille translation*, MTR-1829, Bedford, Mass.: The MITRE Corporation, 1970.

27. Dalrymple, G. F. Transcription of *In Darkness* via DOTSYS III and the Braillemboss, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, November 1972.

28. *Folding Canes*. Technical Description Sheet No. 11, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, May 4, 1971.

29. Woodcock, R. W. Braille research at George Peabody College, *Proceedings, Braille Research and Development Conference*, Sensory Aids Evaluation and Development Center, Cambridge, Mass.: MIT, November 18, 1966, 20-28.

30. Proscia, V. A., Silver, S., & Zumalt, L. E. *Joint enterprise undertaken between two centers for development and evaluation of a tactile communication aid for deaf-blind persons*, SAEDC, Cambridge, Mass.: MIT, August 1971.

31. Russell, L. *Pathsounders Instructor's Handbook*, SAEDC, Cambridge, Mass.: MIT, January 1969.

32. Goldish, L. H., *Braille in the United States: Its production, distribution and use*, Thesis (SM), Sloan School of Management, MIT, February 1967. New York: American Foundation for the Blind, December 1967.

33. Puckett, R. E., *Enhancement of Grade 2 Braille translation/final report*, University of Kentucky, 1971.

A REPORT ON BLINDNESS IN TWO RURAL BLOCKS IN NORTHWESTERN INDIA

I. S. Jain*

Editor's Note: The following was excerpted, with only minor editorial changes, from a more comprehensive report entitled "Blindness and Ocular Morbidity in Two Rural Blocks of Punjab and Haryana." The report covered activities carried out during 1968-1970 under the Research Project "Establishment of a Pilot Rehabilitation Center and Mobile Ophthalmological Unit for Persons Disabled by Eye Disorders," Project No. VRA-IND-39-68/19-P-58135-F-01.

TRACHOMA STUDIES

In 1964 the Trachoma Control Project (under the Indian Council of Medical Research) disclosed that in a rural population of 355 million in the 15 States of India, 19.9 million had visual impairments of various degrees. Of these 3.5 millions were economically blind. Prior to this report some analytical work on ocular problems in the country had appeared as a result of contact studies or the sending of questionnaires to medical centers (Ursekar, 1955; Cooper, 1964; Aggarwal, et al., 1963). After the publication of the report, interest among ophthalmologists increased and more studies appeared (Venkataswamy, 1966; Shukla, 1966, Krishnamoorthy, 1966; Aggarwal, et al., 1966; Chatterjee and Franken, 1968). These studies laid stress on the pattern of disease distribution, an important first step for planning any far-reaching strategy to combat any disease. To combat blindness, one must know the cause and contributing factors. In the part of the country concerned with here, Franken (1968) was the first to study the problem along scientific lines. The study contemplated by Franken included comparison of the pattern of various ocular disorders in both the dry and fertile zones of the plains of Punjab and in mountainous Himalayan terrain. Chatterjee presented his figures from Lahaul and Spiti in the Himalayan area (Chatterjee and Franken, 1968). Franken (1968) completed the study for the dry belt of Punjab, but that on the fertile belt remained undone. To fill in this gap the present study was undertaken in the vicinity of Chandigarh.

What follows is a formal report on our work, but I would like to interject a few personal words. Only those who have actually had the experience of going into the villages can understand the hardships that the team had to endure. One has to shed the ego of being a city dweller before going to a village. Then, after crossing all the barriers of a rugged terrain, one should be ready to face both the active and passive resistance of the villagers, who have every reason to suspect your motives and treat you as an alien. It is all in the game, and I am thankful to the thousands of people who allowed us to examine their eyes, and thus made it possible for us to compile this report. The encouragement of Dr. P. N. Chuttani, Director of the Post-graduate Institute of Medical Education and Research, and the guidance and economic support of the U.S. Government's

*Professor and Head, Department of Ophthalmology, Postgraduate Institute of Medical Education and Research, Chandigarh, India.

Vocational Rehabilitation Administration enabled us to reach the real India--rural India. I express my thanks to all involved in the project for their untiring work and skill. My thanks to D. H. Gupta, Institute statistician, for his help with the statistical aspects of our work and guidance given to our project statistician.

MATERIAL AND METHODS

The study was carried out in two rural blocks in the vicinity of Chandigarh: Kharar Block which is situated in Punjab State, and Raipur Rani Block in Haryana State. Both blocks lie between 30°02'25" and 31°10'35" north latitude and 76°10'55" and 77°36'20" east longitude. The general population of Kharar Block is about 97,396 and that of Raipur Rani Block about 91, 139.

A simple random sample was drawn for Raipur Rani Block and a stratified sample for Kharar Block. A 5 percent sample was selected for the former and 8 percent for the latter. Examination was made of 4,601 persons in the Raipur Rani Block and 8,142 persons in the Kharar Block. An additional 2,193 persons from the Kharar Block were examined, including 321 of the pilot project study, but for scientific analysis they have not been included in this study.

CLIMATE AND POPULATION

Temperatures are high in summer and relatively low in winter. Beginning in March, the temperature rises, reaching 116°F or more towards the middle of June. Hot winds blow over the land but heavy dust storms are rare. The rainy season begins by the fourth week of July and continues until the end of September. During this period the temperature comes down considerably when it rains, but rises again when the rains stop. The atmosphere, then, is sultry and distressing. In October, the weather is fine and turns to the winter season. November and December are pleasant and generally free from rain. January and February are months of severe cold and there may be mild rains. Average rainfall is 34.3 inches.

The economy of the area is based primarily on agriculture. In the 1951 census 57.82 percent of the population was classed as dependent upon agriculture. In the 1961 census, 46.39 percent of the total working force were cultivators and agricultural laborers. The lower figure for 1961 is due partly to noncultivating landowners, who do no other work, no longer being classified as workers.

Land in the area is fairly fertile. The potentialities for production of paddy maize, wheat, groundnut, sarson and sugarcane are great. The peasantry consists of hard working Jat Sikhs, Rajputs, Gujjars and Sainis.

There are three economic groupings among the farmers: peasant-proprietors; tenants; and laborers.

Most of the cultivators are peasant proprietors; owning and cultivating their own land.

SIZE OF OPERATIONAL HOLDINGS

As many as 31.8 percent of the households in villages are engaged in cultivation in the capacity of peasant proprietors and tenants, excluding such households who had let out their lands in entirety or were dependent on agricultural labor. The households of peasant proprietors and tenants are distributed below according to the size of their operational holdings. (Table 1.)

EDUCATION

According to sample population figures, literacy of the area in 1951 was 14 percent; in 1961 literacy was 30 percent.

The scheduled caste and backward classes, particularly those inhabiting the rural areas, still lag in education. Education is free up to Middle Standard in all government and provincialized schools.

TABLE 1

Distribution-per-1,000 Households Engaged in Cultivation by Interest in Land, and Size of Land Cultivated, in Rural Areas Only

Size of Operation Holdings	Per 1,000 Distribution of Households
Less than 1 acre	9.07
1.0 - 2.4 acres	83.77
2.5 - 4.9 "	126.93
5.0 - 7.4 "	181.76
7.5 - 9.9 "	119.93
10.0 - 12.4 "	153.19
12.5 - 14.9 "	59.94
15.0 - 29.9 "	190.77
30.0 - 49.9 "	50.86
50.0 and above	17.07

SPECIFICATIONS OF SUPPORTING ENQUIRIES

A pilot project was undertaken in the village of Lambian (Kharar Block) prior to the regular survey to:

1. Ascertain the variability of population characteristics and to determine whether the size of the sample was adequate.

2. Test the utility of various procedures under field conditions before incorporating them in the survey.

3. Test proformas and other necessary documentation.

4. Estimate the work rate for the given time and resources under actual field conditions.

OBJECTIVES

Every developing country is besieged with plans for rehabilitation and therapeutic work. Before any such plan can be formulated, it is imperative to carry out an accurate assessment in order to evaluate the degree of the problem at hand. Several attempts have been made by various workers utilizing different techniques, e.g., hospital statistics (Venkataswamy and Rajagopalan, 1961; Shukla and Vijay, 1965) by sending questionnaires to medical centers (Ursekar, 1955; Cooper, 1964).

These studies, being biased, do not reflect the disease pattern accurately. Many general surveys were done with a specific disease in mind (Krishnamoorthy, 1966; Sarda, et al., 1961), but few took into account an analytical ophthalmic morbidity of a community. The survey by Franken was conducted in the dry belt of Punjab and Haryana. The present study was done in order to determine the pattern of ophthalmic morbidity in the fertile zone of Punjab to compare it, ultimately, with Chandigarh, considering the impact of education, vocation, and socio-economic status, geographic factors remaining the same. Objectives are:

1. To obtain information on the pattern of ophthalmic diseases.

2. To evaluate, if possible, any factor responsible for a particular disease.

3. To assess the ophthalmic requirements of the area in terms of medical and surgical needs.

4. To study the prevalence rate of blindness and the needs for rehabilitation.

ROAD TRANSPORT

Though motor vehicles are becoming increasingly popular, bullock carts still hold sway in the countryside for conveyance and carriage of goods. They are well suited for the rugged countryside where unpaved roads are unsuitable for sophisticated modern vehicles. Bicycles are extensively used in the villages. (See Table 2.)

WORKING TECHNIQUE

The survey team consisted of a research officer postgraduate in ophthalmology with considerable experience; an assistant research officer, postgraduate; a refractionist with diploma in refraction and optometry; other paramedical personnel

TABLE 2

General Information on Kharar and Raipur Rani Blocks

	Kharar Total Villages Examined: 22	Raipur Rani Total Villages Examined: 29
Present in number of villages		
Good approach road	3	1
Dispensary, local	2	2
within 3 km.	5	1
more than 3 km.	15	26
School, local	17	12
within 3 km.	5	7
more than 3 km.	-	10
Literacy rate (1961 census)	30 percent	30 percent
Density of population per-square-mile (1961 census)	801	920
Average population per village (1961 census)	600	453

including male staff nurse, publicity man, driver, and one or two nursing attendants.

A day before the actual survey was started, the team would visit the place to see the head man and other important persons; especially the school teachers if there was a local school. The teachers were, in fact, the most cooperative in this work. The students in a particular school were examined that same day to establish a favorable atmosphere for the process involved. Then, on the specified day, a survey of the village was started. The team moved from house to house and examined all occupants.

After recording the name, age, sex, and occupation the following procedure was carried out:

1. Brief history.

2. Examination. Visual acuity checked with E charts. Persons having visual acuity less than 6/9 were refracted. Effort was made to see the general improvement and type of refractive error; myopic or hypermetropic.

3. a. Inspection done with naked eye and with corneal loupe 10x.

   b. Visual axis noted and cover test performed.

   c. Fundus examined through undilated pupil. If specifically needed, Drosyn 5% (phenylephrine) was employed to dilate the pupil.

   d. Intraocular tension was taken digitally in earlier part of study, but tension was later recorded with a Schlotz tonometer using two weights, and scleral rigidity was taken into consideration from Friedenwalds Nomogram (1955).

e. Wherever needed, visual field was tested by confrontation method. Field charting is a difficult test to be performed on villagers.

Any person who needed more detailed study was referred to the base hospital.

RECORDING OF DATA

The findings of the surgeon were recorded on a printed form (Appendix 1). The pattern of recording was uniform. Those persons who were blind (economic), were also recorded in a separate form (Appendix 2) and coding (Appendix 3) was noted by the surgeon himself, after consulting the booklet, *Manual on the use of NSPB standard classification of causes of severe vision impairment and blindness, Part II*, 1966.

DATA ANALYSIS

At the start the analysis was done on a pattern adopted by most of the workers, but changed later. Possible ways of analysis are:

1. Tally the diseased eyes and divide by two to get the number of persons. This gives a false impression of prevalence rate. If there are 50 cases having a disease in one eye only and 50 having bilateral disease, according to the method described, the diseased eyes are 150. Of 200 eyes there is an ocular morbidity of 75 percent, but in terms of the number of patients the morbidity is 100 percent because all patients are affected; although in 50 percent it is unilateral and in 50 percent bilateral.

2. The second method takes into consideration the number of persons. In this let us say there are 100 cases; 10 having bilateral immature cataract, 5 with bilateral mature cataract, 15 with immature cataract in one eye only, and in 10 one eye has immature cataract and the other eye has mature cataract. Therefore, the conclusion will be:

Total number of cases 100

Immature cataract cases 10 + 15 + 10	=	35
Mature cataract cases 5 + 10	=	15
Without any cataract 60	=	60
	=	110

Here, immature and mature combined cases have overlapped. Instead of 40 persons, 50 persons appear to have cataract.

3. To resolve this difficulty, we analyzed only in terms of patients, and no overlapping occurred. The figures given in the above example are analyzed as follows:

Bilateral cataract	
Bilateral immature cataract	10
Bilateral mature cataract	5
One mature, one immature	10
Unilateral cataract	
One eye mature cataract, second eye aphakia	0
One eye mature cataract, second eye other than aphakia	0
One eye immature cataract, second eye aphakia	0
One eye immature cataract, second eye other than aphakia	15
Total cataract cases	40
Normal	60
	100

The general approach to analysis has been:

1. Prevalence of disease in relation to age and sex.

2. Bilateral and unilateral occurrence.

3. Consideration of site type and aetiology.

4. Interpenetrating cohesive analysis.

Graphic representation has been utilized wherever needed to facilitate better comprehension of the tabulated data.

Main diseases are analyzed irrespective of other existing ocular pathologies, meaning that a person with perhaps cataract, corneal opacity, and glaucoma combined is included under only one heading, the one diagnosed first. In the discussion of respective diseases the same patient will come under all the headings.

For analysis the population examined was divided into age groups of ten years. Percentages were calculated on the basis of the population examined in the respective age groups, designated in the text as group population.

Main analysis was done under the guidance of a trained and experienced statistician. Chi-square tests were generally used to assess the relative significance of various observations.

POPULATION ANALYSIS

The total number of persons examined in both blocks was 12,743; 6687 males and 6056 females. Male-female ratio was 1:0.9 (Table 3). In the general population of Punjab and Haryana the ratio is also 1:0.89. In

TABLE 3

Distribution of Sample Population Examined and Evaluated by Sex and Age for Each Block

Age Group	Sex	Raipur Rani	Kharar	Belt Total	Belt Total M & F
0 - 10	M	955	1,668	2,623	4,447
	F	659	1,165	1,824	
11 - 20	M	521	1,020	1,541	2,899
	F	458	900	1,358	
21 - 30	M	255	467	722	1,741
	F	348	671	1,019	
31 - 40	M	180	373	553	1,314
	F	310	451	761	
41 - 50	M	185	306	491	972
	F	177	304	481	
51 - 60	M	133	226	359	686
	F	123	204	327	
61 - 70	M	110	140	250	448
	F	87	111	198	
Over 70	M	59	89	148	236
	F	41	47	88	

Ratio male/female 1:0.90

Total Males:	2,398	4,289	6,687
Total Females:	2,203	3,853	6,056
Total Both Sexes:	4,601	8,142	12,743
	5%	8%	

TABLE 4

Distribution of 1000 Persons of Each Sex by Age Group*

Age Group	Males	Females	Average
0 - 10	392	301	347
11 - 20	230	224	227
21 - 30	108	168	138
31 - 40	83	126	104
41 - 50	73	79	76
51 - 60	54	54	54
61 - 70	37	33	35
Over 70	23	15	19
	1,000	1,000	1,000

*For general population, based on census data.

the various age groups the ratio of male-female examined and those distributed in the general population is slightly different. This may be due to the fact that available data on total population is broken up into 9-year age groups while ours was a 10-year age group. The second factor may be the fact that the population figures used are projected figures from the 1961 census. The real figures may differ to a certain extent. Distribution pattern per 1000 persons is shown in Table 4.

VISUAL ACUITY

In 18.6 percent of the population examined it was not possible to examine visual acuity. The maximum number of these was in the first decade. In the other decades they were less common. In the first decade in 50.9 percent visual acuity could not be tested while in subsequent decades the percent figures were 1.6, 1.8, 1.6, 0.5, 0.6, 0.4, and 0.

In total, 77.2 percent of the population had visual acuity between 6/6 and 6/9 in both eyes; in 6.1 percent one eye was normal (6/9 and 6/6) while the other eye had vision of less than 6/12. In 16.7 percent both eyes showed vision of less than 6/12. So the extent of ocular morbidity is 22.8 percent (Table 5).

In the first decade normal visual acuity in both eyes is present in 98.4 percent. Corresponding percent figures for subsequent decades are 95.3, 83.9, 72.1, 49.0, 30.5, 16.1, and 6.8. For both eyes abnormal the percent figures are 0.5, 1.9, 9.4, 16.3, 37.9, 55.2, 70.6, and 89.4.

Thus in every 1000 persons 772 have perfectly normal vision while 228 have subnormal vision in one or both eyes. They need either refraction or other treatment. This points out the great need for the training of more ophthalmologists in India to treat these 25 million persons having subnormal vision.

BLINDNESS

The term blindness has been variously defined from time to time. It is only lately that a clearer definition has emerged. Parsons (1906) defined blindness as being too blind to perform work for which eyesight is essential. In this statement

TABLE 5

Visual Acuity

Age Group	Total population	Total population examined	Both Eyes Normal Vision 6/6 & 6/9				One Eye Normal 6/9 & 6/6. Second eye below 6/12				Both Eyes less than 6/12				Not possible to examine vision		
			Male	Female	Total	Percentage	Male	Female	Total	Percentage	Male	Female	Total	Percentage	Male	Female	Total (%) out of group population
0-10	4,447	2,182	1347	801	2148	98.4	15	9	24	1.1	8	2	10	0.5	1253	1012	2265 50.9
11-20	2,899	2,852	1436	1284	2720	95.3	49	31	80	2.8	26	26	52	1.8	30	17	47 1.6
21-30	1,741	1,708	610	824	1434	83.9	49	66	115	6.7	58	101	159	9.3	5	28	33 1.9
31-40	1,314	1,292	425	507	932	72.1	71	67	138	10.6	52	170	222	17.2	5	17	22 1.7
41-50	972	967	290	184	474	49.0	75	52	127	13.1	124	242	366	37.8	2	3	5 0.5
51-60	686	682	138	70	208	30.5	45	53	98	14.3	174	202	376	55.1	2	2	4 0.6
61-70	448	446	44	27	71	15.9	22	9	31	6.9	183	161	344	77.1	1	1	2 0.4
Over 70	236	236	9	7	16	6.8	7	2	9	3.8	132	79	211	89.4	-	-	-
	12,743	10,365	4299	3701	8003	77.2	333	289	622	6.0	757	983	1740	16.8	1298	1080	2378 18.6

there is no objective criterion with which to measure the blindness. In the United Kingdom the criteria of blindness is a vision of 3/60 or less. *The model reporting area for blindness statistics*, United States Public Health Service in 1962 defined blindness as "visual acuity for distant vision of 6/60 and less in better eye with best correction, or visual acuity of more than 6/60 but with widest diameter of the field of vision not greater than 20°." This has been accepted as a standard definition. Franken and Mehta (1968) surveyed the dry belt of Punjab with these specifications.

Many other reports available, however, have used different criteria, e.g., F.C. 3 meters or vision 1/60. In this survey the criteria of blindness of the National Society for the Prevention of Blindness (United States), 1966 was adopted.

Prevalence of Blindness

Based on the total examined population in the two blocks, comprising 12,743 persons of all age groups, the prevalence of blindness was 3.2 percent as against 2.02 percent reported by Franken and Mehta (1968), 1.98 percent and 2.2 percent in two villages reported by Aggarwal et al. (1966), and 2.5 percent by Ghosh et al. (1969).

Blindness Rate

Blindness rate is defined as number of blind persons per 100,000 of population. The blindness rate reported in various places is:

Canada	-	131
U.S.A.	-	214
U.K.	-	200
India:		
(by Trachoma Pilot Project)		1000
Aggarwal et al., 1966 (Incurable 880)		2240
Franken and Mehta, 1968 (In dry belt of Punjab)		2022
Our Study (Table 6)		3200

The 3.2 percent encountered in our survey differs from the blindness rate obtained from hospital attending population. In 35,000 cases so analyzed this was found to be 5.8 percent as against 26.2 percent reported by Shukla and Vijay (1965).

Out of this rate of blindness of 3200 blind per 100,000 population (Table 6) 972 represented incurable blindness and 2228 curable blindness, thus making the curability rate 69.6 percent. This rate varies from place to place and depends upon the attitude of people and medical facilities available. In Kharar Block this rate is 65.8 percent while in Raipur Rani block it is 73.8 percent, indicating a greater need for medical facilities. The figures 56.25 percent were found in Rajiwin village by a Delhi group of workers.

Among curable blindness only 9.5 percent is preventable as compared to 67.8 percent in the incurable blind series (Fig. 1). Preventability of curable blindness is 13.1 percent for Kharar and 6.2 percent for Raipur Rani. This difference is due to cataract and corneal opacities. The former being more common in Raipur Rani block and the latter being more common in Kharar block. The preventability of incurable blindness is 65.3 percent in Kharar block, while it is 71.2 percent in Raipur Rani block. Though

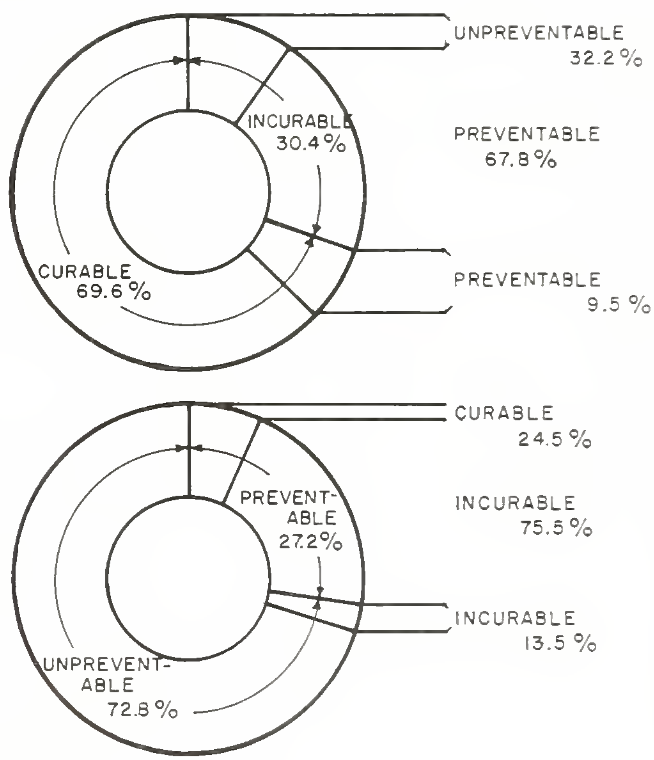


Figure 1. Blindness, Preventable and Curable

TABLE 6

Blindness Rate by Site-Type

	Kharar Block 8,142					Raipur Rani Block 4,601					Total 12,743				
	Curable		Incurable		Total	Curable		Incurable		Total	Curable		Incurable		Total
	Pre-ventable	Un-preventable	Pre-ventable	Un-preventable		Pre-ventable	Un-preventable	Pre-ventable	Un-preventable		Pre-ventable	Un-preventable	Pre-ventable	Un-preventable	
Eye Ball in General															
Number	-	-	3	5	8	-	-	4	1	5	-	-	7	6	13
Blindness Rate (B.R.)	-	-	36	61	97	-	-	86	21	107	-	-	54	48	102
Cornea Sclera															
Number	18	-	38	-	56	9	-	23	-	32	27	-	61	-	88
B.R.	221	-	466	-	687	195	-	500	-	695	212	-	479	-	691
Lens															
Number	-	112	3	-	115	-	137	10	-	147	-	249	13	-	262
B.R.	-	1376	36	-	1412	-	2977	217	3194	3194	-	1954	102	-	2056
Optic Pathways															
Number	-	-	-	3	3	-	-	-	-	-	-	-	-	3	3
B.R.	-	-	-	36	36	-	-	-	-	-	-	-	-	23	23
Retina															
Number	-	-	-	1	1	-	-	-	-	-	-	-	-	1	1
B.R.	-	-	-	12	12	-	-	-	-	-	-	-	-	7	7
Site Type Indefinite															
Number	-	8	3	16	27	-	-	-	14	14	-	8	3	30	41
B.R.	-	98	36	196	330	-	-	-	304	304	-	62	23	236	321
Total															
Number	18	120	47	25	210	9	137	37	15	198	27	257	84	40	408
B.R.	221	1474	574	305	2574	195	2977	803	325	4300	212	2016	658	314	3200
Percentage	13.1	86.9	65.3	34.7		6.2	93.8	71.2	28.8		9.5	90.5	67.8	32.2	
Blindness Rate	1695		879			3972		1128			2228		972		
Percentage	65.8		34.2			73.8		26.2			69.6		30.4		

Preventable: 111 (27%)
Unpreventable: 297 (72.8%)

(B.R. Blindness rate = Blind per 100,000 of population) the need for general prevention in both blocks is considerable, it is greater for Raipur Rani block. This is due to cases of multiple affections (e.g., cataract in combination and glaucoma in combination) in Raipur Rani block. It again speaks for the need of more medical facilities as well as awareness among the people. In every 100,000 of population, 3200 persons are blind in this area. Out of this 2228 cases are curable and they need medical attention while 972 need rehabilitation. Out of the same total 870 cases of blindness per 100,000 could have been prevented while 2330 have unpreventable diseases. Among the former 870, only 212 can be cured now while 2228 in the latter group can be cured. Thus 102 have gone blind just for lack of medical help in the latter group, and 658 in the former group.

Taken age-wise, in the first age-group blindness is 1/2 curable unpreventable and 1/2 preventable incurable. So whole of it is either curable or preventable (Table 7). In the second decade it is unpreventable incurable. In the third decade curable and incurable is in 1:1.75 ratio, while the ratio of preventable unpreventable is 1:0.83. In the fourth decade curable and incurable is 1:1 while preventable and unpreventable is 1:0.86. In the fifth decade curable:incurable ratio is 1:0.44 while preventable:unpreventable is 1:2.82. In the sixth decade ratio of curable and incurable blindness is 1:0.48 while preventable and unpreventable is 1:2.30. In the 7th decade the ratio of curable and incurable is 1:0.3 and the preventable and unpreventable is 1:4.04. Beyond the 7th decade the ratio of curable and incurable is 1:0.34 while preventable and unpreventable is as 1:3.53 roughly.

TABLE 7

Curable and Incurable Patients by Age Group

Age Group	Curable: Preventable	Curable: Unpreventable	Curable: Total	Curable: Percentage	Incurable: Preventable	Incurable: Unpreventable	Incurable: Total	Incurable: Percentage	Grand Total all Types	Percentage	Ratio: Curable:Incurable	Ratio: Preventable:Unpreventable
0-10	-	1	1	0.018	1	-	1	0.022	2	0.040	1:1	1:1
11-20	-	-	-	-	-	1	1	0.034	1	0.030	0:1	0:1
21-30	1	3	4	0.238	5	2	7	0.402	11	0.640	1:1.75	1:0.83
31-40	4	10	14	1.066	11	3	14	1.066	28	2.130	1:1	1:0.86
41-50	5	40	45	4.623	12	8	20	2.057	65	6.680	1:0.44	1:2.82
51-60	7	60	67	9.766	23	9	32	4.664	99	14.430	1:0.48	1:2.30
61-70	5	84	89	19.844	18	9	27	6.026	116	25.890	1:0.30	1:4.04
Above 70	5	59	64	27.538	14	8	22	9.322	86	36.860	1:0.34	1:3.53
Total	27	257	284	2.230	84	40	124	0.9700	408	3.200		
	9.51%	90.49%			67.74%	32.26%						

TABLE 8

Curable and Incurable Patients by Age and Sex

Age Group	Curable				Incurable			
	Males	Group percent males	Females	Group percent females	Males	Group percent males	Females	Group percent females
0-10	1	0.038	-	-	1	0.038	-	-
11-20	-	-	-	-	-	-	1	0.074
21-30	2	0.277	2	0.196	4	0.554	3	0.294
31-40	4	0.723	10	1.314	2	0.362	12	1.577
41-50	13	2.648	32	6.652	10	2.037	10	2.079
51-60	27	7.520	40	12.232	16	4.457	16	4.893
61-70	49	19.600	40	20.202	13	5.200	14	7.071
Over 70	32	21.621	32	36.363	15	10.135	7	7.955
Total	128		156		61		63	

Taking in terms of total blindness, curable:incurable is 1:0.44 and preventable and unpreventable is 1:2.67. So while 1/2 of the blindness is incurable, about 1/3 is preventable.

The percentage of curable blindness in various age groups is as follows:

0.018 percent in the 1st decade,
0.238 percent in the 3rd decade,
1.066 percent in the 4th decade,
4.623 percent in the 5th decade,
9.766 percent in the 6th decade,
19.844 percent in the 7th decade,
27.538 percent in the over 70 group.

Figures for incurable blindness in the corresponding age groups are: 0.022 percent, 0.034 percent, 0.402 percent, 1.066 percent, 2.057 percent, 4.664 percent, 6.026 percent, and 9.322 percent. Further splitting of these sex-wise reveals (Table 8) that in the male population, incurable male blind are:

0.038 percent in the 1st decade,
0.554 percent in the 3rd decade,
0.362 percent in the 4th decade,
2.037 percent in the 5th decade,
4.457 percent in the 6th decade,
5.200 percent in the 7th decade,
10.136 percent in the over 70 group.

The figures for females are 0.074 percent in the 2nd decade and for subsequent corresponding decades are 0.294 percent, 1.577 percent, 2.079 percent, 4.893 percent, 7.071 percent, and 7.955 percent. Though the figures for the males and females do not show any significant difference except in the 4th decade, the corresponding figures for curable blindness are somewhat higher for females.

AGE VS. SITE-TYPE

Considering economic blindness from the point of view of age there is a progressive rise from the 1st decade onwards, except for a small fall from the 1st decade to the 2nd (from 0.04 percent to 0.03 percent). From the 3rd decade on, this percentage in respective age-group populations is 0.63 percent, 2.13 percent, 6.69 percent, 14.43 percent, 25.89 percent, 36.44 percent, in 3rd, 4th, 5th, 6th, 7th decade and onwards (Fig. 2 and Table 9).

TABLE 9

Bilateral Blindness

Age Group	Male blind	Percentage male blind in male population	Female blind	Percentage female blind in female population	Total blind	Total blind per 1000	Male: Female	Percentage of total group population	Eyeball in general	Cornea sclera	Lens	Retina	Optic nerve	Site type indefinite
0-10	2	0.076	-	-	2	5	2:0	0.045	1 50%	-	1 50%	-	-	-
11-20	-	-	1	0.074	1	2	0:2	0.034	-	-	-	-	1	-
21-30	6	0.831	5	0.490	11	27	15:12	0.632	3 27.4%	4 36.3%	4 36.3%	-	-	-
31-40	6	1.084	22	2.890	28	69	15:54	2.131	4 14.3%	13 46.4%	10 35.7%	-	-	1 3.6%
41-50	23	4.684	42	8.731	65	159	56:103	6.687	1 1.5%	17 26.1%	39 60.4%	-	1 1.5%	7 10.5%
51-60	43	11.977	56	17.125	99	243	105:138	14.431	1 1%	25 25%	62 62%	1 1%	-	10 10%
61-70	62	24.800	54	27.27	116	284	151:133	25.893	1 1.8%	15 12.9%	87 75.2%	-	1 0.8%	12 10.3%
Over 70	47	31.756	39	44.318	86	211	115:96	36.441	2 2.3%	14 16.2%	59 68.8%	-	-	11 12.7%
Total	189 46.3%	2.826	219 53.7%	3.161	408	1000	462:538	3.202	13 3.1%	88 21.5%	262 64.5%	1 0.2%	3 0.7%	41 10.0%

In the male population the percentage of cases of blindness in various age groups is as follows: 0.076 percent, 0.831 percent, 1.084 percent, 4.684 percent, 11.977 percent, 2.480 percent, 31.756 percent in the first, third, fourth, fifth, sixth, seventh decades and over seventy group respectively. In the females the same figures are 0.074 percent, 0.49 percent, 2.890 percent, 8.731 percent, 17.125 percent, 27.27 percent and 44.318 percent in 2nd, 3rd, 4th, 5th, 6th, 7th decades and the over 70 group. Thus, in the first decade, only males were encountered and in the second decade, only females. From the third decade onwards males and females show a progressive rise. In the third decade, male population is more involved, otherwise in all the decades it is the female population which is more affected (Fig. 2 and Table 9).

Among those blind encountered in the first decade, half (one case) was due to phthisis bulbi and half due to disease of lens. In the second decade it was optic atrophy following meningitis which was encountered. (See Tables 9 and 10.) In the third decade, lens diseases constituted 36.3 percent, corneal scleral diseases 36.3 percent, and general eyeball diseases 27.4 percent. In "general eyeball diseases" phthisis bulbi was in two-thirds of the cases while myopic blindness was in one-third of the cases. In the 4th decade, "general eyeball diseases" (male:female 1:3) constituted 14.3 percent, cornea sclera (male:female 1:3) diseases 46.4 percent, lens (male:female 1:9) in 35.7 percent, and site type indefinite (multiple affections) 3.6 percent. In the "eyeball diseases" one-half were due to phthisis bulbi and one-half due to glaucoma.

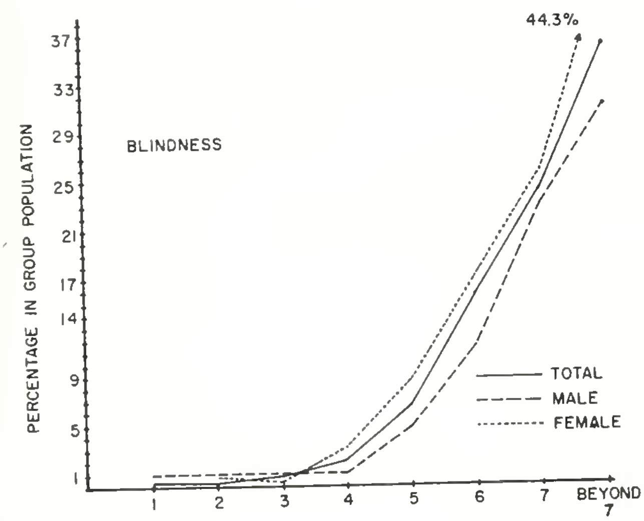


Figure 2. Age Group in Decades.

In the fifth decade "eyeball diseases" were in 1.5 percent, cornea sclera diseases (male:female, 1:1.4) in 26.1 percent, lens diseases (male: female 1:2.5) in 60.4 percent, optic atrophy in 1.5 percent, site type indefinite (male:female 1:0.7) in 10.5 percent (cataract in combination in about 70 percent and glaucoma in combination in about 30 percent). In the 6th decade, atrophic globe constituted 1 percent, corneal opacity (males:females 1:1) 25 percent, lens diseases 62 percent (male:female 1:1.5), macular degeneration 1 percent, site type indefinite (males: females 1:1.5) in 10 percent (three-fifths having cataract in combination, one-fifth having glaucoma in combination and the rest indefinite).

In the seventh decade, atrophic globe was 0.8 percent, corneal opacities (male:female 1:0.9) 12.9 percent, lens diseases (male:female 1:0.9) 75.2 percent, optic atrophy 0.8 percent and site type indefinite (male:female 1:1.4) 10.3 percent (glaucoma in combination 9.8 percent and cataract in combination 90.2 percent).

Beyond 70 eyeball diseases accounted for 2.3 percent (atrophic globe and glaucoma 1:1), corneal opacity (male:female 1:0.6) 16.2 percent, lens (male:female 1:0.9) 68.8 percent and site type indefinite (male:female 1:1.8) for 12.7 percent (cataract in combination 63.6 percent, glaucoma in combination in 18.2 percent and undecided in 18.2 percent).

Table 11 shows some figures regarding the distribution of blindness in various age groups reported from several studies.

TABLE 10

Bilateral Blindness,* Site-Type Indefinite

Age & Sex Etiol-ogy		Eyeball in General									Cornea-Sclera								
		111-99.00	111-91.00	113-91.00	140-99.00	155-29.20	155-31.09	155-20.20	155-22.00	155-28.20	310-22.00	315-22.00	318-29.20	318-28.20	390-91.00	390-28.20	390-29.20	390-22.00	340-80.20
0-10	M					1													
	F																		
11-20	M																		
	F																		
21-30	M				1					2							1		
	F										1					1	1		
31-40	M						1				1		1				1		
	F	1		1				1			3	2	1				2	2	
41-50	M										2				1		1	3	
	F			1							4	1	2				1	2	
51-60	M										1	2	2	2		1	2	2	1
	F		1								7	1	1			1		2	
61-70	M								1		2		4	1			1		
	F											1				1	3	2	
Above 70	M		1			1					3		3				2	1	
	F										2		1				1	1	
Total	M		1		1	2	1		1	2	9	2	10	3	1	1	8	6	1
	F	1	1	2				1			17	5	5			3	8	9	

Age & Sex Etiol-ogy		Lens									Ret-ina	Optic Nerve		
		411-62.21	411-80.20	411-18.00	412-62.21	412-62.22	412-37.08	412-37.18	412-37.19	420-38.08	660-62.21	720-62.21	720-29.20	720-99.00
0-10	M		1											
	F													
11-20	M													
	F												1	
21-30	M		1	1										
	F	2												
31-40	M	1												
	F	9												
41-50	M	11												1
	F	28												
51-60	M	22			1	1			.	1				
	F	35			1			1						
61-70	M	44			2	1						1		
	F	36			3						1			
Above 70	M	30			1	1								
	F	26					1							
Total	M	108	2	1	4	3					1	1		1
	F	136			4		1	1		1			1	

Age & Sex Etiol-ogy		951-99.00	951-95.02	951-91.00	955-91.00	956-95.00	956-62.22	956-22.00	956-62.21	955-62.21	956-91.00	956-28.20	956-29.20	990-99.00	956-95.99	Total M	Total F	Grand Total
0-10	M															2		2
	F																	
11-20	M																	
	F																1	1
21-30	M															6		
	F																5	11
31-40	M												1			6		
	F																22	28
41-50	M				1			1							2	23		
	F			1				1							1		42	65
51-60	M											1			3	43		
	F			2			1							2	1		56	99
61-70	M					2				1					2	62		
	F		1			2						2			2		54	116
Above 70	M	1							1		1			1		47		
	F		1				1	1						1	3		39	86
Total	M	1			1	2		1	1	1	1	1	1	1	7	189		
	F		2	3		2	2	2				2		3	7		219	408

*See Appendix 3 for classification codes.

TABLE 11

Age Distribution of Blindness According to Selected Studies

Age Group	Arnold Sorsby (England)	Madras Census Department	Franken (Ludhiana) Punjab	Our Findings	Aggarwal (1967)
0 - 20	3.4%	20.6%	20.6%	0.73%	2.96%
21 - 30	1.2%	7.9%	5.6%	2.69%	2.96%
31 - 60	12.2%	45.8%	38.9%	46.56%	62.23%
Above 60	83.0%	25.6%	34.9%	49.99%	31.85%

There are a number of further analyses of blindness figures available from contemporary studies. Most of the reports, however, were based on hospital studies or camps, and being biased cannot be taken for comparison.

Taken in terms of group population in each age group our figures are at variance with the Ludhiana report from the dry belt of Punjab (Franken, 1968). The distribution pattern reported by Aggarwal (1967) is somewhat similar to our observations, differences are mainly in the 2nd and 5th decades. The figures are compared in Table 12.

TABLE 12

Comparison of Distribution of Blindness Reported in Three Indian Studies
In Percentage of Total Group Population in Respective Age Groups

Age Group	Franken	Our Findings	Aggarwal 1967
1st decade	0.679%	0.04%	0.044%
2nd decade	0.911%	0.03%	0.220%
3rd decade	0.765%	0.64%	0.420%
4th decade	1.094%	2.13%	1.750%
5th decade	2.971%	6.68%	3.72%
6th decade	7.162%	14.13%	18.380%
Beyond 6th	11.815%	29.53%	27.740%
Total Blind	2.022%	3.2%	2.24%

TABLE 13

Bilateral Blindness by Site-Type and Etiology

	All cases by Site Type	Eyeball in General	111 Glaucoma - Open Angle	113 Glaucoma - Not Specified	140 Myopia	155 Atrophic Globe	Cornea Sclera	318 Other Keratitis	310 Kerato-Conjunctivitis	340 Other Corneal Dystrophy	315 Trachoma	390 Other Affections	Lens	411 Cataract Unoperated	412 Cataract Operated	420 Dislocated Lens	Retina	660 Macular Degeneration	Optic Pathways	720 Optic Atrophy	Site-Type Indefinite	955 Glaucoma in Combination	951 Glaucoma and Cataract	956 Cataract in any other Combination	990 Site-Type not Established
All cases	408	13	3	2	1	7	88	18	26	1	7	36	262	247	14	1	1	1	3	3	41	2	6	29	4
by etiology	(3200)	(101)	(23)	(16)	(8)	(54)	(690)	142	(204)	(8)	(64)	(282)	(2056)	(1937)	(112)	(8)	(8)	(8)	(24)	(24)	(321)	(10)	(46)	(227)	(327)
Infectious	101	6				6	86						1						1		7				
diseases	(792)					(46)	(674)														(54)				
18.00	1 (8)												1 (8)	(1)											
20.20	1 (8)	1				1	48																		
	52					(8)	(376)																		
22.00	(407)	1				1			26		7	15									3(23)			3	
	12					(8)	7																		
23.20	(94)	2				2	(56)	3				4									3(23)			3	
	35					(16)	31																		
29.20	(275)	2				2	(241)	15				16									1(8)			1	
	5					(16)																			
Injuries &																									
poisonings	(39)	1				1(8)							4		3	1									
31.09	1 (8)	1				1(8)																			
37.18	1 (8)												1 (7)		1										
37.19	1 (7)												1 (8)		1										
37.08	1 (8)												1 (8)		1										
38.08	1 (8)												1 (8)			1									
Diseases not	261																								
classified	(2047)												255		11		1		1		4(32)				
elsewhere	256																								
62.21	(2008)												252	244	8		1	1	1	1	2(16)	1		1	
	5												(1977)												
62.22	(39)												3		3						2(16)			2	
															(24)										
Prenatal																									
influences	3(24)						1(8)						2(16)												
80.20	3(24)						1			1			2	2											
Etiology	38																				30				
indefinite	(298)	6					1(8)												1		(237)				
91.00	11 (86)	5	2	2	1		1					1									5(40)	1	3	1	
99.00	7 (56)	1	1																1	1	5(40)		1		4
95.99	14(110)																				14(110)			14	
95.02	6 (47)																				6(47)		2	4	

(Figures in brackets indicate blindness rate)

Blindness by Site and Type of Affection (Table 13 and Fig. 3)

The lenticular affections ranked first at 64.2 percent. Then in order of frequency were corneal diseases 21.5 percent, site type indefinite (90.4 percent being multiple affections) 10 percent, eyeball diseases (glaucoma, myopia, and phthisi bulbi 3.1 percent, optic atrophy 0.7 percent and macular degeneration in 0.3 percent (Table 14).

Franken and Mehta reported lens as responsible for blindness in 38.82 percent. This author reported that cornea constituted 37.8 percent, eyeball in general 17.01 percent, retina 3.05 percent, optic nerve 1.01 percent and site type indefinite 2.31 percent, of the total blind encountered. Leukoma is reported as responsible for 17.1 percent of blindness in Poland (Rostkowski, 1965).

While glaucoma as a cause of blindness is reported as 11.68 percent by Franken and Mehta for the dry belt of Punjab, in our series it was 1.2 percent as such and 2.0 percent combination (3.2 percent total). In Raipur Rani block these figures were 0.5 percent (total), while in Kharar block they were 2 percent and 3.9 percent (5.9 percent total) (Table 14). In North Carolina (U.S.A.) glaucomatous blindness is reported in 15.2 percent, while McDonald (1965) put it at 23 percent in Canada (glaucoma and myopia combined). In Poland Rostkowski reported this as 12.1 percent. Bagchi reported glaucoma as 4.6 percent, Shukla and Vijay (1965) as 14 percent, Venkataswamy (1967) as 25 to 28 percent. Our figures are 3.2 percent for glaucomatous blindness. The common flaw in most studies is the fact that digital tension is taken as criteria and early glaucoma is missed. The present study was done in part by digital tonometry and in part routine tonometry was done beyond 30 years of age. The figures for various countries are given in Table 15.

Table 16 gives a comparison between the data obtained by Franken and by the present study with regard to other diseases. It is evident that the whole pattern of disease is different in this area. Though ophthalmia and trachoma have contributed considerably towards blindness in the dry belt, atrophic globe is not reported. In our own series, atrophic globe takes a considerable toll. Myopic blindness is 0.3 percent in our series, while it is 5.33 percent as reported from the dry belt of Punjab.

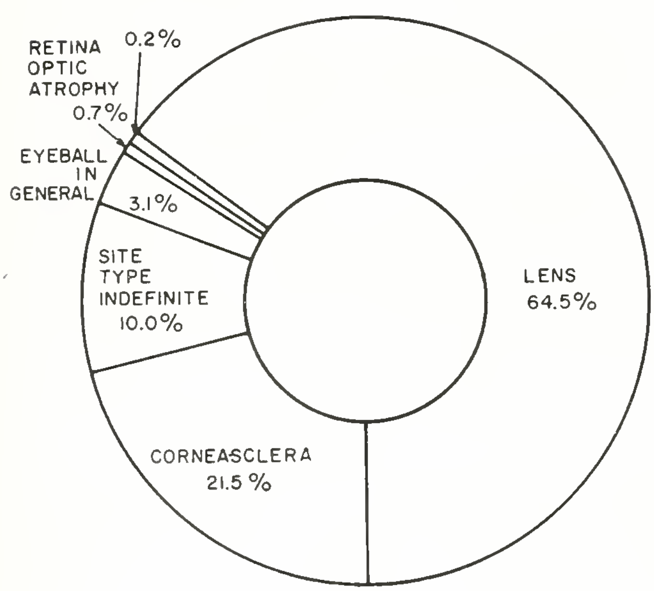


Figure 3. Causes of Blindness by Site and Type

ETIOLOGICAL FACTORS IN BLINDNESS

Etiologically, infectious diseases constituted 24.5 percent, injuries and poisonings 1.2 percent, diseases not classified elsewhere (senile degeneration) 64.0 percent. Prenatal influence was 0.8 percent. Indefinite etiology (including multiple affections) was 9.3 percent.

Corresponding figures reported from dry belt are 25.62 percent due to infections (corneal ulcer 4.57 percent), injuries and poisonings, 7.1 percent, prenatal influence 1.52 percent, indefinite etiology 2.31 percent and unknown to science 54.82 percent (Franken and Mehta, 1968).

TABLE 14

Bilateral Blind (By Site and Type)

	Eyeball in General	111-Glaucoma open angle	113-Glaucoma not specified	140-Myopia	155-Atrophic globe	Cornea Sclera	318-Other keratitis	310-Kerato-conjunctivitis	340-Other corneal dystrophy	315-Trachamatous	390-Other affections	Lens	411-Cataract unoperated	412-Cataract operated	420-Dislocated lens	Retina	660-Macular degeneration	Optic pathways	720-Optic atrophy	Site and Type Not Definite	955-Glaucoma in combination	951-Glaucoma and cataract	956-Cataract in combination	990-Site and type not established	Grand Total
Total	8	2	2	1	3	56	16	14	1	7	18	115	112	3	-	1	1	3	3	27	2	6	15	4	210
Kharar																									
Percentage of group		25	25	12.5	37.5		28.6	25	1.8	12.5	32.1		97.4	2.6			100		100		7.4	22.2	55.6	14.8	
Percent of total blind	3.8	1.0	1.0	0.5	1.4	26.7	7.6	6.7	0.5	3.3	8.6	51.8	53.3	1.4		.5	.5	1.4	1.4	12.9	1.0	2.9	7.1	1.9	
Raipur Rani																									
Total	5	1			4	32	2	12			18	147	135	11	1					14			14		198
Percentage of group		20			80		6.3	37.5			56.3		91.8	7.5	.7								100		
Percent of total blind	2.5	.5			2.0	16.2	1.0	6.1			9.1	74.2	68.2	5.6	.5					7.1			7.1		
Grand Total	13	3	2	1	7	88	18	26	1	7	36	262	247	14	1	1	1	3	3	41	2	6	29	4	408
Percentage of Group		23.1	15.4	7.7	53.8		20.5	29.5	1.1	8	40.9		94.3	5.3	0.4		100		100		4.9	14.6	70.7	9.8	
Percent of total blind	3.1	.7	.5	.3	1.7	21.5	4.4	6.4	.3	1.7	8.8	64.2	60.5	3.4	.3	.3	.3	.7	.7	10.0	.5	1.5	7.1	1.0	
In general population	.101	.023	.016	.08	.054	.690	.142	.204	.008	.054	.282	2.056	1.937	.111	.008	.008	.008	.024	.024	.321	.016	.046	.227	.032	3.2
In 100,000	101	23	16	8	54	690	142	204	8	54	282	2056	1937	111	8	8	8	24	24	321	16	46	227	32	320

TABLE 15

Percentage of Glaucoma, Blindness

	Country	Percent
1.	Algeria	6.0
2.	Australia -	
	Melbourne	20.5
	Queensland	9.0
	Tasmania	12.4
3.	Brazil	0.68
4.	Canada	11.7
5.	Ceylon	4.94
6.	China -	
	a. Cing- 1923	6.8
	b. Chang - 1930	8.9
7.	Egypt	10.0
8.	England and Wales	13.0
9.	Finland	22.5
10.	Germany	15.1
11.	Greece	16.0
12.	Hungary	8.3
13.	India	8.3
	a. Negaw (1937)	9.0
	b. Bagchi (1934-36)	4.6
	c. Shukla (1965)	14.00
	d. Aggarwal (1967)	16.3
	e. Ours (Survey)	3.5
	f. Ours (Hospital, 35,000 patients)	10.7
14.	Italy	11.0
15.	Japan	9.0
16.	Netherlands	12.9
17.	Nigeria	10.00
18.	Philippine Islands	12.1
19.	Poland	12.6
	Rostkowski - 1965	12.1
20.	Rumania	2.69
21.	Scotland	8.1
22.	South Africa	3.36
23.	Sweden	5.5
24.	Switzerland	14.63
25.	Tunisia	4.5
26.	Uganda	2.3
27.	U.S.A.	11.7
28.	U.S.S.R.	11.7
	a. Golwin (1928)	19.2
	b. Savaitov (1932)	21.8

Derived from SORSBY (1950) An International Survey

TABLE 16

Comparison with Franken Study

	Franken 1968 (percent)	Ours (percent)
Eyeball in general		
Glaucoma	11.68	1.2
Myopia	5.33	0.3
Atrophic Globe	-	1.7
Cornea		
Ophthalmia	4.06	-
Trachoma	13.19	1.7
Others	20.55	19.8
Lens		
Unoperated	38.82	60.5
Operated	-	3.4
Dislocated	-	0.3
Retina		
Tumor	0.25	-
Retinopathy	2.29	-
Macular Degeneration	-	0.3
Optic Atrophy	1.01	0.7
Site Type Indefinite		
Cataract in Combination	-	3.7
Glaucoma in Combination	-	5.3
Undetermined and not specified	2.31	1.0

Thus, infections, injuries, and prenatal influence appeared in greater proportion in the dry belt. We observed syphilitic infection in 0.2 percent, rubella 0.2 percent, trachoma 12.7 percent, and unidentified infections causing corneal opacities following corneal ulceration 8.5 percent.

Smallpox has been reported to cause blindness to 8.37 percent in the dry belt (Franken and Mehta). Our series reveal it to be a contributing factor of 2.5 percent only. In Raipur Rani Block, this figure was 1 percent as compared to 3.8 percent in Kharar Block.

In South India, McLaren (1963) cited xerophthalmia as the most common cause of blindness. A survey in Madurai by Venkataswamy (1967) showed 10 percent of blindness was due to keratomalacia. This problem, however, is not encountered in Northern India.

Sharma and Prasad (1962) reported cataract as a cause of blindness in 36 percent, active trachoma in 20.64 percent, mucopurulent ophthalmia 16.76 percent and smallpox 13.97 percent. These workers, however, report blindness in one eye and in both eyes at the same time.

Ghosh et al. (1969) found prevalence of blindness to be 2.5 percent (including unilateral blindness). By etiology, cataract has been labeled as maximum (0.08 percent). Franken reports it as 0.76 percent, while our figures were 2.1 percent. This is taken in terms of total population examined.

Chatterji and Franken (1968) evaluating blindness in Himalayan

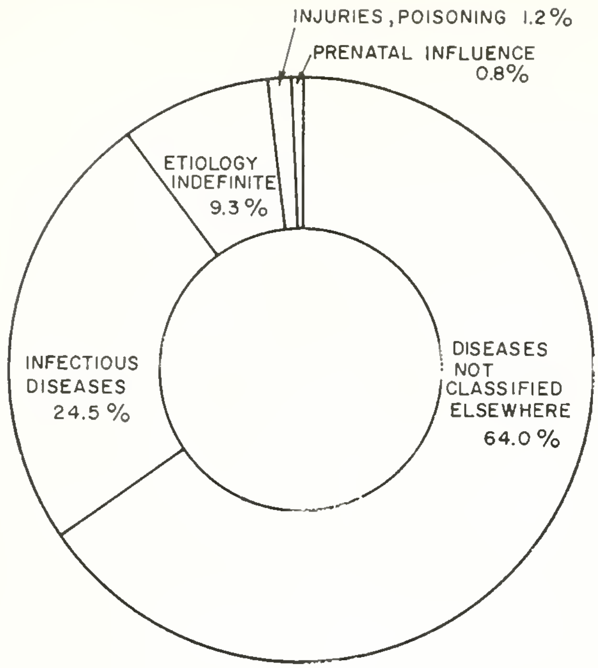


Figure 4. Causes of Blindness by Etiology.

areas, report blindness at 2.71 percent and 70.5 percent of the blindness was due to cataract. The later figure compares with the Raipur Rani Block (74.2 percent) reported in this study.

We encountered another unfortunate cause of blindness, operating in 3.4 percent of the total blind. It is due to surgical fault included under 411-37.18--37.19--37.08 and 62.21 (in the camps this figure rises to 6-10 percent just because most of the people who are blind are common denominators for all the camps which are held within approachable distance). Multiple etiological factors operated in 3.4 percent of the blind. They were all from Raipur Rani Block.

SITE TYPE AND ETIOLOGY (Table 13)

Cataract

Projecting the findings to the rate-per-100,000 persons in the general population 2,056 persons would be blind because of lenticular changes. In this 8 cases are due to rubella, 23 due to faulty surgery, 8 due to injury, 1977 due to senility, 24 assumed senile changes, and 16 to prenatal influence.

Corneal Diseases

Blindness in 690 persons per 100,000 can be ascribed to corneal disease. These are due to infectious disease in 674, prenatal influence in 8, and indefinite etiology in 8.

In the infectious group 376 are due to trachoma, 56 due to smallpox and unknown infections, and 241 due to unidentified corneal infections causing ulcers and subsequently corneal opacity.

Eyeball, General

In 100,000 of general population 101 have blindness due to glaucoma and myopia and phthisis bulbi; 23 have glaucoma (open-angle); and 16 unspecified glaucoma, 8 having myopia and 54 atrophic globe. In this last group 46 are due to infection and 8 due to injury. Infections include syphilis, trachoma, smallpox, and other nonspecified infections. Eight are due to syphilis, 8 to trachoma, 16 to smallpox, 16 following corneal ulcers.

Retina and Optic Pathways

Thirty-two cases of blindness-per-100,000 of population belong to this group. Eight having macular degeneration, and 24 due to optic atrophy. Of the latter one-third are due to meningococcal infection, in one-third it is senile phenomenon, and in one-third it is due to unknown causes.

SITE TYPE INDEFINITE

In this category 321 per 100,000 fall. Of these 54 would have infective processes where corneal opacity and cataract were in combination, 23 of these opacities being due to trachoma, 23 due to smallpox, and 8 due to unidentified infections.

Thirty-two fall in the group of diseases not classified elsewhere (16 being senile and 16 presumed senile). Etiology is indefinite in 237.

TABLE 17

Blindness by Etiology

	All cases by etiology	Infectious diseases	Rubella 18.00	Syphilis 20.20	Trachoma 22.00	Other identified infectious diseases 28.90	Unidentified infectious diseases 29.20	Injuries and poisonings	Surgical 37.18	Violence, blow or fall 38.08	Post-surgical 37.19	Post-surgical 37.08	Foreign body-occupational activity 31.09	Diseases not classified elsewhere	Senile degeneration by reported diagnosis 62.21	Assumed senile degeneration 62.22	Prenatal influence	Probable hereditary origin 80.20	Etiology indefinite	Unknown to science 91.00	Etiology not established 99.00	All others 95.99	Senile degeneration 95.02
Kharar Block																							
No. of persons	210	65	1		29	9	26	2				1	1	117	114	3	3	3	23	10	7		6
Group percentage			1.5		44.6	13.8	40.00					50	50		97.4	2.6		100		43.5	30.4		26.1
Total blind percentage		31.0	0.5		13.8	4.3	12.4	1				0.5	0.5	55.7	54.3	1.4	1.4	1.4	11.0	4.8	3.3		2.9
Raipur Rani Block																							
No. of persons	198	36		1	23	3	9	3	1	1	1			144	142	2			15	1		14	
Group percentage				2.8	63.9	8.3	25.0		33.3	33.3	33.3				98.6	1.4				5.25		93.75	
Total blind percentage		18.2		0.5	11.6	1.5	4.5	1.5	0.5	0.5	0.5			72.7	71.7	1.0			7.6	0.5		7.1	
Total																							
No. of persons	408	101	1	1	52	12	35	5	1	1	1	1	1	261	256	5	3	3	38	11	7	14	6
Group percentage			1.0	1.0	51.5	11.9	34.6		20.0	20.0	20.0	20.0	20.0		98.1	1.9		100		28.9	18.4	36.8	15.8
Total blind percentage		24.7	0.3	0.2	12.7	2.9	8.6	1.2	0.3	0.3	0.3	0.2	0.2	64.0	62.7	1.2	0.7	0.7	9.3	2.7	1.7	3.4	1.5
Blindness Rate	3200	792	8	8	407	94	275	39	7	8	8	8	8	2047	2008	39	24	24	298	86	55	110	47

Among the total 321 in this group of site-type indefinite, 16 are "glaucoma in combination," 46 "glaucoma and cataract," 227 "cataract in combination," and in 32 site-type could not be established.

RESIDUAL VISION

Out of the total of cases of blindness encountered, 24.7 percent had 6/60 vision, 12 percent had vision of 5/60 to 4/60, 19.4 percent had acuity of 3/60 to 2/60 and 30.4 percent had 1/60 or hand-movement vision. Among the rest 7.1 percent had only light perception, and 6.4 percent complete blindness. It is thus 6.4 percent of the blind who are totally blind (Table 18).

This gives a rate of absolute blindness of 204-per-100,000 of population. Of these 119 are male and 85 female. In the entire range of impairment classified as blind, these proportions are 1717 females to 1483 males-per-100,000. The projected age distribution of absolute blindness-per-100,000 was 8 in the first decade, 24 in the third decade, 16 in the fourth, 24 in the fifth, 54 in the sixth, 16 in the seventh, and 62 cases in the over 70 group.

TABLE 18

Visual Acuity (Bilateral Blind)

Age group	6/60		5/60-4/60		3/60-2/60		1/60-HM		PL-PR		Total Blindness		Total		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F		
0-10	-	-	-	-	-	-	1	-	-	-	1	-	2	-	2	0.500
11-20	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1	0.300
21-30	-	-	2	-	2	1	2	1	-	-	-	3	6	5	11	2.700
31-40	4	9	1	1	1	6	-	4	-	-	-	2	6	22	28	6.900
41-50	9	20	3	2	5	9	4	7	1	2	1	2	23	42	65	15.900
51-60	11	14	3	8	9	14	15	15	-	3	5	2	43	56	99	24.310
61-70	17	8	8	6	11	6	21	26	4	7	1	1	62	54	116	28.400
Above 70	8	1	9	6	7	7	13	15	7	5	3	5	47	39	86	21.000
Total	49	52	26	23	35	44	56	68	12	17	11	15	189	219	408	
Total for both sexes, all ages	101		49		79		124		29		26					
Percentage	24.7		12.0		19.4		30.4		7.1		6.4		46.3	53.7		100.000

BLINDNESS AND SEX (Table 19)

It has been mentioned previously that significantly more blindness was found among females ($p < 0.01$).

Taken by site and type, the involvement of the eyeball in general is 0.119 percent in males and 0.082 percent in females, and is statistically insignificant ($p > 0.05$). Involvement of the lens is 1.779 percent in males and 2.361 percent in females. This difference is highly significant ($p < 0.05$). Retinal involvement occurred only once in a male (0.015 percent). Optic atrophy is 0.029 percent in males and 0.016 percent in females, and is statistically insignificant ($p > 0.05$). Site type indefinite is 0.269 percent in the males and 0.379 percent in the females, and is statistically insignificant ($p > 0.05$), (Table 19). Lens involvement, therefore, is the only significant factor contributing towards higher incidence in females.

TABLE 19

Blindness by Site and Type in Male and Female Population

Total Males: 6687

Total Females: 6056

	Male	Percentage in Male Population	Female	Percentage in Female Population	Remarks
Eyeball in general	8	0.119	5	0.082	($p > 0.05$)
Cornea-sclera	41	0.613	47	0.776	($p > 0.05$)
Lens	119	1.779	143	2.361	($p > 0.05$)
Retina	1	0.015	-	-	-
Optic nerve	2	0.029	1	0.016	($p > 0.05$)
Site-type indefinite	18	0.269	23	0.379	(0.05)
	189	2.826	219	3.616	

Table 20 shows the distribution by etiology. Infectious diseases are 0.747 percent in the males and 0.858 percent in the females, and is statistically insignificant ($p > 0.05$). Injuries 0.029 percent in males, and 0.049 percent in females are insignificant ($p > 0.05$). Diseases not classified elsewhere (including senile degeneration indicated by diagnosis) are 1.749 percent in males and 2.361 percent in females. This difference is highly significant ($p < 0.01$). Prenatal influence could be observed only in males in 0.044 percent. "Etiology indefinite or not reported" did not show a significant difference between males and females.

UNILATERAL BLINDNESS

Blindness (visual acuity of 6/60 or less) in one eye only was found in 3.272 percent of the total population. This is comparable to bilateral blindness for which the figure was 3.2 percent. From the point of view of distribution by age group 0.247 percent are unilaterally blind in the first decade. For subsequent decades the figures are 0.793 percent, 2.584 percent, 7.613 percent, 11.078 percent, 16.964 percent and 22.457 percent, showing a progressive rise right from the 1st decade, (Table 21).

The findings on unilateral blindness translated into rate-of-blindness figures per 100,000 of population are shown in Tables 22, 23, 24, 25 and 26.

TABLE 20

Bilateral Blind by Etiology in Male and Female Population

Etiological diseases	Male	6.687 Percentage	Female	6.056 Percentage	Remarks
Infections	50	0.747	52	0.858	Difference insignificant ($p > 0.05$)
Injuries	2	0.029	3	0.049	Difference insignificant ($p > 0.05$)
Diseases not classified elsewhere	117	1.749	143	2.361	Difference significant ($p < 0.01$)
Prenatal influence not classified elsewhere	3	0.044	-	-	
Etiology indefinite or not reported	17	0.254	21	0.346	Difference insignificant ($p > 0.05$)
Total	189	2.826	219	3.614	Difference significant ($p < 0.01$)

TABLE 21

Visual Acuity in Cases of Unilateral Blindness

Age Group	6/60 M	6/60 F	5/60-4/60 M	5/60-4/60 F	3/60-2/60 M	3/60-2/60 F	1/60-HM M	1/60-HM F	PL-PR M	PL-PR F	Totally blind M	Totally blind F	Total M	Total F	Grand Total	% In total population	% In group population	% In total one eye blind
0-10	-	1	-	-	-	1	5	1	2	-	-	1	7	4	11	0.086	0.247	2.6
11-20	1	-	2	1	1	1	5	5	-	1	1	5	10	13	23	0.180	0.793	5.5
21-30	4	6	3	3	4	1	8	8	3	2	1	2	23	22	45	0.354	2.584	10.8
31-40	2	10	5	7	2	5	6	9	1	3	7	4	23	38	61	0.478	4.642	14.6
41-50	8	4	7	4	4	2	10	17	3	4	9	2	41	33	74	0.581	7.613	17.7
51-60	6	9	3	4	5	5	15	12	5	5	3	4	37	39	76	0.597	11.078	18.2
61-70	5	5	3	4	4	3	11	7	5	16	6	5	34	40	74	0.581	16.964	17.7
Over 70	3	-	3	3	3	-	14	10	7	4	3	3	33	20	53	0.415	22.457	12.9
Total	29	35	26	26	23	18	74	69	26	35	30	26	208	209	417	3.272		
Male and Female Total	64		52		41		143		61		56							
Percentage out of 417	15.4		12.5		9.8		34.3		14.6		13.4							

In the first decade, aged 0 to 10 years in a general population of 100,000, the number of unilaterally blind cases is 86. Among these, general eyeball involvement is seen in 16: 8 have multiple congenital anomalies and 8 phthisis bulbi following smallpox (Table 22). Cornea involvement accounts for 30 cases: 16 have corneal opacities due to trachoma, 7 have corneal involvement due to corneal ulcer, and 7 have corneal opacities which are unspecified (Table 23). Lens is involved in 16, all being traumatic in nature (Table 24). Eight have congenital persistent hyperplastic vitreous (Table 25). Eight have anisometropic amblyopia, and 8 have cataract in combination with opacities of cornea and/or glaucoma, etc. (Table 26).

In the second decade, out of 180 persons having unilateral blindness, 32 have phthisis bulbi: 8 due to smallpox, 16 following unidentified corneal infections, and the other 8 due to unspecified causes. In 118 cases blindness is due to corneal opacities: 40 due to smallpox, 64 due to corneal ulceration, and of the remaining 14 cases 7 are due to nutritional deficiency and 7 due to chemical burns. Lenticular opacities account for 23 cases. Of these 15 are due to injury, and 8 due to congenital cataract. The remaining 7 cases fall into the unspecified group.

In the 3rd decade the extrapolated figure for unilateral blindness is 354. Of this, 40 are cases of

TABLE 22

Unilateral Blindness Per-100,000-Population
Eyeball in General

		0-10 M	0-10 F	11-20 M	11-20 F	21-30 M	21-30 F	31-40 M	31-40 F	41-50 M	41-50 F	51-60 M	51-60 F	61-70 M	61-70 F	Above 70 M	Above 70 F	Total
Glaucoma Open angle	111-91.00								8	8				8				24
Glaucoma Surgical or medical procedure	111-37.19													7				7
Glaucoma Type not specified	113-91.00												8				8	16
Glaucoma Etiology not established or reported	113-99.00														7			7
Myopia Etiology not established or reported	140-91.00					8			8									16
Multiple congenital malformation. Heredity probable	147-80.20		8															8
Multiple congenital ocular malformation, congenital origin not elsewhere classified	147-89.00								8									8
Atrophic globe smallpox	155-28.20		8		8	8		8	14	16								62
Atrophic globe unidentified infections (corneal ulcer)	155-29.20			8	8		8	40		8				8			8	87
Atrophic globe recreational activity-blow or fall	155-34.08									8			8					16
Atrophic globe foreign body in eye	155-34.09						8		8									16
Atrophic globe unidentified infectious diseases, prenatal	155-29.10						8											8
Atrophic globe occupational	155-31.09								8	8								16
Atrophic globe violent act	155-38.09											8						8
Atrophic globe causal activity not specified	155-49.19				8													8
Atrophic globe etiology not established	155-99.00												7			7		14
Other causes	190-29.20												7					7
Total		-	16	8	24	16	24	48	54	48	-	8	30	23	7	7	15	328
Total Male and Female		16		32		40		102		48		38		30		22		328

TABLE 23

Unilateral Blindness Per-100,000-Population
Cornea Sclera

		0-10 M	0-10 F	11-20 M	11-20 F	21-30 M	21-30 F	31-40 M	31-40 F	41-50 M	41-50 F	51-60 M	51-60 F	61-70 M	61-70 F	Above 70 M	Above 70 F	Total
Kerato-conjunctivitis trachoma	310-22.00					8			14								8	30
Corneal opacity - pannus tra- . choma	315-22.00		8						8									16
Corneal opacity - pannus, specified disease not classified elsewhere	315-78.00	8																8
Corneal opacity - smallpox	318-28.00			16	8	15	16	14	8			16	8					101
Corneal opacity - unidentified infection (corneal ulcer)	318-29.00	7		24	16	48	8	32	40	36		23	16	8	22	8		288
Other corneal dystrophy (xerophthalmia, nutritional deficiency)	340-62.30				7													7
Other corneal dystrophy. Etiology not established	340-99.00											8						8
Other causes of cornea-sclera (corneal opacity, trachoma)	390-22.00						8	8	16		8			8				48
Corneal opacity (smallpox)	390-28.20				16		14	8	8	8	8	8						71
Corneal opacity (corneal ulcer)	390-29.00			8	16	16	32	8	8	24	16	31	16		8		8	191
Corneal opacity (chemical cause, injury)	390-48.01				7													7
Corneal opacity (causal agent not specified)	390-48.19						8											8
Corneal opacity (causal activity not specified)	390-49.19	7																7
Corneal opacity (occupational activity, blow, or fall	390-31.09					7	7		8					24	8	7	7	68
Corneal opacity diseases not classified elsewhere	390-78.00									8								8
Corneal opacity etiology not established or not reported	390-99.00					7		8		8		8		8				39
Total		22	8	48	70	101	93	78	110	84	32	94	40	48	38	15	23	
		30		118		194		188		116		134		86		38		

TABLE 24

Unilateral Blindness Per-100,000-Population
Lens

		0-10 M	0-10 F	11-20 M	11-20 F	21-30 M	21-30 F	31-40 M	31-40 F	41-50 M	41-50 F	51-60 M	51-60 F	61-70 M	61-70 F	Above 70 M	Above 70 F	Total
Senile cataract	411-62.21						8	8	87	124	160	144	185	142	245	180	89	1372
Recreational activity, cataract (blow, or fall)	411-34.08	8	8	8			8	8			8							48
Congenital cataract	411-89.00				8	8												16
Occupational activity, cataract (blow, or fall)	411-31.08					8												8
Operated cataract	412-37.00						8											8
Senile cataract operated	412-62.21									16						8		24
Cataract operated, assumed senile degeneration	412-62.22										8	16		8				32
Congenital cataract, operated	412-89.00															8		8
Dislocated lens due to occupational activity	420-31.19								7									7
Dislocated lens due to recreational activity not specified	420-34.19									8								8
Dislocated lens due to recreational activity (blow, or fall)	420-34.08			7														7
Dislocated lens etiology not established	420-99.00											16						16
Total		8	8	15	8	16	24	16	94	148	176	176	185	150	245	196	89	
		16		23		40		110		324		361		375		285		1554

general eyeball disease: 32 of phthisis bulbi, and 8 of myopic degeneration. Corneal opacities account for 194 cases, of which 45 are due to smallpox, 104 due to corneal ulcers, and 16 due to trachoma. Of the remaining 29 cases, 14 are due to occupational activity, and in 15 cases etiology could not be established. Lenticular opacities total 40 cases (32 unoperated and 8 operated). Of these, 32 are cases of presenile cataract including 8 congenital cataract. Eight are due to occupational injury and 8 due to recreational injury. There are 8 cases of macular degeneration and optic atrophy. A remainder of 64 cases in this age group are site-type indefinite: cataract in combination in 16, and amblyopia in 48 cases.

The overall blindness rate figure for the 4th decade is 478 persons blind of one eye. These comprise 102 cases of general eyeball involvement, 188 of corneal diseases, and 110 lens changes. There are 7 cases of retinal disease, and 71 classed as site type indefinite. The causal factors in eyeball diseases were distributed as follows: glaucoma in 8, myopia in 8, atrophic globe due to smallpox in 22, following corneal ulcer in 40, and 8 cases of multiple congenital anomalies. Corneal disease accounted for 188 cases. Etiological factors in this are trachoma in 46, smallpox in 38, ulcer in 88, injury in 8, and 8 cases listed as undiagnosed. Of the 110 lens disease cases, presenile type of cataract account for 95, and traumatic cataract for 15. Classification in the remaining cases is macular degeneration 7, cataract in combination other than glaucoma 16, myopia 8, and amblyopia 47.

In the 5th decade 581 cases of unilateral blindness are encountered in a general population of 100,000. Forty-eight cases have general eyeball disease, of which 40 are due to phthisis bulbi, and 8 to glaucoma. The cause of phthisis bulbi is smallpox in 16, ulceration in 8, and trauma in 16. In 116 cases, corneal disease accounted for blindness: 76 following corneal ulceration, trachoma 8, smallpox 16, and 16 cases where etiology could not be established. Cataract accounted for unilateral blindness in 324

TABLE 25

Unilateral Blindness Per-100,000-Population
Uvea, Retina, Optic Pathways and Vitreous

		0-10		11-20		21-30		31-40		41-50		51-60		61-70		Above 70		Total
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Uvea	51-99.00									7								7
Retina	660-48.03								7									7
	690-48.03					8												8
Optic pathways	720-21.08													8				8
	770-99.00					8												8
Vitreous	890-89.00	8																8

TABLE 26

Unilateral Blindness Per-100,000-Population
Site-Type Indefinite

		0-10		11-20		21-30		31-40		41-50		51-60		61-70		Above 70	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Amblyopia	915	8				32	16	39	8	8	22	8		8	8		
Myopia	958								8								
Cataract in any other combination	956	8					16		16	16	24	8	48	24	14	32	38
Glaucoma and cataract	951										8			8			
Site-Type indefinite	990			7						8							
Total		16		7		32	32	39	32	32	54	16	48	40	22	32	38

persons. Senile cataract is present in 284, aphakia in 24, traumatic cataract in 8, and dislocated lens in 8 cases. Uveitis is present in 7 cases.

In the 6th decade the rate of unilateral blindness is 597. In 38 of these there is general eyeball involvement; in 134 cases corneal involvement; in 361 cataract, and in 64 cases site type is indefinite. General eyeball diseases were due to glaucoma in 8, phthisis in 16 was due to trauma of various types, and in 14 cases etiology could not be established. In corneal involvement, 32 were due to smallpox, 86 due to corneal ulceration, 8 due to corneal dystrophy, and in 8 cases etiology could not be established. Unilateral blindness due to lenticular changes accounted for 361 cases; 16 operated and 329 unoperated. In 16 subjects the lens was dislocated due to unknown factors. In 64 cases the site type is classified indefinite. Amblyopia is present in 8 of these, and 56 show cataract in combination.

In the 7th decade the figure for one eye blindness is 581. There is general eyeball involvement in 30, corneal and scleral involvement in 86, cataract in 395, optic atrophy in 8 and, in 62 cases site type is indefinite. In general eyeball involvement, 22 were glaucoma cases and 8 phthisis bulbi due to smallpox. Among 86 corneal diseases, 38 are following corneal ulceration; 8 because of trachoma and in 32 cases occupational trauma was responsible. In 8 cases no definite etiology could be labeled. In 395 cases the blindness was due to lenticular changes. Only 8 of these were operated upon. Optic atrophy due to trauma accounted for 8 cases. Of the remaining 62 cases, 38 were cataract in combination, 16 amblyopia, and 8 glaucoma in combination.

In the over 70 years old group the total unilateral blindness rate figure was 415. In 22 of these there is general eyeball involvement; of it 8 due to glaucoma, 7 phthisis bulbi following ulceration, and in 7 phthisis due to unknown causes. Thirty-eight have corneal diseases; 8 due to trachoma, ulceration in 16, and injury in 14 cases. In 285 cases blindness is due to cataract, which is unoperated in 269 and operated in 16 cases. The remaining 70 in this age group fall under site type indefinite where cataract in combination is present in all the 70 cases.

A tabulation of the actual cases of unilateral blindness found in all age groups of the survey population is made in Table 27. It can be seen that eyeball involvement was

was present in 10.07 percent, corneal in 27.83 percent, lens in 47.25 percent, and the remaining 14.84 percent had uveal, optic nerve, retinal involvement, and other diseases in combinations.

TABLE 27

Unilateral Blindness

	Cases	Percentage
Eyeball in General		
Glaucoma	7	1.68
Myopia	2	0.48
Phthisis (atrophic)	31	7.43
Congenital anomaly	2	0.48
	42	10.07
Cornea-Sclera		
Corneal Opacity (smallpox)	22	5.28
Corneal ulcer	61	14.63
Trachoma	13	3.12
Injury	13	3.12
Others	7	1.68
	116	27.83
Lens		
Cataract unoperated	182	43.65
Cataract operated	9	2.16
Dislocated and others	6	1.44
	197	47.25
Uvea	1	0.23
Retina		
Macular degeneration	2	0.48
Vitreous		
Persistent hyperplasia	1	0.23
Optic atrophy	2	0.48
Site-type indefinite		
Cataract and glaucoma	2	0.48
Cataract in combination	31	7.43
Amblyopia	20	4.80
Myopic degeneration	1	0.23
Unknown	2	0.48
	62	14.84

OVERALL PATTERN OF THE BLINDNESS DATA

Bilateral blindness is 69.6 percent curable and 30.4 percent incurable. The incurable to curable ratio is maximum in the 3rd decade and it is equal in the 4th decade. Later it falls progressively in various age groups. The preventability of blindness in general is 27.2 percent. The ratio of unpreventable to preventable goes on rising with age. This is solely due to cataract. Of the total population, 3.2 percent is blind (2.826 percent in males and 3.616 percent in females). The greater involvement in females is highly significant ($p < 0.01$). This is because of more curable blindness caused by cataract (prevalence of cataract is also significantly higher in females). Lenticular opacities as cause of blindness rank first in the list of site-type affection and as senile degeneration in the etiological section. Corneal diseases rank second by site type and infectious diseases rank second by etiology.

Unilateral blindness prevalence is almost the same as bilateral blindness, 3.272 percent. There is a tendency for it to rise progressively with age. Regarding causative factors, cataract ranks first; then in order of importance are corneal opacity, eyeball in general, and others. The similarity of general pattern in both unilateral and bilateral blindness is striking.

SUMMARY AND CONCLUSIONS*

The results of a survey conducted during two and a half years in Raipur Rani Block of Haryana and Kharar Block of Punjab are presented. By drawing a simple random sample from one block and a stratified sample from the other, a house-to-house survey was conducted to cover 5 percent and 8 percent of the population in the two blocks respectively. In

*Editor's Note. This section summarizes the entire report. Consequently it refers to some data not contained in the portions dealing with blindness which we have reprinted here.

all, 12,743 persons were examined, 52.50 percent being males and 47.50 percent females. The ratio of 1:0.90 so covered was akin to the general population distribution figures of 1:0.87 as taken from the figures projected from the 1961 census.

Of the persons so examined, 77.290 percent had perfectly normal vision while the rest, 32.8 percent, had vision less than normal in one or both eyes. Loss of vision because of refractive errors was 5.132 percent (2.777 percent being myopic while 2.354 percent was hypermetropic). The remainder of the loss could be accounted for by various ocular diseases.

The prevalence of economic blindness encountered was 3.2 percent. In the male population it was 2.862 percent and in the female population 3.616 percent. The significantly higher prevalence of blindness in females is due to the presence of cataract which was more frequent in females than in males, the prevalence of other blinding diseases remaining the same.

By site-type, the involvement of lens was observed in the greatest number and then in order of prevalence cornea-sclera, site-type indefinite, eyeball in general, optic pathology, and retinal diseases.

Etiologically, senile changes were the causative agents in the greatest number of cases. Infectious diseases were second. The next group in order of frequency was "etiology indefinite or not reported." Injuries and poisonings and prenatal influence were the next in order.

Curable blindness was 69.69 percent and 30.49 percent incurable. The preventability of blindness in general is 27.29 percent. In the series of curable blindness this preventability is 9.51 percent while in the incurable blindness series this preventability is 67.74 percent.

Unilateral blindness prevalence is almost the same as bilateral blindness: 3.272 percent. In causative factors, cataract rates first and next in order are corneal opacity, eyeball in general, and others. The similarity of general pattern in both the unilaterally and bilaterally blind is striking.

The general prevalence rate of trachoma was 54.86 percent (55.24 percent in males and 54.45 percent in females). Stage I and II was encountered in 15.15 percent while 84.85 percent had III and IV stage. One of the trachoma sequalae, i.e., entropion, trichiasis, xerosis was found in 3.97 percent of all the trachoma patients. Entropion and trichiasis were seen in 1.35 percent while xerosis was seen in 2.34 percent.

Corneal opacities were seen in 4.51 percent of the examined population (3.9 percent males and 5.1 percent females). Among the causes encountered, trachoma and miscellaneous group ranked first. Next in order of frequency were ulcer, smallpox, injury, surgery, and dystrophy in that order. In 24 percent trachoma could be labeled as a definite cause. A larger proportion of cases where no definite cause could be attributed or where trachoma was held responsible by implication, are grouped under the miscellaneous heading.

The prevalence of corneal opacity in the female population was significantly higher as compared to males. The bilaterality of the corneal opacities is 42.09 percent and the remaining 57.91 percent are unilateral. More than one fourth (26.26 percent) of the patients having corneal opacities were economically blind. Thus persons who need keratoplasty are 2.57 percent in the general population.

Cataract and aphakia combined were encountered in 10.484 percent of the general population (males 9.735 percent, females 11.331 percent). Only aphakia, without cataract, was encountered in 1.451 percent of the population (1.445 percent in males and 1.469 percent in females). While aphakia did not show any statistically significant difference between males and females, the combined group showed prevalence significantly more in the females than in the males. The higher prevalence was noticed in the 4th, 5th, and 7th decades. 1.687 percent of the total population had mature cataract (16.4 percent having bilateral and

83.6 percent unilateral cataract). For every 1000 patients with aphakia there were 1162 with cataract, who needed immediate surgery.

Glaucoma prevalence in the general population was 0.486 percent (2.264 percent above 40 years, 1.641 percent above 30 years). Primary glaucoma was 58 percent and secondary glaucoma 42 percent. In all, 45 percent of the glaucoma patients have reached the stage of absolute glaucoma. The prevalence in females was significantly higher than in males.

Other diseases of the eye have been grouped under headings of infection, allergies, congenital, and other acquired diseases. Among these were pterygium, pinguecula, and squint. Phthisis bulbi was encountered in 0.29 percent of the population, and accounts for 1.2 percent of the economic blind.

CONCLUSIONS

If we project the survey figures to the entire states of Punjab and Haryana, using census figures for 1971, we obtain the following picture:

Total number of blind	759,212
Curable blind	522,335
Incurable blind	227,877

Patients who can be immediately rehabilitated by cataract surgery are 395,502 and the number of those who need corneal surgery is 602,514. Apart from the urgency of relief work the problem of rehabilitation of incurable blind is also colossal in both states. The need for creating a rehabilitation and vocational counseling unit in each state with branches in each district, is the paramount need brought out by this survey. This would not only help the state to save enormous sums now lost due to the unproductive status of the blind, but would also bring new hope and selfesteem to this helpless mass of humanity. It would enable them to gain social acceptability and achieve permanent adjustment in the family and community.

If we calculate the loss in terms of earning capacity at the rate of 881 rupees per capita per annum, the total loss in both states is 660,936,772 rupees per annum. Money spent for attendants to care for the blind (taking the working hours as 8 hours/day) is 165,234,193 rupees. The cost of supporting the blind at the rate of 30 rupees per month per blind person is 270,007,632 rupees per annum. The gross loss to both states is 8,531,778,597 rupees per annum.

Consider the human misery! Taking life expectancy to be 52 years, the total period endured by the blind in perpetual darkness is over 5,270,638 years (over 5 million). This period can be made fruitful and worth living only if all government and private agencies look at this problem from the human angle and take it up on a priority basis.

APPENDIX 1

Serial No.

Card No.
Date
Sex M_ F_

Name

Age

Occupation:
1. Student
2. Field worker
3. Office worker
4. Teacher/engineer
5. Businessman
6. Housewife

Address

Dependents
S.M.C.W.

Income

Literate/illiterate
Nutrition: Good/Average/Poor
Vegetarian/Non-vegetarian

Complaints:
Past history:

whether consulted the Doctor or not at any moment.

Examination	R.E.	L.E.	Examination	R.E.	L.E.
Vision:			Palpebral:		
Uncorrected			Follicles		
Corrected			1. Trachomatous		
Color vision			2. Spring catarrh		
			3. Folliculosis		
Ref. error with number			Papillae		
Myopia			Scarring		
Hyperopia					
Astigmatism			Fornix:		
Presbyopia			Pterygium		
			Nasal		
Amblyopia:			Temporal		
Squint:			Both		
Paralytic			Vascular and fleshy		
Concomitant			Thin and avascular		
Convergent			Diagram for its extent		
Divergent			Xerosis		
Vertical			Bitot's spots (and the site)		
Lids:			Trachoma:		
Congenital			Active		
Inflammatory			Healed		
Neoplasm			Stage		
Any other affection			Sequalae		
Lid margin					
			Lac. Sac:		
Conjunctiva:			Cornea:		
Conjunctivitis			Ulcer		
Bulbar			Vessels		
Limbus			Opacity		
Pannus			Nebular		
Progressive			Macular		
Regressive			Leucoma		
Horbert's pits			Leucoma adh.		
Scarring			Staphyloma		

APPENDIX 1 (Continued)

Examination	R.E.	L.E.
Etiology of Corneal Opacity:		
Post ulcer, infection		
traumatic		
Trachoma		
Deep keratitis		
Dystrophy		
Keratomalacia		
Chemicals		
Iris and Corneal Body:		
Iris:		
Pupil		
Lens:		
Normal		
Congenital Cataract		
Traumatic Cataract		
Diabetic Cataract		
Senile Cataract		
Presenile Cataract		
Incipient Cataract		
Cortical cataract		
Nuclear cataract		
Color cataract		
Subluxated lens		
Mature		
Cortical cataract		
Nuclear cataract		
Color cataract		

Examination	R.E.	L.E.
Hypermature type		
Morgagnian		
Calcified capsule		
Shrunken		
Swollen ens		
Aphakia; Intraocular		
Pressure		
Normal		
Raised		
Glaucoma		
Type: Congenital primary		
narrow angle		
Open angle		
Secondary		
Cause		
Absolute Vitreous Fundus:		
Optici disc		
Macula		
Blood vessels		
Any other positive finding)		
Eyeball and Extra		
Ocular Muscles		
Proptosis		
Panophthalmitis		
Phthisis bulbi		
Nystagmus		
Cranial nerve		
Palsy peripheral		
Fields		

Summary	Right	Left	Refraction
Normal sighted/partial sighted			
One eye blind/Both eyes blind			
Better than 6/60 but field restricted 20°			
6/60 in better eye			
3/60-6/60			
2/60-3/60			
Less than 2/60			
Light projection			
Light perception			
Absolute blindness			

Diagnosis	Treatment
Refractive error	
Lids	
Pterygium	
Trachoma	
Squint	
Corneal opacity	
Cataract	
Aphakia	
Glaucoma	
Optic atrophy	
Any other	

APPENDIX 2

Eye Relief, Rehabilitation and Survey Project Chandigarh (India)
Chief Investigator: Dr. I. S. Jain

Department of Ophthalmology,
Postgraduate Institute of Medical
Education and Research, Chandigarh

OPHTHALMOLOGIST'S REPORT OF EYE EXAMINATION

Card No. ___
O.P.D.No. ___

Name: first__________ middle__________ last ______________________

Address: Home No. _____ City or Village__________ Block_____ District___

Date of birth or Age: __________ Economic status v. poor/poor/average/good ___

Sex: Male________ Female________

Occupation before vision impairment:

I. History

a. Probable age at onset of severe vision impairment.
Right eye _____ Left eye______

b. Severe ocular infections, injuries, operations, if any, with age at time of occurrence ____________

c. Were patient's parents blood relatives? _____ Is patient's ocular condition believed to have occurred in any blood relative(s)? _____ If so, what relationship(s)? ______________

II. Measurements

a. Visual acuity

	Distant Vision with best correction with ordinary lenses	Near Vision with best correction with ordinary lenses
R.E.	_____	_____
L.E.	_____	_____
B.E.	_____	_____

b. Field of vision

Right eye ____________________ angle substended by widest diameter of field of vision
Left eye ____________________

c. Intraocular Pressure

Tension in mm. Hg: R.E. _____ L.E. _____ (Gm. wgt. _____ Yr. of calibration _____)

III. Cause of Blindness or Severe Vision Impairment

a. Present ocular condition(s) responsible for vision impairment. (If more than one, specify all but underline the one which probably first caused severe vision impairment) R.E. ________ L.E. ________

b. Preceding ocular condition; if any which led to present condition, or the underlined condition, specified in a. R.E. ________ L.E. ________

c. Etiology (underlying cause) of ocular condition primarily responsible for vision impairment (e.g. specific disease, injury, poisoning, heredity or other prenatal influence) R.E. ________ L.E. ________

d. If etiology is injury or poisoning, indicate circumstances and kind of object or poison involved ________

e. Has patient had any nonocular disease not specified in c, which could have contributed to the vision impairment? ________ If so, specify ________

IV. Prognosis and Recommendations

a. Is patient's vision impairment considered to be: Stable-Deteriorating-Capable of improvement-Uncertain

b. What treatment is recommended, if any? ________

c. Is reexamination advised? ________ If so, after what interval? ________

d. Other recommendations: ________

Examining Ophthalmologist

Date of examination ________

Signature ________ Coding ________

RE Λ LE Λ BE

APPENDIX 3

Standard Classification of Causes of Severe Vision Impairment and Blindness
1966 Revision

I. Classification by Site and Type of Affection

Eyeball in General
110 Glaucoma. Subdivided:
- 111 Glaucoma, open angle
- 112 Glaucoma, closed angle
- 113 Glaucoma, type not specified

115 Hydrophthalmos
120 Microphthalmos
125 Anophthalmos, congenital
130 Albinism
140 Myopia
141 Other refractive error
147 Multiple congenital ocular malformations
150 Panopththalmitis, endophthalmitis
155 Atrophic globe
190 Other affection of eyeball

Cornea, Sclera
310 Keratoconjunctivitis
311 Interstitial keratitis
314 Scleritis
315 Pannus
318 Other keratitis
330 Keratomalacia
340 Other corneal dystrophy
370 Keratoconus
390 Other affection of cornea or sclera

Lens
410 Cataract
- 411 Cataract, unoperated
- 412 Cataract, operated
- 413 Cataract, no report concerning operation

420 Dislocated lens
490 Other affection of lens

Uveal Tract
510 Uveitis, iritis, iridocyciltis, choroiditis
520 Chorioretinitis
530 Choroidal degeneration
570 Sympathetic ophthalmia
575 Absence of iris, congenital
590 Other affection of iris, ciliary body or choroid

Retina
610 Retinitis
615 Retinopathy
630 Retrolental fibroplasia
640 Detachment of retina
650 Retinitis pigmentosa
660 Macular degeneration
670 Other retinal degeneration
690 Other affection of retina

Optic Nerve, Optic Pathway, Visual Center, Oculomotor Centers
710 Optic neuritis, including retrobulbar neuritis
720 Optic nerve atrophy
725 Coloboma of optic nerve, congenital
730 Other affection of optic nerve
750 Other affection of optic pathway or visual center
770 Nystagmus

Vitreous
810 Vitreous hemorrhage
890 Other affection of vitreous

Site and Type Indefinite or Not Reported
915 Amblyopia
950 Multiple affections reported without indication of priority as to cause of severe vision impairment. Subdivided:
- °951 Glaucoma and cataract without mention of retinal affection, any type, with or without other affection
- °952 Glaucoma and retinal affection, any type, without mention of cataract, with or without other affection
- °953 Cataract and retinal affection any type, without mention of glaucoma, with or without other affection
- °954 Glaucoma, cataract, and retinal affection, any type, with or without other affection
- °955 Glaucoma in any other combination
- °956 Cataract in any other combination
- °957 Retinal affection, any type, in any other combination
- °958 Myopia, degenerative, in any combination (category added for MRA)

°979 All other
990 Site and type of affection not established on examination or not reported

°Do not use for degenerative myopia. Code 958, instead.

II. Classification by Etiology

Infectious Diseases

11.00 Diphtheria
12.00 Fungus infection
13.00 Gonorrhea
14.00 Herpes simplex
14.50 Herpes Zoster
15.00 Measles
16.00 Meningococcal infection
17.00 Onchocerciasis
18.00 Rubella
19.00 Scarlet fever
20.10 Syphilis, specified as prenatal
20.20 Syphilis, other
21.10 Toxoplasmosis, specified as prenatal
21.20 Toxoplasmosis, other
22.00 Trachoma
23.00 Tuberculosis
24.00 Leprosy
28.10 Other identified infectious disease, specified as prenatal
28.20 Other identified infectious disease
29.10 Unidentified infectious disease, specified as prenatal
29.20 Unidentified infectious disease, other

Injuries, Poisonings

A. Causal activity
31. Occupational activity
32. Military activity
33. Household activity
34. Recreational activity
35. Transportation, Traffic
36. Birth process
37. Surgical or medical procedure
38. Act of violence
39. Prenatal event
48. Other causal activity specified
49. Causal activity not specified or no specified causal activity

B. Causal agent
.01 Chemical causing burn
.03 Radiation, including radiant heat
.04 Firearm
.05 Fireworks
.06 Other explosive
.07 Airgun or slingshot
.08 Blow or fall
.09 Foreign body in eye
.11 Methyl alcohol
.12 Lead
.13 Oxygen
.14 Quinine
.15 Other toxic agent
.18 Other nontoxic agent
.19 Causal agent not specified or no specific causal agent

Neoplasms

51.00 Retinoblastoma
52.00 Melanoma, malignant
53.00 Phakomatosis
56.00 Neoplasm of pituitary gland or stalk
57.00 Other intracranial neoplasm
59.00 Other neoplasm

Diseases or Disorders Not Elsewhere Classified

61.00 Anemia or other blood disease
62.10 Diabetes mellitus
62.20 Senile degeneration
Subdivided:
62.21 Senile degeneration indicated by reported diagnosis
62.22 Senile degeneration assumed from age and other reported data
62.30 Nutritional deficiency
62.90 Other metabolic or growth disorder
63.00 Renal disease other than complication of pregnancy
64.10 Cerebrovascular condition
64.90 Other disease of the circulatory system
65.10 Multiple sclerosis
65.20 Other demyelinating disease
65.90 Other disease of the central nervous system
66.00 Psychogenic disorder
67.00 Complication of pregnancy
68.00 Sarcoidosis
69.00 Noninfectious inflammatory disease
78.00 Other specified disease or disorder not elsewhere classified

Prenatal Influence Not Elsewhere Classified

80.00 Hereditary origin probable or possible. Subdivided:
80.10 Hereditary origin probable or possible, occurrence in genetic family reported
80.20 Hereditary origin probable or possible, occurrence in genetic family not reported
89.00 Congenital origin not elsewhere classified

Etiology Indefinite or Not Reported

91.00 Unknown to science
95.00 Multiple etiologies for cases of multiple affections included in site and type categories 950-979. Subdivided:
95.01 Senile degeneration and diabetes mellitus, with or without other etiology
95.02 Senile degeneration and other etiology except diabetes mellitus
95.03 Diabetes mellitus and other etiology except senile degeneration
95.99 All other
99.00 Etiology not established on examination or not reported

Aggarwal, L. P. *Proceedings of the 1st annual conference of the National Society for the Prevention of Blindness*, 1967, p. 77.

Aggarwal, L. P., Dhir, S. P., and Lamba, P. A. Trachoma, eradication: A pilot study. (Trachoma survey in children below 5 years of age.) *Journal of All India Ophthalmological Society*, 1966, 14:197.

Aggarwal, L. P., Malik, S. R. K., and Madan, M. *Orient. Archives of Ophthalmology*, 1963, 1:106.

Bagchi, S. *Calcutta Medical Journal*, 1934-35, 29:283.

Bagchi, S. *Calcutta Medical Journal*, 1936, 30:460.

Chatterjee, A., and Franken, S. Vision survey in Himalayan area. *American Journal of Ophthalmology*, July 1968, 66:1, 113-116.

Cooper, S. N. Trachoma: A biometeorlogical approach. *Journal of All India Ophthalmological Society*, 1964, 12:50.

Cooper, S. N. Editorial. *Journal of All India Ophthalmological Society*, 1964, 12:91.

Franken, S. *Report on research activities carried out during 1967-68.* Ludhiana: Christian Medical College, 1968.

Franken, S., and Mehta, K. K. *Ophthalmic morbidity in the dry belt of Punjab and Haryana.* Ludhiana: Christian Medical College, 1968.

Ghosh, B. N., Datta, S. P., Gopala Krishnan, B., Lamba, K., Sood, N.N., and Lamba, P. A. Ophthalmic morbidity in a semi-urban community. *Orient. Archives of Ophthalmology*, 1969, 7:16.

Krishnamoorthy, R. Incidence of trachoma among the school children in Madurai City. *Journal of All India Ophthalmological Society*, 1966, 14:165.

McDonald. Causes of blindness in Canada: An analysis of 24,605 cases registered with the Canadian National Institute for the Blind. *Canadian Medical Association Journal*, 1965, 92, 264-279.

McLaren, D. S. *Malnutrition and the eye.* New York/London: Academic Press, 1963, p. 308.

Manual on the use of NSPB standard classification of causes of severe vision impairment and blindness, Part II. New York: National Society for the Prevention of Blindness, 196(

Parsons, J. H. *Pathology of the eye.* Vol. 3. London: Aodder & Stoughton, 1906, p. 929.

Rostkowski, L. Causes of blindness in Poland: Ophthalmology as basis of research. *Journal of All India Ophthalmological Society*, 1965, 13:50.

Sarda, R. P., Harj, C., and Kheterpal, R. C. Screening of 1000 cases for incidence of simple glaucoma over age of 35. *Journal of All India Ophthalmological Society*, 1961, 15:222.

Sharma, K. L. and Prasad, B. G. An epidemiological study of blindness in Bani Block of Barkandi District U.P. *India Journal of Medical Research*, 1962, 50:842.

Shukla, S. P. Epidemiological survey of incidence of trachoma in the district of Nagpur. *Journal of All India Ophthalmological Society*, 1966, 14:147.

Shukla, B. R. and Vijay, S. D. Glaucomatous blindness in India. *Journal of All India Ophthalmological Society*, 1965, 13:123.

Sorsby, A. *The incidence and causes of blindness: An international survey. British Journal of Ophthalmology*, 1950, Monograph Supplement No. 14.

Sorsby, A., Benjamin, B., Bavey, J. B., Sheridan, M. and Tanner, J. M. Journal of Medical Research Council, Special Serial Report No. 293.21. 103.104, 1957.

Ursekar, T. N. Trachoma map of India. *Journal of All India Ophthalmological Society*, 1955, 2:94.

Venkataswamy, G. Problem of blindness in India. *Proceedings All India Ophthalmological Society*, 1966, 34:32.

Venkataswamy, G. and Rajagopalan, A. V. Etiology of blindness in South India. *Journal of All India Ophthalmological Society*, 1961, 12:77-81.

MOBILITY MAPS FOR THE VISUALLY HANDICAPPED: A STUDY OF LEARNING AND RETENTION OF RAISED SYMBOLS

G. A. James* and J. M. Gill**

Twenty five visually handicapped schoolchildren participated in a paired associate learning experiment. They had to learn the meanings of 14 different tactual symbols to a criterion of two errorless trials. Retention was measured by the savings method, and the results showed a savings of 40.2 percent. Total percentage error scores showed that some symbols were easier to learn than others; these differences are explained in terms of symbol discriminability and information content. A further experiment showed that the children could locate and identify these symbols in the context of a map. No significant differences in the number of correct symbols identified were found between children using a key and those using memory alone.

INTRODUCTION

In many situations a tactual map will provide information to visually-handicapped persons more effectively than a verbal map. Many of these situations have yet to be defined. However, at a practical level, some teachers have found tactual maps to be a viable means of teaching visually-handicapped students orientation and mobility skills, or reinforcing environmental concepts. *Tactual maps* used for this purpose are commonly known as mobility maps in Britain and travel maps in the United States. Leonard and Newman (1970) and Bentzen (1971) have shown experimentally that mobility maps can present information allowing highly mobile, visually-handicapped persons, who are also braille readers, to travel in unknown environments.

Listing the useful environmental features for orientation and navigation by the visually handicapped has been undertaken in two recent studies (James, 1972; and James, Armstrong and Campbell, 1973). In the first of these studies the problems of representing environmental information on tactual maps were discussed. Two of these problems will be discussed briefly here.

First, empirical studies of tactual symbols of areas, lines, and points have indicated that there is a limited variety of tactually distinctive symbols that can be produced within these classes (Nolan and Morris, 1971; James, 1972; Gill, 1972; Gill and James, 1973). Nolan and Morris (1971) stated "until an inventory of greater numbers of legible symbols is accumulated, the potential for standardization is limited." These studies, done by the paired comparison method, only tested discrimination and did not test the possible improvements that perceptual training may have on performance.

Second, mobility maps are generally handmade at a local level, sometimes employing volunteer help. Different production methods and different materials are used from one locality to another. As yet, no study has been made of the different qualities and forms of symbols that can be made by these different methods.

In spite of these two problems, there has been a frequent plea among teachers and the visually-handicapped map users for some agreement on the

*Blind Mobility Research Unit, University of Nottingham.

**Inter-University Institute of Engineering Control, University of Warwick.

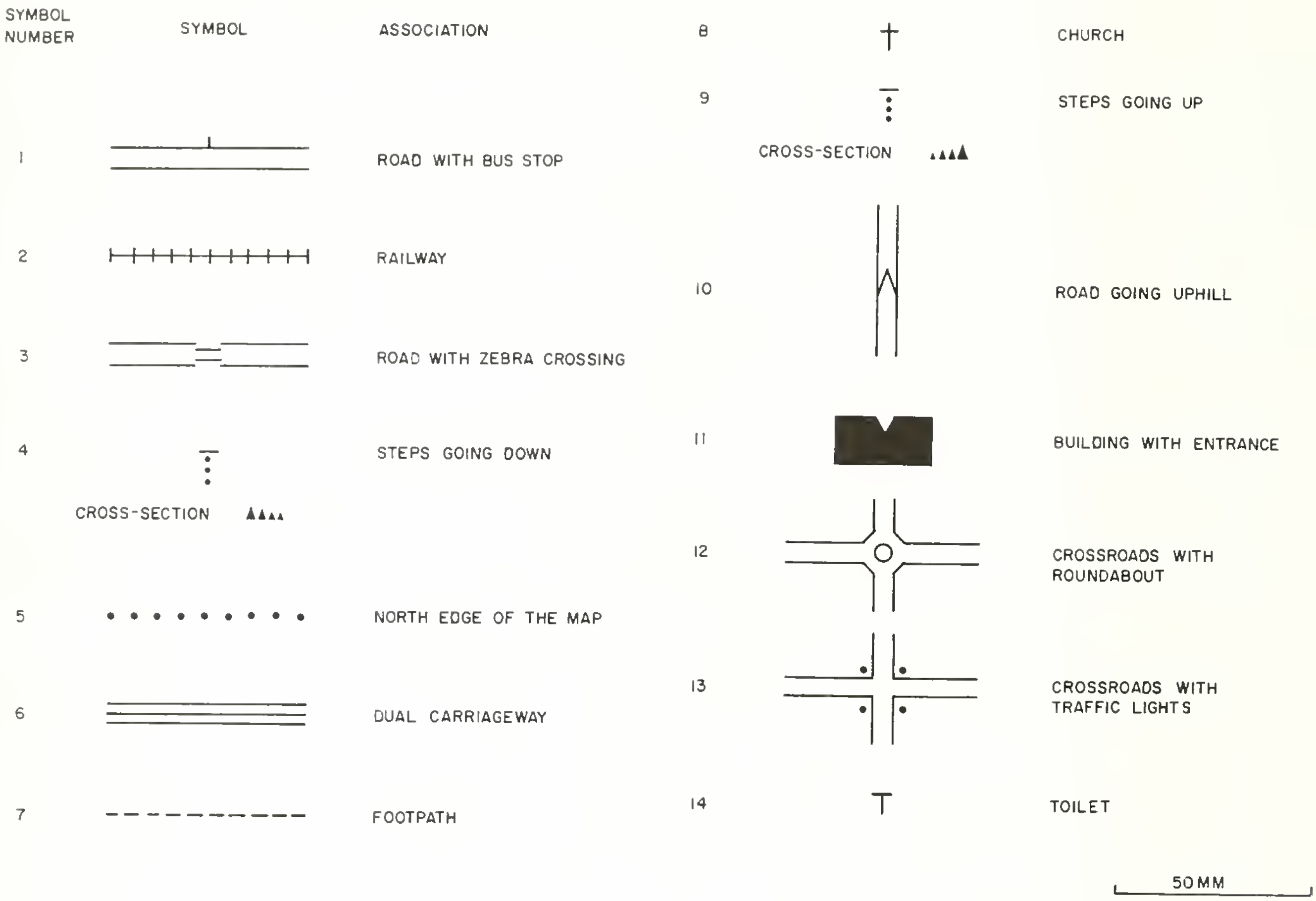


Figure 1. Print Outlines of Tactual Symbols Presented to Subjects

symbols to be used on mobility maps. Some conventional use of symbols would save the mapmaker from developing his symbols out of trial and error, but would still give him scope for making improvements; moreover, a visually-handicapped map user would be able to familiarize himself with some basic symbols and would not be required to learn a new code for every different map he encountered.

Sighted map readers do not learn the great variety of symbols found on print maps by a process of common sense, but through familiarity with conventional symbols which often contain several points of information. The distinctive information properties of symbols can facilitate the learning and retention of their meanings.

Foulke and Morris (1961) and Nolan and Morris (1963) used paired associate learning tasks to assess the learning and retention of associations between tactual symbols and verbal responses. Both studies indicated that associations could be easily learned and retained at a fairly high level.

To extend the approach made by these paired associate learning studies to cover a more practical problem, tactual symbols were chosen from those in common use to represent different environmental features or landmarks used by the visually handicapped for orientation and navigation. An experiment was designed to discover how easily the chosen symbols could be associated with their meanings and how well the associations could be retained in memory over a period of time. Information was also sought concerning the relative confusability of the symbols, and the principles which determine good legibility. Finally, it was hypothesized that once symbols and their meanings had been learned they could be identified on a tactual map without recourse to a key.

METHOD

The total duration of the experiment was 43 days, involving three separate experimental sessions.

Session 1: The Initial Learning Phase

Fourteen different symbols were produced using a computer assisted production system (Gill, 1972). Plastic copies were vacuum formed in Brailon, which is a semirigid calendered vinyl 0.2 mm thick. The relief of line symbols was 1.0 mm, and of point symbols 1.5 mm. Line and point symbols were combined to represent some features. Print outlines of the symbols used are shown in Figure 1. The tactual symbols were mounted on stiff card 150 x 100 mm. Instructions (see Appendix 1) were presented to the subjects on a magnetic tape recording. Subjects received randomly ordered symbols to a maximum of 10 trials so that each symbol could be inspected 10 times. On the words "next symbol" the subject received a symbol, and had 10 seconds to inspect it before the association words were heard from the tape recorder. After examining each symbol and hearing its meaning once, students were required to give these association words before they were heard from the tape recorder. The criterion for completion of the task was two errorless trials, each trial consisting of the 14 symbols.

Session 2: Relearning Phase

Twenty-one days after the learning phase of the experiment, a further session was conducted to assess the recall of symbol associations and "savings" on retention. The procedure was identical to the first session.

Session 3: Identifying Symbols on a Tactual Map

After a further period of 21 days, students were assigned to one of two matched groups on the basis of their recall scores from the previous session. One group was randomly designated the Key Group (K) and the other the No Key Group (NK). Subjects in both groups were given a tactual pseudomap displaying all the symbols used previously (Figure 2). Group K were also given two pages of Brailon showing the 14 tactual symbols with the associations in braille. Group NK was asked to identify the symbols on the pseudomap from memory. Instructions for this task are shown in Appendix 2.

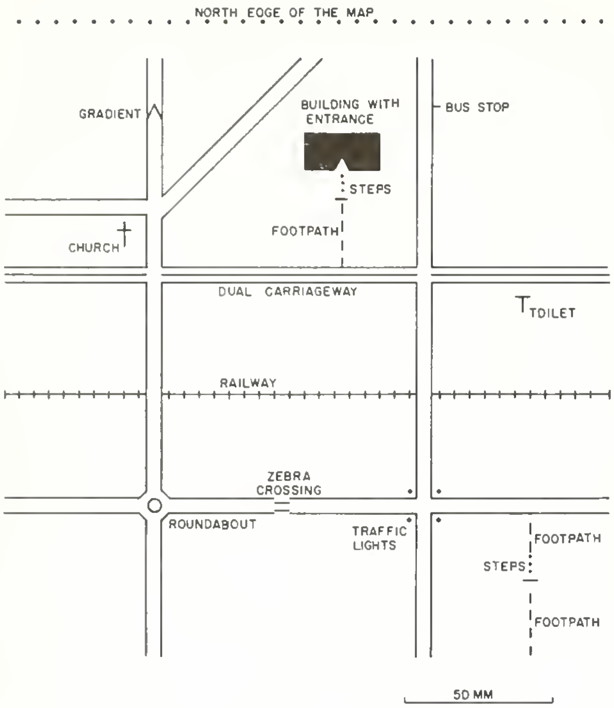


Figure 2. Pseudomap Used for the Evaluation of Symbols in the Context of a Map.

SUBJECTS

Subjects were 25 visually-handicapped schoolchildren. One subject was unavailable for the second session and 4 were unavailable for the third session. There were eight girls and 17 boys. Only one child relied on some residual vision to aid tactual inspection of the symbols. The sample included a range of ages from junior to secondary level (mean age = 11.54 yrs., range 7.41 to 17.66 yrs., SD = 3.05).

IQ scores for 21 of the students were obtained from the school (mean IQ = 100, range 75 to 144, SD = 13.91). IQ had been measured by the Williams IQ test for the visually-handicapped (Williams, 1956). The authors would like to point out that although the majority of the IQ scores were obtained within the last two years, one student was tested as long as 10 years ago. One of the items commonly used in the Williams test is a digit span of apprehension. This test was administered at the school by the authors and consisted of reading lists of digits and asking the subject to repeat them correctly in the same order (Woodworth and Schlosberg, 1954, page 696). The mean score was 3.3 digits (range 1.5 to 5.5, SD = 0.97).

RESULTS

The results of the experiment were scored on several dependent variables; in addition, correlations were computed to assess the effects of several independent variables (Table 1).

Six children in the learning trials, and one in the relearning, failed to reach the set criterion of two errorless trials.

Figure 3 shows curves for the learning and relearning sessions. As some students failed to reach the criterion, alternative methods of plotting the learning curves were not attempted. Only one child was responsible for the error rate from trial 5 to 10 on the relearning curve.

The children took a mean of 6.83 trials (SD = 2.1) for the learning phase, and 4.08 trials (SD = 1.8) for relearning; this gives a savings of

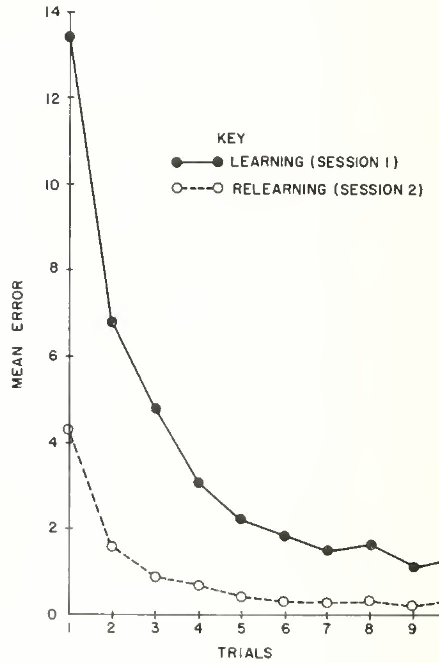


Figure 3. Comparison of Learning Curves

TABLE 1

Statistical Results, Spearman Correlations

Session number	Variables	Spearman's Rho	t for significance of Rho	DF	Significance and correlation
1	age/no. of trials	- 0.21	- 1.01	22	No -
1	age/no. of errors	- 0.27	- 1.31	22	No -
2	age/no. of trials	- 0.18	- 0.88	22	No -
2	age/no. of errors	- 0.22	- 1.06	22	No -
3	age/no. of errors	- 0.35	- 1.65	19	No -
1	IQ/no. of trials	- 0.14	- 0.61	19	No -
1	IQ/no. of errors	- 0.25	- 1.16	19	No -
2	IQ/no. of trials	- 0.04	- 0.20	19	No -
2	IQ/no. of errors	- 0.25	- 1.16	19	No -
3	IQ/no. of errors	0.06	0.26	17	No +
1	STM/no. of trials	0.05	0.27	22	No +
1	STM/no. of errors	- 0.02	- 0.12	22	No -
2	STM/no. of trials	0.02	0.13	22	No +
2	STM/no. of errors	- 0.01	- 0.07	22	No -
3	STM/no. of errors	- 0.21	- 0.97	19	No -

40.2 percent. The percentage error out of total responses for each symbol is shown in Fig. 4 and indicates considerable variability among error rates for different symbols. Differences between the percentage errors for the learning and relearning sessions are more apparent than suggested by the savings score.

Table 2 shows a confusion matrix compiled from data for incorrect responses given by the subjects. The scores for the two matched groups who had to identify symbols on a pseudo-map are shown in Table 3.

The data for this analysis were negatively skewed (-1.75), and although mean scores are used for descriptive purposes a nonparametric test, the Mann-Whitney U Test (Siegel, 1956), was computed to test for any significant difference between the two groups. Since the value of U was 32, which was not equal or less than the critical value of 12, the null hypothesis was supported. There was no significant difference between groups K and NK.

DISCUSSION

At its inception, it was hoped that this study would throw some light on the developmental problems accompanying the use of tactual maps in schools for the blind. However, the correlations between various independent variables (Table 1) were not significant and no firm conclusions can be made. With a larger N it should be possible to identify what Berla' and Nolan (1972) have recently called the "developmental norms for tactual perceptual memory span."

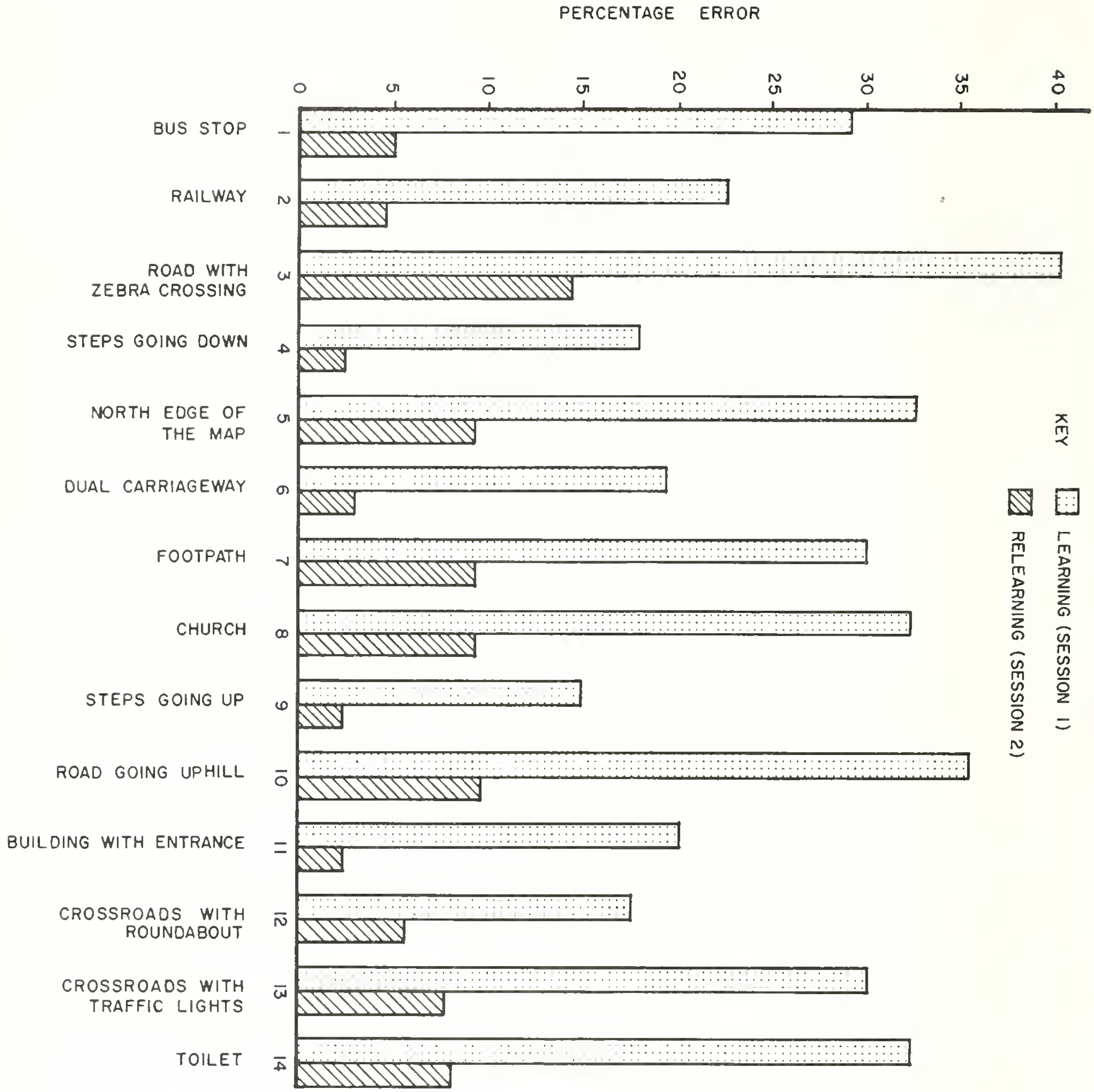


Figure 4. Histogram Showing Percentage Error for Each Symbol

TABLE 2

Confusion Matrix (Learning and Relearning Trials Combined)

Reply from Subject	Bus stop (1)	Railway (2)	Road with zebra crossing (3)	Steps going down (4)	North edge of the map (5)	Dual carriageway (6)	Footpath (7)	Church (8)	Steps going up (9)	Road going uphill (10)	Building with entrance (11)	Crossroads with roundabout (12)	Crossroads with traffic lights (13)	Toilet (14)
1		0.2	2.2		0.4	0.2	0.6	0.2		2.0				
2					1.8	1.2	3.3							
3	1.0									2.7			0.8	0.2
4								1.2	2.0					1.8
5		0.6					1.8	0.2		0.2				
6		0.4			0.4		0.4				0.2			
7		2.2			2.9	0.2								
8				0.2										3.1
9		0.2		2.0				0.6						1.4
10	0.8		3.5					0.2				0.8		
11				0.2										
12			0.2					0.6		0.8			1.4	
13	0.2		0.8	0.2				0.2		1.2		1.0		
14	0.2			0.2	0.2			1.4	0.2		0.2			

The lack of significant age/IQ correlations with performance over a wide age range may have an explanation in the particular school system. Children who have greater academic potential usually leave the school at the age of 11 to continue their education elsewhere. This factor may account for the apparent similarity in symbol learning performance between junior and secondary schoolchildren. Usually children receive no experience with tactual maps until the secondary school, which suggests that there is

TABLE 3

Mean Correct Scores and Ranges for the Two Matched Groups for Identifying Symbols on a Pseudomap

Group	*N*	Mean	Range
K	10	12.4	9 - 14
NK	11	10.63	2 - 14

considerable unrealized potential in the junior school if map reading can contribute significantly to a visually-handicapped child's education.

No previous studies of tactual stimulus memory span have presented to subjects as many as 14 different stimulus items. In view of the large number of items, a savings score on the relearning trials of 40.2 percent is very reasonable. This compares with the 52.88 percent found by Foulke and Morris (1961) using only six tactual patterns and association words from the New International Phonetic Alphabet. It is important that, in this study, the association words were more meaningful than the phonetic or nonsense words commonly used in paired-associate learning tasks. Most of the association features used in this study were familiar to the children.

The differences in discriminability and associative value of the verbal terms are apparent in Figure 4. Differences in form, relief, and size contribute to making a legible tactual symbol. In addition symbols can have informational properties which may aid recognition. Schiff, Kaufer, and Mosak (1966) found that a tactual line, sawtooth in cross-section, can be used to indicate direction since it feels smooth in one direction and rough in the other. The tactual arrow provided an "intensity basis" for tactual perception. Point symbols on visual maps commonly specify direction, but when embossed often seem inadequate to specify the same information for the visually handicapped.

Stimulated by Schiff's findings on the tactual arrow, the authors utilized variation in height as a principle of symbol construction. Symbols 4 and 9 (steps) were adaptations of a symbol developed by Wiedel and Groves (1972) and consisted of units of increasing or decreasing height (see Fig. 1 for side elevations). These units specified "up" or "down." In contrast to these symbols, similar information was specified in Symbol 10 (road going uphill), and although this symbol may have been masked by the linear symbols bounding it, the differences in the effectiveness of the multi-height versus single-height symbols as indicators of up or down are evident in Figure 4. Subjects feeling Symbols 4 and 9 (steps) were able to run the pad of the finger down or up the symbol, and because of its distinctive informational properties often guess that the symbol implied "up" or "down." As a result of this finding, a multi-height symbol will be used in the evaluation of mobility maps using gradient (road going up- or downhill) as a navigational cue.

Symbols 4, 6, 9, and 12 had particularly low percentage error (<20 percent) for the learning trials, but on the relearning trials Symbols 2, 4, 6, 9, and 11 had a very low percentage error rate (<5 percent). Using a 10-percent error criterion of acceptability for the relearning trials, all symbols with the exception of Symbol 3 (road with zebra crossing) would prove acceptable. Symbols 3 (road with zebra crossing) and 10 (road going uphill) had the highest percentage error of all the symbols tested and this can be partly explained by reference to Table 2. Both symbols were displayed in the context of two parallel lines which represented a road. Subjects found these two symbols difficult to distinguish. Therefore, it is probable that if one symbol was successfully altered the other would remain more legible. The substitution of a multi-height symbol for number 10 (gradient) has already been suggested. Symbols 2 (railway) and 7 (footpath) were relatively highly confused, but this was mainly in the initial phase of the experiment and perceptual training might have been responsible for the lower percentage of errors in the relearning phase.

The shortcoming of evaluating tactual symbols in isolation as discrete stimuli is apparent when attempts are made to put these symbols together in a more complex display. Gëstalt psychologists support the idea that in perception the whole is more than the sum of the distinctive parts. Thomson (1968) summarizes this as "the whole has properties of its own, so that the parts and relationships within the whole are largely a product of the entire configuration."

Table 3 shows that when the tactual symbols were displayed in a pseudomap children were able to obtain a high level of correct symbol identifications either with or without a key. However, instead of having the symbols presented to them the children had to search the entire configuration to find a particular symbol. Observations of the strategies adopted by the students confirmed recent analyses of tactual map reading strategies by Nolan and Morris (1971). One child in this experiment noted the importance of "full-scale coverage," but few applied any systematic search pattern. One would expect that children with higher IQ's would perform better than children with low IQ's on this task even without training. The lack of efficiency in search strategy used by children to locate symbols on the pseudomap caused some of them to give up their haphazard search even when they had a key. Failure to find symbols was particularly evident for children reading the lower right hand part of the map which was more isolated than other parts of the map (see Fig. 2). Symbol 4 (steps) was frequently missed completely or not detected as being distinct from Symbol 7 (footpath).

Since the data show no significant differences in correct identification of symbols for the matched groups, one using a key and another using memory alone, memorizing a key of as many as 14 symbols may be a viable proposition. Constant reference to a key presents several problems:

1. A key placed on the tactual map itself could be mistaken as part of the map.

2. Since two sheets (230 x 260mm) were required to present the key in this experiment, there is the problem of bulk of material.

3. Reading the key and then the map may be significantly more time consuming than referring straight to the map after memorizing the necessary symbols.

It is hoped to examine these problems in a further experiment comparing the use of memory alone and key alone to locate symbols on a tactual pseudomap, and to use dependent measures of time, errors, and efficiency to compare both methods.

Most of the children showed a high degree of familiarity with the features and landmarks to be associated with the tactual symbols. Some of the younger children required some simplification of the terms involved; for instance, a dual carriageway needed to be represented as "two roads." One child began searching the central area of the pseudomap to find the symbol for "north edge of the map" implying that he did not understand the concept involved. This child, at least, had attached a verbal label to a symbol without realizing the significance of that label. These observations confirm the necessity for development of rudimentary environmental concepts before or as part of a mobility program utilizing tactual maps. Furthermore, development of these basic concepts would seem to be a prerequisite of meaningful use of tactual maps in any context (Franks and Baird, 1971; Franks and Nolan, 1970).

The majority of children tested on the pseudomap were able to plan and follow a simple route from the zebra crossing to the entrance of the building (see Fig. 2), indicating that they understood the significance and interrelationships of the tactual symbols they had learned.

ACKNOWLEDGMENTS

The authors have carried out this work with the financial assistance of the Medical Research Council and the Science Research Council. The authors would like to thank Dr. J. D. Armstrong (B.M.R.U.), Prof. J. L. Douce (I.U.I.E.C.), and Dr. M. J. Tobin (R.C.E.V.H.). They would also like to thank the Headmaster and pupils of Lickey Grange School. Thanks are also due to Pauline James who prepared the tape recording.

APPENDIX 1

Instructions for
Sessions 1 and 2

There are 14 different raised map symbols I wish you to feel. Each raised symbol means something, and you have to try and learn what these symbols mean.

Here is an example of a raised symbol which means a road (present *S* with sample card).

I am now going to give you some more symbols, but the meanings of the symbols are recorded on the tape recorder and you will hear them 10 seconds after you feel the raised symbols. You have to try and give me the meaning of the symbol before the tape recorder tells you. In other words, you have to beat the tape recorder in giving your answer.

Try to remember the meaning of each symbol so that you can give the right answer before it is given by the tape recorder.

(Repeat instructions and answer any questions.)

(1st session only.) You will not be able to give the answer to the meaning of the symbols until you have heard them once, so you can guess what they mean to begin with.

(After the 1st trial.) You have now felt all 14 symbols. This time try to beat the tape recorder with your answers, but remember that the symbols will not be in the same order as before.

Instructions for Session 3

1. Find the north edge of the map. Turn the map so that it is at the top of the page.
2. Find the building with entrance.
3. Find the railway.
4. Find the crossroads with roundabout.
5. Find the steps going up.
6. Find the church.
7. Find the toilet.
8. Find the bus stop.
9. Find the zebra crossing.
10. Find the dual carriageway.
11. Find the road going uphill.
12. Find the steps going down.
13. Find the crossroads with traffic lights.
14. Find the footpath.
15. Show how you would get from the zebra crossing to the entrance of the building.

Bentzen, B. L. An orientation and travel map for the visually handicapped: Hand production, testing and commercial reproduction. Master's thesis, Boston College, 1971.

Berla', E. P. & Nolan, C. Y. Tactual maps: A problem analysis. International Council of Educators of Blind Youth, Madrid, 1972.

Foulke, E. & Morris, J. E. The learning and retention of associations between tactile stimuli and verbal responses. Unpublished manuscript, American Printing House for the Blind, 1961.

Franks, F. L. & Baird, R. M. Geographical concepts and the visually handicapped. *Exceptional Children*, 1971, 38(4), 321-4.

Franks, F. L. & Nolan, C. Y. Development of geographical concepts in blind children. *Education of the Visually Handicapped*, 1970, 2, 1-8.

Gill, J. M. Computer production of tactile diagrams and maps. The Leonard Conference, Cambridge, England, 73-77, January 1972.

Gill, J. M. & James, G. A. A study on the discriminability of tactual point symbols. *Research Bulletin*, Number 26, June 1973, 19-34.

James, G. A. Problems in the standardisation of design and symbolisation in tactile route maps for the blind. *New Beacon*, April 1972, 56(660), 87-91.

James, G. A., Armstrong, J. D., & Campbell, D. W. Verbal instructions used by mobility teachers to give navigational directions to their clients. *New Beacon*, May 1973, 56(672), 86-91.

Leonard, J. A. & Newman, R. C. Three types of maps for blind travel. *Ergonomics*, March 1970, 13(2), 165-179.

Morris, J. E. & Foulke, E. The learning and retention of associations between pairs of tactual and auditory stimuli. Unpublished manuscript, American Printing House for the Blind, 1960.

Nolan, C. Y. & Morris, J. E. Tactual symbols for the blind: Final report. American Printing House for the Blind, 1963, OVR-RD-587.

Nolan, C. Y. & Morris, M. E. Improvement of tactual symbols for blind children. Report of Department of Health, Education, and Welfare. Project No. 5-0421, 1971.

Schiff, W., Kaufer, L., & Mosak, S. Informative tactile stimuli in the perception of direction. *Perceptual and Motor Skills*, 1966, 23, (Monogr. Suppl. 7).

Siegel, S. Nonparametric statistics for the behavioural sciences. New York: McGraw-Hill, 1956.

Thomson, R. *History of psychology*. Pelican, 1968.

Wiedel, J. W. & Groves, P. A. Tactual mapping: Design, reproduction, reading and interpretation. University of Maryland, Occasional Papers in Geography No. 2, 1972.

Williams, M. Williams intelligence test for children with defective vision. University of Birmingham, England, 1956.

Woodworth, R. S. & Schlosberg, H. *Experimental psychology*. (Rev. ed.) New York: Holt, 1954.

EDUCATIONAL BACKGROUND AND CONSIDERATIONS OF LOW VISION AIDS: REVIEW OF RELATED LITERATURE**

Dennis E. Kelleher*

EDUCATIONAL BACKGROUND AND CONSIDERATIONS OF LOW-VISION AIDS

The primary goal underlying the rehabilitation of people with low vision is to enable them to function in the visually oriented environment as "normally" as possible. In order to achieve this goal, it is often necessary to provide some type of aid which reduces some of the disabilities characteristic of the impairment.

Rosenbloom (1963) cited special techniques in low-vision rehabilitation and reported specific research needs in the area of low-vision aids. He stated that there was a great demand for the development of new low-vision aids which would increase the application, versatility and acceptability of low-vision aids among children and youth with marked visual impairment.

Sibert also recognized the need for the research and development of new low-vision aids to assist in the rehabilitation and integration of visually-impaired children into the sighted community.

> It is recognized that low-vision aids and magnification of all kinds is legion. We also know that these aids should not be considered a panacea for all children with seriously impaired vision. However, we do not know for whom or at what age this added assistance in seeing might really work. We need to try to find out. (Sibert, 1965, p. 73.)

Sibert also suggested the possibility of a traveling low-vision clinic which would work in the schools for the dissemination of devices and information. She contended that this type of arrangement could be very conducive to the development of new low-vision aids.

The intent of this study was to analyze the bioptic, telescopic system as a low-vision aid. The question of the desirability of this type of aid must first be established since it could presumably be eliminated if education of the visually impaired

---

*Low Vision Program, Yolo County Schools, Woodland, California.

**The Review of Related Literature was extracted from the author's Doctoral dissertation, entitled *The Effect of Bioptic, Telescopic Spectacles upon the Self Concept and Achievement of Low-Vision Students in Itinerant Programs*; the dissertation was submitted in partial satisfaction of the requirements for the degree of Doctor of Education in Educational Curriculum in the Graduate Division of the University of California, Berkeley, California. The dissertation is available in either Xerographic copy or microfilm from University Microfilms, Ann Arbor, Michigan, 48106 as publication number 72-23-346.

were conducted in an atmosphere where the norm was visual limitation. Educational planning in residential schools for the visually impaired uses modes of instruction other than those dependent upon normal vision. The bioptic telescope or any other aids for distance viewing would not be as essential in this type of segregated educational environment as they would in an integrated teaching approach.

In education of the blind and visually impaired, the four basic organizational patterns which have evolved in the past one and a half centuries are the residential school, the cooperative plan, the resource room, and most recently the itinerant approach.

The residential school, a great social advance at the time of its conception 150 years ago, functioned on the premise that the blind and visually impaired could not function in the sighted community. It was felt that they could be better prepared to cope with their disability if they were educated in a special school attended only by those with similar limitations. These residential schools, though segregated, attempted to undertake the learning process as seriously as the regular schools except that all types of special equipment to facilitate learning through the auditory and tactile senses were utilized. It was not for nearly a century that educators began to realize the "separate but equal" education approach of the blind was more an illusion than a reality; preparation in a synthetic setting was not nearly as helpful as it could be in a more realistic situation, (Ashcroft, 1963).

In the cooperative plan, the visually-impaired student attends regular school but is enrolled in a special class for the visually limited. He participates in some activities which do not require good vision along with sighted children.

The resource room enrolls the visually-limited child in the regular classroom. When the student feels the need for special assistance, he goes to the resource room where there is a trained teacher and special equipment to help the student with low vision.

The itinerant approach, which utilizes a traveling teacher of the visually impaired, evolved with the advent of some of the technological advances of the past thirty years, such as better transportation enabling greater mobility in less time. The itinerant approach is used primarily in rural and suburban areas where there is an insufficient number of visually-impaired students to constitute a cooperative class or a resource room. Like the resource room, the itinerant plan is integrated, but the service is on a more sporadic basis.

This current trend of integrating the visually limited into the regular classroom reflects the change in philosophy of most educators. It is now felt that individuals with low vision can adapt to the sighted community better if educated in a sighted environment. According to Lowenfeld (1971), integration of the visually-limited student into the sighted classroom was primarily instigated by parents urging educators to enroll their visually-limited children in "normal" classes instead of "special" classes which carried a stigmatizing label. Changing the name from "sight saving classes" to "classes for the visually impaired" indicated the change in attitude among many medical practitioners from unnecessarily conserving sight to utilizing whatever residual vision remained most effectively. Other factors which encouraged the integration of visually-impaired students into the regular classroom included a realization that visually-limited children could learn with their normally sighted classmates and benefit from the social interaction, a trend toward equal opportunity education for everyone, and technological advances such as improved transportation facilities, (Lowenfeld, 1971).

> Emphasis has been placed on the need to avoid sending the child to a special school, unless this is strongly indicated. Once a child is admitted, the entire school life is usually spent there, an unnecessary state of affairs in quite a few cases. (Bier, 1970, p. 23.)

Many studies have been conducted which have analyzed and compared the four organizational approaches for educating the visually impaired. Jones stated that most researchers favored the resource and itinerant approaches for the following reasons:

> 1. Integrated programs emphasize childrens' abilities and likenesses to other children rather than the differences as segregated programs.
>
> 2. The wealth of resources within the regular school program is made available to these children by including them in most general school activities.
>
> 3. The services of specially prepared teachers may be made available more easily to these children by including them in most general school activities.
>
> 4. Under these plans teachers of the visually limited devote full time to individualized instruction of children.
>
> 5. The visually-impaired child is educated in a setting more nearly approximating that which he will encounter in adult life. (Jones, 1963, pp. 35-36.)

Ashcroft contends that itinerant and resource approaches permit greater flexibility of training than the residential school. He also states that the partially sighted when educated in an integrated program become more proficient in basic skills and are consequently able to function with less assistance than their sheltered counterparts in segregated classes.

Morin (1960) credited two other benefits to itinerant approaches as opposed to all others. He suggested that there was a reduction in costs for transportation and teacher salary since one teacher was able to serve a larger number of students than a teacher who stayed in the classroom.

Bertran (1958) asserted that itinerant programs which were more individualized than a classroom could serve children with varying intellectual ability more easily.

Murphy (1960) expressed the opinion that the continuance of segregated educational approaches was due to a reluctance of regular class teachers to accept exceptional children into their classes. Stephens and Birch (1969) argue that there is inconclusive evidence to support Murphy's statement.

In a recent comparative study of the advantages and disadvantages of various educational settings for teaching the visually impaired, McGuiness concluded that the special school encouraged fewer social pressures and less independence for the blind and visually-impaired children who attended it. Students in itinerant programs were usually expected to develop greater independence, maturity, and ingenuity in solving their own problems and a stronger self-concept of being "normal."

> It would seem that the integrated educational settings amply fulfill the purpose for which they were established, that of facilitating the social integration of visually limited children with their sighted peers, promoting social maturity and independence, and enabling them to better cope with the sighted world in their adult life. (McGuiness, 1970, p. 45.)

McGuiness also stated that students in itinerant programs develop a stronger self-image due to the greater number of friendships they develop with sighted people.

If it is the intent to train low-vision students to function as "normally" as possible despite their poor vision, it must be concluded that itinerant programs which permit greater flexibility than any of the other educational approaches are the most likely to achieve this goal.

Whenever we want to know whether or not we have achieved a certain goal, we must evaluate a person according to some baseline to determine if the individual's performance level is commensurate with a predicted level.

> The evaluation process attempts to ascertain what a person might be able to do; what a person is presently doing and why and in what areas an individual is not performing. The notion of potential capacity is an illusive concept and a controversial subject in psychological and educational literature. (Smith, 1969, p. 14.)

Points of view range from belief that one's capacity can never be generally ascertained to the feeling that an individual's capabilities can be precisely predicted.

"Tests must be used for the purposes which they were intended." (Delp, 1962, p. 49.) Unfortunately, there is confusion among professionals as to the purposes tests serve among "normal" children which are compounded when one is considering exceptional children, (Kirk, 1962, p. 44).

> If any deviation is made from the standard directions or time limits, the results are invalid as far as the reported norms are concerned. Selection of a test whenever possible that does not have delimiting factors which will of themselves affect the results of an individual's effort regardless of his mental, physical or sensory limitations, should be made. When evaluating the achievement level of exceptional children therefore, extreme care should be exercised in selecting the instrument to be used. (Johnson, 1967, pp. 646-7.)

Shapiro, Hallenbeck, and others assert that there are additional practical problems of administration in addition to psychological factors which deserve special attention when dealing with the blind and visually impaired.

Neff and Weiss have stated (1965, p. 789):

> We must distinguish between the consequences of congenital impairment and one that takes place in adult life. In the one case, we are dealing with a set of factors which may powerfully affect the development process, so that the individual may grow into a very different sort of person from what he otherwise might have been. This sequence of early and later traumata is one that needs to be kept continuously in mind in our endeavor to conceptualize the psychological aspects of disability and the evaluation of those with impairments.

Most researchers express the opinion that individualized tests yield more valid evaluations of the blind and visually impaired. (Bishop, 1971.)

Jastak and Jastak feel that their Wide Range Achievement Test is well suited for "studying the nature of reading, spelling and arithmetic ability of the brain injured and others with physical disabilities" (Jastak and Jastak, 1965, p. 1) because it has flexibility allowing individual administration and avoidance of duplication of material.

PSYCHOLOGICAL CONSIDERATIONS IN REHABILITATION OF LOW VISION

There is an abundance of literature stating the importance of developing positive attitudes toward one's self. Bower, Stewart, Maeger, Allport, Krathwohl and many others expound upon the importance of developing a strong self concept.

Bishop (1976, p. 133) said of the importance of encouraging positive self attitudes among the visually impaired:

> He may need encouragement in the areas of self acceptance and self expression and may require many positive personal contacts who offer him security by accepting him as he is. These will assist him in developing his own acceptance of himself and his limitations if social and emotional security are firmly established and will enhance the chances for greater success through positive adjustment.

Allan (1972, p. 30) wrote, "The key to a more satisfying and meaningful life for an individual with partial vision is to develop an awareness of the interrelationship between himself and the rest of the world."

Scott (1969) asserted that the blind and visually impaired are often made helpless as a result of failure to develop positive self attitudes. The sighted world misleads them into believing they are greatly handicapped and this negative self-concept manifests itself in a personality reflecting a self-fulfilling prophecy of failure. The maximum potential of some of these individuals would probably never be realized unless their self-concept is positively influenced.

Successful rehabilitation and optimal use of a low-vision aid are due to many factors, but the positive attitude of the subject is probably the most important. (Kelleher, Mehr and Hirsch, 1971.)

Mehr, Mehr, and Ault used low-vision discussion groups to study why a partially-sighted person who could be helped by a low-vision aid often chose not to use it. Factors such as duration, and severity of the visual problem, patient motivation, age, intelligence, and the nature of the visual pathology were all cited as contributing factors in the successful rehabilitation of patients with low vision. Specific implications for the rehabilitation of the young child, adolescent, young adult, adult, and senior citizen were discussed with regard to the varying needs of each group. It was concluded that patients who were inclined to be successful with low-vision aids were more flexible, had a higher self regard and developed stronger peer group relationships.

Feinbloom (1935) discussed some psychological problems in adapting to low-vision aids and contended that the cosmetic appearance of an aid is of paramount importance and often determines whether an aid is accepted or rejected by the patient.

Freeman (1954) reported that the skill and experience of the examiner, the personality and outlook of the patient, and the type of adjustment the patient made to his visual impairment were important factors in determining how well a patient adapted to the use of a low-vision aid.

Faye (1970) asserted that high motivation, intelligence, sufficiently strong central acuity, adequate eye motility, stable pathology of long duration, and optimistic attitude were qualities in the low-vision patient which favored a successful prognosis.

DEVELOPMENT OF THE BIOPTIC AND ITS USES

Telescopic spectacles as an aid for the visually impaired are not a new concept. Full field telescopic glasses never achieved much popularity because of "the marked restriction in the field of view through a telescope." (Sloan, 1971, p. 56.) The weight of the telescopic systems made from glass was heavy and the unconventional appearance caused many low-vision patients mental and physical discomfort while wearing them. Recently, the advent of new lightweight optical plastics encouraged the development of bioptic, telescopic spectacles. Bioptic systems are manufactured by Univis, Kollmorgen, Selsi, Keeler, Bier, and Feinbloom. In the opinion of the writer, the Feinbloom bioptic contained the finest optics and its design permitted greatest flexibility so this system was used exclusively for this study.

Feinbloom described the development of his bioptic system in 1958 as follows:

> The bioptic is a specially designed Galilean telescopic-type device with a round ocular lens and either a rectangular or round objective lens depending upon the power of the system. Both the ocular and the objective lenses are compound lenses of a fused flint and crown glass combination. This type of system markedly reduces the spherical and chromatic aberrations. The placement of the telescope in the superior bioptic position, and its limitation in size have made utilization in all tasks a reality. The bioptic is produced in three powers: 2.2X; 3.0X and 4.0X. (Feinbloom, 1972.)

Though the components of the telescope are glass to minimize aberrations, the regular lens and the carrier housing of the bioptic are plastic to reduce the weight of the system. The Galilean telescopic design was selected instead of the astronomical design because the former provides an erect image. The combination of a concave and convex lens, as found in the Galilean design, produces a shorter length telescope, resulting in less weight and a more conventional appearance.

Many critics have discouraged the use of any type of telescopic aid.

> For driving a car, riding a bicycle or even walking, the restricted field of view makes the telescope more a hindrance than an asset. The apparent change in the distance of objects (they appear closer rather than larger) and the apparent increase of the rate of motion of moving objects are other difficulties. Even for tasks in which the user is not moving about, i.e. for watching ball games, for the theatre and movies, for TV, for reading from a blackboard, etc., telescopes are usually accepted only when it is impractical to obtain all of the required magnification by a suitable decrease in the viewing distance. (Sloan, 1971, p. 56.)

Fonda (1970, p. 60) agrees with Sloan's statement and continues, "Non-optical magnification is much more advantageous than are telescopic spectacles."

Magnification can be produced in three ways. It is defined as stimulation of a larger area of the retina than would normally be stimulated by the visual image of an object. Magnification produced through optical means such as a telescope is called angular magnification. A second way to achieve magnification is to decrease the distance from the eye to the object being viewed and is called relative distance magnification. Increasing the actual size of the object viewed, called relative size magnification is a third means of producing magnification.

Fonda and Sloan both expressed the opinion that the use of relative size and relative distance magnification or non-optical magnification was very often superior to angular or optical magnification. Feinbloom and many others assert that it is not often feasible to use non-optical magnification in many school activities without stigmatizing the low-vision student. For example, wearing a bioptic which is only slightly conspicuous is more desirable because it is less stigmatizing than moving to a distance of two or three feet from the blackboard of a classroom and blocking the view of the remainder of the class.

The criticisms made by Sloan and Fonda are valid problems encountered with full field telescopic spectacles or hand held telescopic aids, but they are not descriptive of the bioptic system where peripheral vision can be maintained and either the normal lens or magnified image can be selected quickly.

Korb (1970) has made the only extensive study on the uses of the Feinbloom bioptic system to date. The study deals with operation of motor vehicles by patients with low vision. Driving a car is probably one of the most visually demanding tasks so if the bioptic has been used successfully by over 100 low-vision patients to obtain drivers licenses in over eight states and two provinces of Canada, it certainly must be indicative of the flexibility and usefulness of this system in all tasks.

Korb set up the following criteria as prerequisites for his prospective subjects. Visual acuity through the telescopic portion was required to be at least 20/40, in addition to full peripheral fields, adequate color recognition and eye motility, visual pathology of long duration, and a stable eye condition had to exist before the subject was accepted as a sample member.

Some of the problems in fitting and prescribing the bioptics which first had to be surmounted included exact determination of the pupiliary distance, the angle of the bioptic and the horizontal placement so that maximum acuity could be achieved. If one angle of gaze was favored or showed a reduction in nystagmus, this also had to be determined for optimal use of the bioptic.

Another difficulty was the reduction of the vertex distance to maximize the telescopic field without placing the bioptic so close that it irritated the eyelashes or became constantly fogged with tears or perspiration. This was accomplished by cutting a hole in the standard ophthalmic lens and mounting the telescopic unit through the regular lens so that it protruded in back of it. The distance from the eye could be slightly manipulated by adjustment of the frames.

Other problems Korb reported which were overcome with practice included head-hand-and-eye coordination, telescopic parallax, vibration, reference within the magnified field and looking around the ring scotoma of the bioptic.

Korb stated that the 26 subjects who received licenses out of his initial sample of 67 represented a variety of eye pathologies and a wide range of ages.

> The 26 licensed persons have an unblemished safety record to date. The total driving time of the 26 persons utilizing telescopic prosthesis involves approximately 32 man years. (Korb, 1970, p. 625.)

In the most recent study on the use of the bioptic for driving, Kelleher, Mehr, and Hirsch (1971) added the prerequisites of high motivation and intelligence to Korb's criteria for use of the bioptic as a driving aid. A useful modification for driving, a prism cap added to the bioptic, was described. It eliminated the need for the hand-head-and-eye coordination by creating a diplopia whereby the subject could see a magnified image and an unmagnified image simultaneously to judge depth monocularly and overcome the problem of telescopic parallax.

Specific training procedures to promote good defensive driving on the part of the subject included keeping your eyes moving, looking as far ahead as possible to steer, getting the whole picture of what's happening around you, making sure the other guy sees you and if all else fails, leaving yourself an escape.

Non-optical aids suggested were the use of sun visors, wide brimmed hat, sun glasses, and a dark colored vehicle in exterior and interior to help control illumination and reflection. Utilizing a small, import-sized vehicle to facilitate handling and a standard transmission which offered more positive braking was also proposed.

It was concluded that the bioptic was to be used only as a spotting system while driving and never exclusively. The amount of use of the bioptic was to vary according to the nature of the driving conditions.

Since using the bioptic to drive required highly sophisticated visual performance and since this was the only use of this flexible device thus far explored, it was hoped that the present study would be able to contribute to our knowledge of the uses of the bioptic, telescopic system by some low-vision students in itinerant programs.

REFERENCES

Allan, D. Yet another minority. *Education of the visually handicapped*, 1972, IV(1), 30-2.

Allport, F. H. *Theories of perception and the concept of structure.* New York: Wiley & Sons, 1955.

Ashcroft, S. C. Blind and partially seeing children. In L. M. Dunn (Ed.), *Exceptional children in the schools.* New York: Holt, Rinehart and Winston, 1963, pp. 413-61.

Ballou, S. V. *A model for theses and research papers.* Boston: Houghton Mifflin, 1970.

Barraga, N. C. *Teacher's guide for development of visual learning abilities and utilization of low vision.* Louisville: American Printing House for the Blind, 1970.

Bertran, F. The education of partially sighted children. In W. M. Cruickshank & G. O. Johnson (Eds.), *Education of exceptional children and youth.* Englewood Cliffs, New Jersey: Prentice-Hall, 1958, 265-94.

Bier, N. *Correction of subnormal vision.* London: Butterworth, 1970.

Bishop, V. E. *Teaching the visually limited child.* Springfield, Illinois: Charles C. Thomas, 1971.

Borish, I. M. *Clinical refraction.* (3rd ed.) New York: Professional Press, Inc., 1970.

Bower, E. M. *Application of Q methodology.* Unpublished Doctoral dissertation, Stanford University, 1953.

Bower, E. M. Mental health. In R. Ebel (Ed.), *Encyclopedia of educational research*, (4th ed.) New York: Macmillan, 1969.

Campbell, D. T., & Stanley, J. C. *Experimental and quasi-experimental designs for research.* Chicago: Rand McNally, 1969.

Delp, H. A. Psychological evaluation: Some problems and suggestions. In *Mental retardation*, J. Rothstein (Ed.), New York: Holt, Rinehart and Winston, 1962.

Dixon, W. J., & Massey, Jr., F. J. *Introduction to statistical analysis.* New York: McGraw-Hill, 1969.

Faye, E. E. *The low vision patient.* New York: Grune and Stratton, 1970.

Feinbloom, W. *The bioptic telescopic system.* Paper read before the section on contact lenses and subnormal vision, American academy of Optometry meeting, December, 1958.

Feinbloom, W. *Examination procedures of the partially sighted patient.* New York: Designs for Vision, 1965.

Feinbloom, W. Report of 500 cases of subnormal vision. *American Journal of Optometry*, 1935, 12, 6.

Feinbloom, W. Training of the partially blind patient. *Journal of the American Optometric Association*, 1958, 29(11), 679-90.

Feinbloom, W. Personal correspondence, January 9, 1972.

Fonda, G. *Management of the patient with subnormal vision.* (2nd ed.) St. Louis: The C. V. Mosby Company, 1970.

Fonda, G., Thomas, H., & Gore III, G. V. Educational and vocational placement, and low vision correction in albinism. *Sight Saving Review*, 1971, 41(1), 29-32.

Fox, D. J. *The research process in education.* New York: Holt, Rinehart and Winston, 1969.

Francois, J. *Heredity in ophthalmology.* St. Louis: The C. V. Mosby Company, 1961.

Freeman, E. Optometric rehabilitation of the partially blind--A case report on 175 cases. *American Journal of Optometry and Archives of the*

American Academy of Optometry, 1954, 31(4), 230-39.

Freudenberger, H. J. & Robbins, I. Characteristics of acceptance and rejection of optical aids in a low vision population. *American Journal of Ophthalmology*, 1958, 47(4), 582-4.

Garrison, W. & Force, J. *The Psychology of exceptional children.* New York: Ronald Press Company, 1950.

Genensky, S. M. *Closed circuit TV and the education of the partially sighted.* Santa Monica, Calif.: The Rand Corp., 1970.

Genensky, S. M. *A functional classification system of the visually impaired to replace the legal definition of blindness.* Santa Monica, Calif.: The Rand Corp., 1970.

Hallenbeck, P. N. Some issues concerning the use of standard personality tests with the blind. In *Proceedings of the conference on new approaches to the evaluation of blind persons.* New York: American Foundation for the Blind, 1970.

Hatfield, E. M. *Estimated statistics on blindness and vision problems.* New York: National Society for the Prevention of Blindness, 1966.

Hathaway, W. *Education and health of the partially seeing child.* New York: Columbia University Press, 1959.

Havill, S. J. The sociometric status of visually handicapped students in public school classes. American Foundation for the Blind, *Research Bulletin Number 20*, 1970, 57-69.

Hiatt, R. L., Waddell, M. C. & Ward, R. J. Evaluation of a low vision aids program. *American Journal of Ophthalmology*, 1963, 56(4), 596-602.

Hogan, M. J., Zimmerman, L. E. *Ophthalmic Pathology.* (2nd ed.) Philadelphia: W. B. Saunders Co., 1968.

Hurst, J. Unpublished essay, University of California, Berkeley, 1970.

James, W. *Humanistic thought.* New York: Random House, 1944.

Jastak, J. F. & Jastak, S. P. *The Wide Range Achievement Test.* Wilmington, Delaware: Guidance Associates, 1965.

Johnson, O. G. Guidance for exceptional children. In *Education of exceptional children and youth.* William M. Cruickshank and Orville G. Johnson (Eds.) (2nd ed.) Englewood Cliffs, New Jersey: Prentice-Hall, 1967.

Jones, J. W. *The visually handicapped child.* Washington: U.S. Department of Health, Education and Welfare, 1963.

Jones, J. W. & Collins, A. P. Trends in programs and pupil placement practices in the special education of visually handicapped children. *The Education of the Blind*, 1965, (14), 97-101.

Kelleher, D. K., Mehr, E. B., & Hirsch, M. J. Motor vehicle operation by a patient with low vision. *American Journal of Optometry and Archives of the American Academy of Optometry*, 1971, 48 (9), 773-77.

Kirk, S. A. *Educating exceptional children.* Boston: Houghton Mifflin, 1962.

Koetting, R. A. The simplified approach to low vision. *Journal of the American Optometric Association*, 1970, 40(8), 851-53.

Korb, D. Preparing the visually handicapped person for motor vehicle operation. *American Journal of Optometry and Archives of the American Academy of Optometry*, 1970, 47(8), 619-29.

Lloyd, D. J. Learning through experiencing. *Education of the Visually Handicapped*, 1972, IV(1), 19-22.

Lowenfeld, B. *Our blind children: Growing and learning with them.* Springfield, Illinois: Charles C. Thomas, 1971.

Lowenfeld, B. Psychological foundations of special methods in teaching blind children. In P. A. Zahl

(Ed.), *Blindness.* Princeton, New Jersey: Princeton University Press, 1950, 269-304.

Maeger, R. F. *Developing attitude toward learning.* Palo Alto: Pearon Co., 1968.

Maier, F. B. *Subnormal vision--A clinical guide to care of the partially sighted.* Memphis: Southern College of Optometry, 1965.

Maslow, A. Toward a psychology of being. In Rollo May (Ed.), *Existential psychology.* New York: Random House, 1969, 61-82.

May, R. *Existential psychology.* New York: Random House, 1969.

McGuiness, R. M. A descriptive study of blind children educated in the itinerant teacher, resource room, and special school settings. American Foundation for the Blind, *Research Bulletin Number 20*, 1970, 1-57.

Mehr, E. B., & Fried, A. Unpublished manuscript on telescopic testing techniques with low vision patients, University of California, Berkeley, 1971.

Mehr, E. B., Mehr, H. & Ault, C. Psychological aspects of low vision rehabilitation. *American Journal of Optometry and Archives of the American Academy of Optometry*, 1970, 47(8), 605-12.

Mendenhall, W. *Introduction to probability and statistics.* Belmont, California: Wadsworth Publishing Company, 1969.

Morin, A. Waukegan finds advantages in the itinerant teacher plan. *Sight Saving Review*, 1960, 30, 31-35.

Murphy, A. T. Attitudes of educators toward the visually handicapped. *Sight Saving Review*, 1960, 30, 31-35.

Neff, W. S. & Weiss, S. A. Psychological aspects of disability. In B. B. Wolman (Ed.), *Handbook of Clinical Psychology.* New York: McGraw-Hill, 1965.

Pinter, R. Intelligence testing of partially sighted children. *Journal of Educational Psychology*, 1942, 33, 265-72.

Powers, M. H., Schall, S. M. & Welsch, R. A. Utilization of medical information in school planning for visually handicapped children. *Exceptional Children*, 1965, 32, 5-14.

Rogers, G. R. *On becoming a person.* Boston: Houghton Mifflin, 1961.

Rosenbloom, A. Prognostic factors in low vision rehabilitation. *American Journal of Optometry and Archives of the American Academy of Optometry*, 1970, 8, 600-05.

Rosenblum, A. The partially seeing child. In M. J. Hirsch & R. Wick (Eds.) *Vision of children.* Philadelphia: Chilton Book Co., 1963.

Schapero, M., Cline, D., & Hofstetter, H. *Dictionary of visual science.* (2nd ed.) New York: Chilton Book Company, 1968.

Scheie, H. G. & Albert, D. M. *Adler's textbook of ophthalmology.* Philadelphia: Saunders, 1969.

Scholl, G. T. The education of children with visual impairments. In W. M. Cruickshank & O. G. Johnson (Eds.), *Education of exceptional children and youth.* Englewood Cliffs, New Jersey: Prentice-Hall, 1967.

Scott, R. A. *The making of blind men.* New York: Russell Sage Foundation, 1969.

Shapiro, B. The Stanford battery of tests for blind youths and adults. In L. L. Clark (Ed.), *Proceedings of the West Coast Regional Conference on Research Related to Blind and Severely Visually Impaired Children.* New York: American Foundation for the Blind, 1965.

Sibert, K. N. Instructional materials and procedures for the partially seeing. *Sight Saving Review*, 1960, 30, 162-65.

Sibert, K. N. Research needs in education from a teacher's viewpoint. In L. L. Clark (Ed.), *Proceedings of the West Coast Regional Conference on Research Related to Blind and Severely Visually Impaired Children.* New York: American Foundation for the Blind, 1965.

Sloan, L. L. *Recommended aids for the partially sighted.* (2nd ed.) New York: National Society for the Prevention of Blindness, 1971.

Smith, R. M. *Teacher diagnosis of educational difficulties.* Columbus, Ohio: Charles E. Merrill Publishing Company, 1969.

Stein, H. A. & Slatt, B. J. *The ophthalmic assistant.* St. Louis: The C. V. Mosby Company, 1968.

Stephens, T. M. & Birch, J. W. Merits of special class, resource and itinerant plans for teaching partially seeing children. *Exceptional Children*, 1969, 2, 481-84.

Stephenson, W. *The study of behavior: Q technique and its methodology.* Chicago: University of Chicago Press, 1953.

Stewart, L. H. & Warnath, C. F. *The counselor and society: A cultural approach.* Boston: Houghton Mifflin, 1965.

Suchman, M. *Evaluative research.* New York: Russell Sage Foundation, 1967.

Wright, B. A. *Physical disability: A psychological approach.* New York: Harper & Row, 1960.

DREAMS OF THE VISUALLY HANDICAPPED: TOWARD A NORMATIVE APPROACH

Donald Kirtley*
Katherine Cannistraci*

The relation of visual impairment to dreaming is a topic which has long interested psychologists, as well as curious laymen--both blind and sighted. For the most part, research here has focused upon the imaginal ingredients of dreams, comparing various visually-handicapped groups with one another, the sighted, and, occasionally, other disability groups. Notwithstanding the great value of dream analysis for the understanding of personality, relatively few studies have delved deeply into the nature of motivational or other characterological factors in the dreamlife of the sightless. Although several important investigations have thrown considerable light on certain developmental aspects of the subject, (Heerman, 1838; Jastrow, 1888), their emphasis has typically been upon cognitive rather than psychodynamic variables. Thus, much is known about the sensory structure of the blind's dreamlife but little regarding the bearing of their dreams upon individual attributes of personality; in other words, we know a great deal about *how the blind dream* but almost nothing of *what they dream about* or *the manner in which this material relates to the actual, waking behavior of such persons.*

The present exploratory study addressed itself to the first of the above two questions. It is the initial phase of a much broader investigation, still in progress, which will, it is hoped, culminate in the establishment of meaningful norms of dream behavior for the blind, at least as representative of this population as those reported by Hall and Van de Castle (1966) are for sighted dreamers.

Previous empirical work on the dreams of the blind is perhaps best classified in accordance with the diverse types of research techniques which have been employed:

1. introspective
2. clinical
3. experimental
4. questionnaire
5. direct interviewing
6. qualitative content analysis
7. quantitative content analysis

The vast majority of published reports rest upon introspective, questionnaire and simple interviewing techniques--the latter two often occurring in combination. Both clinical and experimental studies, though generally more revealing, constitute only a handful of the total available publications (Blank, 1958; Von Schuman, 1959; Berger, et al., 1962; Offenkrantz & Wolpert, 1963). Among the former, the chief emphasis has been psychoanalytic, while in the latter category, the most reliable findings have been those of psychophysiological investigations utilizing the EEG method. The qualitative content analysis of recorded dream reports, involving an extensive series of dreams derived from one or more subjects, is an approach rarely applied--though occasionally

*California State University, Fresno.

a short dream series is evaluated in this way. Kirtley and Hall's recent study of 307 dream reports contributed by an adventitiously blinded male is, so far as we know, the first in this field to use the method of quantitative content analysis (manuscript in preparation). The scoring system employed was one earlier developed by Hall and Van de Castle (1966), which is, to date, the most comprehensive system of its kind, consisting of 21 empirical and theoretical scales (to be described below) that permit the tabulation of a wide variety of manifest dream elements and, hence, straightforward normative comparisons. Previous comparative research in this area has usually been highly ambiguous because of its chronic failure to utilize reliable, quantified norms. Indeed, such statistical data was not made available to dream researchers at large until 1966, when Hall and Van de Castle published extensive normative information on 200 normal male and female adults. In conjunction with their content analysis system, these data should be of appreciable value to future investigators interested in clarifying certain longstanding issues regarding the dreamlife of the blind.

The present study was a continuation of the work of Kirtley and Hall and applied the Hall-Van de Castle system to the dreams of a group of visually-handicapped people representing all major categories of blindness: totally blind and severely visually impaired (i.e., acuity at or less than 20/200 in the better eye after correction) occurring prior to age five, and totally blind and severely visually impaired with onset after age seven.

METHOD

Dream diaries kept over a two-to-four-month period were obtained from seven visually-handicapped volunteers, five females and two males. Diary instructions followed the Hall-Van de Castle format, except that allowance was made for tape or braille reporting. Altogether, the subjects contributed 128 written dream reports; 82 of these met the Hall-Van de Castle criterion-length of 50-to-300 words and, consequently, were the only dreams content analyzed. The range of diary length ran from 10 to 35 dreams with a median length of 18.

Five of the subjects were adventitiously impaired from ages 9, 12, 16, 18, and 33--four of whom were totally blind, except for one case of mere light reception, while the remaining subject had some useful vision. Two subjects were congenitally impaired, one totally, the other partially. The ages of the female subjects were 20, 31, 36, 39, and 47; those of the males 31 and 53. All subjects were caucasian and of the middle class, with the completed level of formal education varying from high school to the Ph.D. One subject was a housewife; three were college students; and three were professional people, one of the latter being retired at the time of the study. Save for their visual handicap, these individuals appeared to constitute a psychologically normal sample.

The Hall-Van de Castle system, by means of which these subjects' dream-reports were scored, comprises 15 empirical and six theoretical scales. The former measure such dream contents as physical settings; objects; characters; aggressive, friendly and sexual interactions; sensory, motor, mental and verbal activities; success vs. failure and good fortune vs. misfortune; emotions; negative and temporal references; and descriptive dimensions of a physical, perceptual or evaluative nature. The theoretical scales are based upon psychoanalytic theory and, therefore, assume the correctness of certain Freudian hypotheses concerning the meaning of dream symbols. These scales purport to measure attributes central to the castration complex (castration anxiety, castration wish, and penis envy), as well as other items of importance in psychoanalytic theory (orality and regression). However, in the present investigation the Regression Scale was not applied, for no normative data are as yet available for it.

Already, many dream studies have demonstrated the general worth of the foregoing system. It has been fruitfully employed on the dream reports of literally thousands of culturally, physically, and psychologically diverse people: normal adults and children, psychiatric patients, primitives, and historical personages (Bell and Hall, 1971; Hall, 1966; Hall and Domhoff, 1968; Hall and Lynd, 1970; Hall and Nordby, 1972; Hall and Van de Castle, 1966; Offenkrantz and Wolpert, 1968; Van de Castle, 1971.

This study, it would appear, has been the first to utilize the method of quantitative content analysis (the Hall-Van de Castle scales) on the dreams of persons visually impaired both early and relatively late in life--both before and after the Heermann-Jastrow "critical period" of five to seven years of age. Although the total number of dreams here analyzed was much smaller than that examined in the Kirtley-Hall investigation (their subject's series being, by far, the longest ever contributed by a blind person), the present sample, deriving from a mixed group of subjects rather than a single case, was probably somewhat more representative of the blind at large.

On the other hand, the results which follow must be regarded as suggestive only, as our subject sample was much too small to warrant generalizations to the total visually-handicapped population or, for that matter, to any major segment thereof. There is in this field a distinct tendency among researchers to generalize from inadequate samples; indeed, the well known stereotypes of the blind seem to be almost as characteristic of blindness researchers as they are of the unenlightened public. We, therefore, have chosen to stress only those findings which would seem to have a high probability of future replication.

RESULTS

Considering the content analysis categories generally, the single, most striking result was a clean demonstration of the central role of individual differences in determining the specific nature of dream elements for our subjects. On many variables, their scores differed markedly from those of the male and female norm groups against whom they were compared; but on most of the same variables, they also differed just as much from one another. This inter-individual spread was not only pronounced among the visually handicapped as a group but also among the various subgroups into which these subjects could be divided--males vs. females; the totally blind vs. the severely visually impaired; and the congenitally vs. the adventitiously impaired. Of course, such a finding will not be at all surprising to professional workers for the blind who have long known that the principle of individual differences applies as much to blind persons as to the seeing. Indeed, score variability was usually so great as to render mean comparisons highly artificial. For this reason, no customary statistical test of the significance of mean differences was employed. A subject's proportion score for any given content category was deemed significantly different from the corresponding norm figure if the deviation exceeded 20 percent of the norm proportion. The 20-percent criterion was also used in connection with inter-subject comparisons.

On the other hand, the visually-handicapped subjects were similar to their respective sighted, male or female norm group on relatively few variables. These were as follows:

- average number of settings per dream;
- total architectural structures;
- average number of characters per dream;
- total human characters;
- total single human characters;
- total male characters;
- total unfamiliar characters;
- dreamer-involved friendliness;
- general use of temporal and negative terms.

In references to the head, the visually handicapped tended to be either similar to, or higher than the norms. In oral interests they were also comparable to the norms or somewhat lower.

(Note: Tables 1-19, listing subjects' and norms' proportions for each content classification, appear in the Appendix.)

Subjects scored lower than the norms on dream contents, such as:

- total dreams with no settings;
- total familiar settings;
- total geographical references;
- total settings questionable as to their familiarity or unfamiliarity;

building materials;
implements;
objects pertaining to travel;
streets, paths, sidewalks, railroad tracks and the like;
architectural structures involved with vocational or entertainment activities;
characters of uncertain identity;
acts of physical aggression;
dreamer- involved and uninvolved aggression involving two or more aggressing characters with no identifiable instigator;
self-aggression in the dreamer or other characters;
dreamer as victim of aggression;
dreamer as aggressor against male characters in general;
dreamer aggressing on unfamiliar males and unfamiliar females;
dreamer aggressing on animals;
dreamer as victim of male aggression, of animal aggression;
dreamer- involved and uninvolved acts of friendliness or love entailing close, longterm relationships, such as marriage or engagement;
dreamer as befriender of animals;
proportion of aggressive acts to aggression plus friendliness (in other words, the dreams of these subjects involved more friendliness than aggression);
problem-solving cognition or goal-directed thinking activities in the dreamer or other characters;
incidents of good fortune to characters other than the dreamer;
references to mental or physical stimuli involving strong intensity;
references to heat or warmth and to newness or youth;
references to both high and low velocity;
references to density (to emptiness or vacancy and to fullness or crowding).

Although most of the visually handicapped were also lower in sex dreams, subsequent data obtained from two of them, as well as six new blind subjects, suggest that this low incidence was probably the product of censored reporting, mainly on the part of the female subjects. In this connection, the blind man studied by Kirtley and Hall was much higher than the male norm group in all types of sexual interaction. For a number of additional categories, our subjects were significantly, though not markedly, lower than the norms:

total residential structures;
dreamer as reciprocating aggressor;
dreamer aggressing on females in general;
dreamer victimized by females and by unfamiliar characters;
dreamer- involved and uninvolved friendly interactions entailing bodily contact between persons, invitations, gift giving and the like;
witnessed friendliness in other characters;
dreamer as befriender of familiar characters;
failures for human characters other than the dreamer;
linearity (e.g., straightness vs. curvature of objects)/

and low temperatures.

The blind were lower or no different from the norms in the frequency of references to:

outdoor settings;
clothing;
known characters;
excluding immediate family members and other relatives;
smallness, thinness, shortness, lowness, or narrowness of objects.

The visually handicapped were considerably higher than the norm on the following:

total settings ambiguous as to whether indoor or outdoor;
unfamiliar settings;
household articles;
body parts;
verbal and covert aggression;
friendly feelings or thoughts;
proportion of dreams in which dreamer-involved and uninvolved friendliness occurs;
verbal behavior in the dreamer and other characters;
physical activities occurring with the dreamer in a stationary position or moving in a small area of space.

Subjects were higher but not greatly so on:

body extremities;
witnessed aggression;
dreamer as aggressor against familiar males;
verbal friendliness;
dreamer as befriender of unfamiliar characters;
sadness in the dreamer;

negative moral and aesthetic evaluations; and
achromatic color.

In regard to this last finding, the two adventitiously totally-blind females reported much more general visual activity and chromatic color images than did the sighted female norm group; this result seemed to stem from these subjects' unusually heightened attention to that visual imagery which yet remained to them and not from mere verbalism. A similar explanation would seem appropriate for the finding on achromatic color.

The one congenitally totally-blind female (C1) differed markedly in numerous interesting ways from the other female subjects (see Tables 1-19). However, the extent to which these deviations were ascribable to the congenital nature of her blindness was not clear. A qualitative inspection of dream reports recently collected from three additional TCF volunteers suggests that the bulk of the differences stemmed from unique characteristics of the subject's personality rather than from the fact of her never having seen.

When the two visually-impaired females were compared with the two adventitiously totally-blind females (C2), only a few differences emerged. On total indoor settings, the adventitiously visually-impaired subject (C3) was comparable to the norm group, while the congenitally visually-impaired female (C4) was only somewhat lower; but both C2's were considerably higher than the norm. On total outdoor settings, the visually-impaired persons did not deviate from the norm, whereas both C2's were significantly lower. For objects associated with travel, the C2's were again lower, though C3 was higher and C4 no different from the norm. A pattern similar to the latter occurred for references to the body torso, as well as to incidents in which the dreamer reciprocates aggression. In chromatic color and overall visual activities, the C2's were much higher than the sighted norm group, with C3 being lower and C4 no different, suggesting that visual phenomena hold less interest for the latter than for the C2's, owing to the visually-impaired subjects' much fuller visual experience and, consequently, their reduced need to counter sensory deprivation via stimulation from visual images. C3 and C4 were above the norm in references to the straightness or flatness of objects, as well as in negative moral and aesthetic evaluations, while both C2's were lower. As to the proportion of dreams with no temporal reference, neither C2 differed from the norm, but both visually-impaired subjects exceeded it. Likewise, in the number of dreams with one teporal reference, the C2's were comparable to the norm, and C3 and C4 were lower. Apparently a temporal frame of reference is more important to the totally blind than to individuals with some useful vision. When C3 alone was compared with the two C2's, as well as with C4, many more differences appeared. In part, these seemed to reflect certain advantages of partial sight over total blindness, and of visual impairment after the Heermann-Jastrow critical period over such impairment from birth.

Tables 1 through 19 show that sex differences in the blind group were of appreciable importance in determining the nature of subjects' deviations from the norms. When the two males were compared with the five females, the previous pattern of deviations changed in numerous ways. However, the most interesting comparison was that made between the males, C5 (both adventitious totally-blind subjects), and the females, C2; all four of whom had lost their vision after age seven. In addition, age differences were less likely to have been a contaminating factor here since each of these subgroups contained one older and one younger person--the males having been 31 and 53, the females 20 and 47.

The C2's were much higher in references to animals and money than were the C5's, a direct reversal of the male and female norm differences. On the other hand, the C5's were higher than the C2's in references to the head, another reversal of the norm sex difference. Yet with respect to dreamer's success, success to others, and dreamer good fortune, the subjects' pattern of differences was similar to that of the norms. The C5's experienced far more dreamer success and good fortune than did the C2's, and far less success for other characters than did C2's. Some of the foregoing findings were easily explainable on the basis of certain events in the life histories of the individuals in question, but others were not, such as those pertaining to animals, money, and success. A qualitative examination of the dream diaries suggested that the importance of animals to the female subjects arose largely from the frequent use of such characters to symbolize sex and aggression; the males, on the other hand, were more inclined to express these impulses openly. The findings for money and success appeared to indicate appreciable feelings of insecurity and self-doubt in the females, feelings which were not characteristic of the males.

DISCUSSION

Although the central thrust of the present study consists in a demonstration of the overriding importance of individual differences in determining dream content for our subjects, certain findings may, nonetheless, have stemmed more from visual handicap than from other variables. The results to which we refer are grouped below into five broad categories and concern the impact of visual deficit upon:

1. mobility;
2. aggressive behavior;
3. friendly interactions;
4. self-perception; and
5. perception of the physical environment.

A number of additional findings, those highlighting similarities between the blind and the sighted, are also of particular interest in that they suggest a variety of content in the dreams of the blind comparable to that which has been found in the dreams of the seeing. Our subjects' dreams did not show the paucity of imagination which some researchers (Kimmins, 1937; Singer and Streiner, 1966) have thought characteristic of the dreams of the blind, especially individuals blind from early life. This will be discussed later.

Factors Related to Restricted Mobility

Because blindness, by its very nature, profoundly limits freedom of movement, most blind people probably do not travel about the environment nearly so extensively as do the seeing. Such a fact would explain a number of our results. Compared with the sighted norms, our subjects' scores were, on the whole, lower with respect to total number of outdoor settings, geographical regions, objects associated with travel, thoroughfares of various types, and public places of entertainment. Likewise, they were relatively high in references to household articles and to numerous kinds of narrowly delimited physical movement--e.g., standing up, sitting down, combing the hair, brushing the teeth, pacing, walking across a small room, and the like. Thus, in dreams, as in waking life, the blind are restricted in their mobility and would appear to spend less time outdoors and more time within the home than do the sighted. Although some seemingly compensatory movement (flying, running, swimming, and so on) was reported by some dreamers, such instances tended to be exceptional, suggesting that previous investigators (Von Schumann, 1959), who have stressed such movement in the dreams of the blind, may have assigned it greater importance than it actually deserves. Moreover, it should be pointed out that dream mobility in our subjects was not strongly related to degree of vision. Those individuals with some functional sight differed only modestly here from the totally blind, and the one subject who showed the highest incidence of travel, even exceeding the norm, possessed only light reception. This man, a retired health professional, enjoyed traveling and had been overseas a number of times, all facts from his waking life which were clearly mirrored in the manifest content of his dreams.

The Effects of Visual Handicap upon the Discharge of Aggression

The dreams of our subjects were comparatively low in incidents of physical aggression (murder, assault, destruction of property, etc.). Yet when such aggression did occur, it tended to be unusually extreme--the dreamer dynamiting hated characters, beheading criminals, or observing other characters engaged in bloody combat, sometimes involving maiming and torture. In this connection, Von Schumann has reported that the dreams of the blind are characterized by much violent aggression, a finding he attributed to the immense frustrations experienced by the blind in everyday life, which arise partly from the limitations of blindness and partly from conditions extrinsic to it, societal prejudice and discrimination. Our results, however, suggest that, for the blind at large, such massive aggression may be infrequent compared with its milder, nonphysical counterpart. Since Von Schumann's sample consisted primarily of patients undergoing psychotherapy (a number of whom were newly blinded), his emphasizing reactive dream aggression is not surprising. One would expect such persons to experience the frustrations of blindness more acutely than do psychologically stable individuals whose blindness is of long standing; a characteristic of our own sample. Thus, we suspect that the dreams of blind people in general are characterized by low rather than high physical aggression. Such a tendency would appear to issue from the obvious fact that visual handicap in real life does significantly reduce the ease with which effective physical aggression can be carried out. In other words, the general nature of dream aggression reflects the pattern of aggression characteristic of the individual during waking. On the other hand, the occasional episodes of dream violence do apparently serve a safety-valve function of releasing reactive aggression cumulatively built up during waking. Blindness even in the healthiest individuals invariably entails certain stresses which would be absent given normal vision. In our sample, extreme aggression appears in waking fantasy, though not in overt behavior. Thus, it appears that the cathartic role of dreams during sleep is taken over by fantasy during the waking hours.

In striking contrast to the scores for physical aggression, those for aggressive thoughts and verbalizations were much higher in the visually handicapped than in the norm groups. Indeed, with respect to verbal activities in general, our subjects greatly exceeded the sighted. Such findings, of course, follow naturally from the paramount part played by language (including covert symbolic processes) in the actual lives of sightless people. Visual loss deprives the individual of a major channel of communication and environmental representation, leaving, as it were, an experiental lacuna which can be bridged only by means of a highly augmented reliance on words and mental images. Earlier research (Berger, olley, and Oswald, 1962; Von Schumann, 1969) has similarly stressed the special role of thought and language in the dreams of the blind, one comparable to that performed by these functions during waking. In regard to aggression, it may be concluded that language and fantasy readily assume priority in the blind person's hierarchy of outlets because the motoric-locomotor modes of expression are less directly accessible to him. Related to this point are other findings from the present study which suggest that the blind may tend to displace or disguise their aggression much more extensively than do the seeing. Compared with the norms, our subjects' dreams revealed more negative moral and aesthetic evaluations, more witnessed aggression, and less good fortune to other characters. The fact that the visually handicapped were below the norm groups in references to strong external and internal stimuli perhaps also represents a symbolic extension of the tendency away from direct physical aggression. On the other hand, we cannot conclude that our subjects were "passive characters" in their dreams, since a great deal of their verbal aggression was straightforward and effective.

Two further results in the aggression category are of particular interest. The visually handicapped were much lower than the norms in mentions of dreamer aggressing against himself or being victimized by other characters, suggesting relative freedom from masochistic and paranoid tendencies in the former group. As already stated, our subjects appeared well adjusted; perhaps such persons cannot afford traits such as the above to the same extent that the sighted can. Successful adjustment under the stress of blindness may demand more energy for reality orientation, and hence greater pressure to resolve merely intrapsychic problems than would be needed for the same level of adaptation, given the reality-testing advantages of sight.

Finally, neither quantity nor quality of aggressive dream behavior was related to amount of useful vision in our subjects. The partially sighted manifested the same pattern as did the totally blind.

Characteristic Modes of Friendly Interaction

Our subjects' scores were higher in friendly speech and thoughts and lower in friendly acts involving longterm relationships, gift giving, invitations, and physical contact (handshaking, caressing, and nonerotic kissing) than were the scores of the norms. Such findings are not surprising in view of the general importance of language and covert, representational processes in the everyday life of the blind person. That the visually handicapped tended to be lower in the more demonstrative types of friendliness, while at the same time had as their highest category friendly thoughts, suggests that such persons may find it more difficult to act out their friendly impulses than do the seeing. The problem would seem to stem both from conditions inherent in blindness (restricted mobility and the unavailability of certain emotional cues communicated by vision, that is, gestures and facial expressions), and from irrational social rejection or misunderstanding of the blind. On the other hand, the dreams of some subjects showed considerable helping behavior toward other characters, and generally the scores for gift giving, inviting, and physical friendliness were not strikingly lower than those of the seeing. Similarly, the category for long-term relationships involved the establishment of marriages, engagements, as well as lasting friendships. Most of our subjects, unlike the norms, were married and fairly well settled with a circle of regular friends.

In regard to our subjects' high verbal friendliness, one further source would appear to be the great instrumental value of such behavior in meeting certain basic life needs which would tend to be heavily thwarted without it. Blind people may have a stronger inclination than the sighted to behave in a friendly manner toward others, since, to some extent, blindness realistically increases one's dependence on seeing persons for particular types of assistance--for guiding, reading, driving, information about the environment, and the like. If the blind person is adequately to satisfy such needs, his style of approach to those who can help him (especially when the latter are strangers) must at least be tactful and agreeable; otherwise he might easily induce an avoidance reaction or procure only insufficient assistance. In this connection, our subjects, compared with the norm groups, were somewhat lower in acts of befriending familiar characters (family members and friends) and somewhat higher in the befriending of unfamiliar characters. Since needs for sighted aid from family and friends would seem to be relatively assured of satisfaction, the blind person might naturally have a greater inclination to befriend strangers, from whom the receipt of such help would, of course, be less predictable. Also interesting is the fact that, with respect to the character classes generally, the present subjects were more likely to befriend others than to be befriended by them, the reverse of what one would expect had the friendly interactions of these subjects been essentially passive.

The pattern of friendly interactions, described above, was similar for visually-impaired and totally-blind subjects.

The Effects of Visual Handicap on Self-Perception

Blindness or extreme visual defect of the kind considered here appears to change the self-image in certain respects, mainly the body image. Compared with the norms, our subjects were much higher in reference to body parts. Blindness makes the body more immediate, more prominent in the perceptual field because of the absence of the superior distance reception afforded by vision. The incidence of body extremities was also somewhat higher in the visually-handicapped group than in the seeing, perhaps because of the former's special concern for mobility and touch contact. Also, the male subjects were much higher than the male norms in mentions of the head or parts thereof, but this deviation may only have arisen from the fact that in both these cases blindness had been caused by traumatic injury to the head or neck region.

In their dreams our subjects were generally below the norms in references to clothing, indicating that the appeal of clothing is primarily visual. However, female subjects tended to be more interested in clothes than were the blind males, and in this regard, the interest of the partially sighted was no greater than that of the totally blind. Nonetheless, wearing apparel, including jewelry, seems to play a less important role in the self-image of the visually handicapped than in that of the visually normal.

Although the present subjects differed widely in most pleasant and painful emotions, they did, nevertheless, consistently exceed the norms in instances of dreamer sadness. Such a finding, of course, is not surprising insofar as visual handicap, even the best adjusted persons must, to some degree, add to the ordinary complications of daily living. However, we would not label any of our subjects as "depressive types." As pointed out above, self-aggression in their dreams was low, the opposite of what one would expect to find, were he to be dealing with pathological depression. In addition, a qualitative examination of the diaries did not reveal the general drabness of content which would tend to characterize the dreams of the depressively inclined. In any case, the difference between the visually handicapped and the seeing in the sadness category was not great.

The Impact of Visual Deficit on General Perception of the Environment

Normal vision seems to be especially important in determining interest in certain features of the physical environment.

Our subjects' dreams were lower than those of the norm groups in references to building materials and various kinds of implements, including tools, weapons and recreational articles--though the latter deviation was not marked. Similarly, the visually handicapped were either slightly or considerably lower in the use of modifying terms concerned with small or minute size--thinness, narrowness, shallowness, shortness, or lowness; fullness and emptiness, crowding and vacancy; fast and slow speed; straightness and crookedness, or flatness and curvature. Of the preceding, those attributes which pertain to the size, density, and linearity of objects are often highly accessible to the sense of touch, while velocity can easily be perceived kinesthetically and, to some extent, even aurally. However, with respect to these particular dimensions, the present findings indicate that vision may generally produce greater phenomenal saliency than any of the other sensory modalities, even when the latter function cooperatively in some specific object perception. On the other hand, the visually handicapped did not differ from the sighted in the total number of modifiers used in dreams.

Other findings suggest that the visually handicapped have a stronger need than the sighted to identify environments in terms of their familiarity or unfamiliarity. Our subjects had fewer dream settings questionable as to this dimension than did the norms, for whom the latter is a high-frequency category. Nevertheless, the visually handicapped were comparatively low in the incidence of familiar settings and high in that for unfamiliar settings, and, moreover, exceeded the norms in the number of settings ambiguous as to whether indoor or outdoor.

Any one of the following explanations could resolve this seeming contradiction:

1. In the recognition of physical surroundings, visual cues are far more important than those from the other senses--that is, the blind are more likely than the seeing, in dreams as in waking experience, to find themselves in unfamiliar surroundings, and, conversely, less likely to be in familiar ones. This alternative, however, strikes us as improbable, since the majority of blind people we have observed over the years appeared to spend most of their time in known environments

(especially the home and place of employment). Furthermore, the blind man studied by Kirtley and Hall, whose diary, as previously mentioned, contained 307 dream reports, manifested a pattern opposite to that of the present subjects (many more familiar and many fewer unfamiliar settings than the male norm group, and relatively few settings unspecified with regard to their being in or out of doors). Which of these patterns is more typical of the blind is, of course, a question that only future content-analysis research can answer, though we suspect the second type will be found more often, owing to a natural carry-over of known waking environments into dreams.

2. The results for familiar vs. unfamiliar and inside vs. outside settings suggest that the blind may tend to feel substantially alienated from the external environment. Yet we find this explanation even less plausible than the first. Our subjects' dreams did not show any trends toward isolation from physical objects or other people, and feelings of loneliness or depersonalization were infrequent, all of which should have been pronounced had these individuals, in fact, felt environmentally estranged.

3. In recording their dreams, the sighted norms may have been less careful than our subjects about reporting degree of setting familiarity, so that the results at hand artificially exaggerate the true differences for this dimension, assuming there are any. Since the sighted do not share the environmental-orientation problem of the blind, they could easily be less inclined to label dream surroundings in terms of familiarity vs. unfamiliarity; for this variable would be of much less consequence to the sighted than to the blind in affecting freedom of movement. Likewise, for the orientation of the blind, the latter type of identification would seem to be of much greater importance than that concerning indoor vs. outdoor location, which elicited as little specific labeling from our subjects as did degree of familiarity from the norm groups. Once the blind person has established whether the dream situation is known or not, the further step of labeling its indoor or outdoor nature may seem somewhat trivial and hence tend to be ignored. We suspect that the indoorness or outdoorness of settings is just as often discriminated by the blind as by the seeing, but the former, for reasons given above, are less interested (unconsciously less inclined) to report such characteristics. Of the three explanations here presented, we find this last the most cogent.

Other findings lend support to the hypothesis of the visually handicapped's heightened need for environmental clarification. Our subjects were lower than the norms in the number of dreams entirely lacking in physical setting, also lower in references to characters of uncertain identity.

Regarding characters in the "known" category, subjects' scores tended to be relatively low or else were similar to those of the norms. This finding, however, should not be interpreted to mean that the visually handicapped were often lower in all types of known characters, for the category only covers friends and acquaintances. It does not, for example, include immediate family members, distant relatives, or prominent persons. Low scoring in the "known" category seems to have stemmed, at least in part, from a high incidence of family members in the dreams of several subjects. Also, it seems likely that visually-handicapped people generally would tend to have fewer friends and acquaintances than do the sighted, owing to the importance of normal mobility in the widening of the individual's interpersonal contacts.

In conclusion, it appears that in proportion as visual handicap shuts one off from the environment, the normal human need for environmental knowledge concomitantly intensifies, not so much with respect to information about the physical dimensions of particular objects (their size, linearity and density), but chiefly through pressures to identify other persons and certain broad aspects of the physical environment (one's position in space relative to surrounding objects and their positions in relation to one another). In other words, the dominant need is for environmental Gestalten or cognitive maps, which can facilitate mobility, the class of behavior we believe most seriously frustrated by visual loss. All things being equal, the need for environmental awareness would seem most fully realizable in individuals with some functional sight or at least visual memory.

The Relation of Visual Handicap to Originality and Variety of Dream Content

From their research on the dreams of blind children, Kimmins (1937) and Singer and Streiner (1966) have reported a lack of the originality and variety of content which is so common in the dreams of seeing children. They regarded early blindness, *sui generis*, as profoundly dettrimental to the development of imaginative ability. On the other hand, four of our subjects had been blind or nearly so since childhood (two from birth, one from age nine, one from age twelve), and they, as well as the three subjects blinded later, were generally comparable to the sighted norms in variables, such as: average number of settings per dream, total architectural structures, average number of characters per dream, total human characters, total single humans, total males, total unfamiliar characters, general references to time and average number of descriptive elements per dream. For the above content categories, our findings clearly suggest that the dreams of these persons were not devoid of variety. Furthermore, a qualitative comparison of their dream reports with several hundred contributed by sighted college students, did not reveal any greater novelty of content in the latter. Consequently, we strongly suspect that the abovementioned studies, because of major methodological shortcomings, both substantially exaggerate the damaging effects of childhood blindness.

Theoretical Implications

In general, the present findings were congruent with Hall's (1966, 1972) continuity hypothesis: dream mentation is continuous with waking behavior in the sense that dream concerns and activities tend to be repeated during waking, either explicitly through action or implicitly by way of conscious thoughts, fantasies, attitudes and preoccupations. The identity, however, is one of general behavioral form, not of specific behavioral content. Contrary to the compensation hypothesis, the continuity position holds that dreams do not typically embody total reversals of waking tendencies. Dreams are, of course, compensatory to some extent in that they frequently fulfill wishes which cannot adequately be gratified through waking action. Yet in most such cases, conscious daydreaming plays a similar compensatory role, and there is continuity in this respect. Thus, the same personality organization appears to underlie both dream and waking behavior, and the visually handicapped cannot escape it any more than can the seeing.

CONCLUSION

It should be pointed out that the norm groups employed in this study consisted entirely of college students from 19 to 25 years of age. Therefore, it is likely that many of the deviations here reported resulted from the age variable rather than blindness or other factors. Our use of these admittedly imperfect norms was justifiable on at least two grounds: to date, no other norms are available; with respect to dream diaries continued over periods of 20 or more years (some from early adulthood to late life), the weight of current evidence indicates general consistency in dream content notwithstanding the effects of aging and changes in environment (Hall and Nordby, 1972).

Because of the smallness of the sample, we have refrained from drawing any far-reaching, substantive conclusions from our results, though a number of them would intuitively seem applicable to the blind in general and, hence, highly likely to be reproduced by future researchers. We believe that the chief value of the present study consisted in its illustration of the scientific superiority of quantitative content analysis, particularly the Hall-Van de Castle system, over other methods previously used in this field. We hope our work will encourage more investigators to adopt a similar approach. If truly representative normative information on the dreams of blind people is ever to be obtained, some form of quantitative content analysis would appear mandatory.

TABLE 1

Settings

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Average number of settings per dream	1.29	1.20	1.13	1.31	1.16	1.43	1.47	1.60	1.15
Indoor	0.440	0.333	0.556	0.550	0.591	0.700	0.727	0.406	0.467
Outdoor	0.469	0.500	0.222	0.351	0.136	0.100	0.273	0.344	0.333
Ambiguous	0.072	0.167	0.222	0.086		0.200		0.250	0.133
No setting	0.019			0.011	0.273				0.067
Familiar	0.305	0.083	0.111	0.369	0.182	0.100	0.546	0.250	0.267
Distorted	0.022		0.333	0.058	0.046		0.091	0.094	0.200
Geographical	0.079	0.083		0.035				0.031	
Questionable	0.384	0.333	0.222	0.429	0.364	0.300	0.046	0.156	0.200
Unfamiliar	0.190	0.500	0.333	0.099	0.136	0.600	0.318	0.469	0.267

C5-H - Total, Adventitious, Male - Henry

C5-B - Total, Adventitious, Male - Bill

C1 - Total, Congenital, Female

C2-S - Total, Adventitious, Female - Sally

C2-E - Total, Adventitious, Female - Ethel

C4 - Congenital, Visually Impaired, Female

C3 - Adventitious, Visually Impaired, Female

TABLE 2

Objects

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Average number of objects per dream	4.8	8.8	6.1	5.3	3.1	4.1	8.0	4.1	9.6
Architecture	0.271	0.102	0.327	0.317	0.345	0.345	0.258	0.378	0.160
Residential	0.113	0.046	0.122	0.146	0.052	0.241	0.100	0.195	0.088
Vocational	0.048		0.020	0.052	0.207		0.033	0.073	0.088
Entertainment	0.031	0.011	0.041	0.026	0.017		0.017	0.024	
Institutional	0.012			0.015	0.052	0.035	0.008	0.024	
Detail	0.063	0.046	0.122	0.070	0.017	0.069	0.108	0.061	0.056
Building Materials	0.002			0.001					
Miscellaneous	0.002			0.007					0.008
Household Articles	0.082	0.125	0.102	0.104	0.155	0.035	0.167	0.085	0.200
Food or Drink	0.018	0.079		0.021	0.017		0.067	0.012	0.056
Implements	0.066		0.061	0.020	0.017	0.103	0.033	0.012	0.008
Tools	0.014			0.003		0.103	0.008		0.008
Weapons	0.301			0.008				0.012	
Recreational	0.021		0.061	0.009	0.017		0.025		
Travel	0.112	0.261	0.020	0.084	0.035	0.035	0.058	0.037	0.072
Streets	0.067	0.046		0.044			0.025	0.024	0.056
Regions	0.056	0.034	0.184	0.047	0.035	0.035	0.050	0.171	0.064
Nature	0.091	0.102	0.020	0.075		0.104	0.075	0.110	0.048
Body parts	0.102	0.171	0.225	0.118	0.172	0.241	0.092	0.098	0.232
Head	0.033	0.046	0.102	0.061	0.052	0.069	0.058	0.061	0.080
Extremities	0.038	0.102	0.020	0.034	0.086	0.069	0.017	0.012	0.080
Torso	0.014	0.011	0.041	0.012	0.017		0.008	0.012	0.048
Anatomy	0.008		0.020	0.011		0.035	0.008	0.012	0.024
Sex	0.009	0.011	0.041	0.001	0.017	0.069			
Clothes	0.057	0.046		0.102	0.017	0.035	0.092	0.024	0.080
Communication	0.039	0.011	0.061	0.042	0.172	0.035	0.033	0.024	
Money	0.015			0.007	0.017	0.035	0.017	0.012	

TABLE 3

Characters

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Average number of characters per dream	2.4	2.7	2.9	2.8	2.5	2.3	2.9	3.2	1.8
Animals	0.060	0.037		0.042	0.021	0.063	0.114	0.063	0.167
Creatures	0.001							0.016	
Single animals	0.036			0.029	0.021	0.063	0.068	0.047	0.125
Plural animals	0.024	0.037		0.013			0.046	0.016	0.042
Human characters	0.939	0.963	1.000	0.958	0.979	0.938	0.886	0.922	0.833
Single human characters	0.687	0.808	0.870	0.719	0.652	0.533	0.692	0.763	0.750
Plural human characters	0.313	0.192	0.130	0.281	0.348	0.467	0.308	0.237	0.250
Male	0.530	0.308	0.522	0.372	0.435	0.467	0.385	0.254	0.400
Female	0.258	0.500	0.266	0.401	0.239	0.400	0.333	0.576	0.300
Joint sex	0.131	0.115	0.130	0.133	0.283	0.067	0.205	0.117	0.200
Indefinite	0.081	0.077	0.087	0.095	0.044	0.067	0.077	0.051	0.100
Familiar	0.452	0.346	0.783	0.584	0.630	0.200	0.667	0.627	0.600
Unfamiliar	0.548	0.654	0.217	0.416	0.370	0.800	0.333	0.373	0.400
Adults	0.973	0.923	1.000	0.933	0.783	0.667	0.949	0.915	0.900
Teenagers	0.006			0.014	0.087	0.333		0.034	
Children	0.018	0.077		0.042	0.130		0.051	0.017	0.050
Babies	0.003			0.011				0.034	0.050
Immediate family	0.095	0.192	0.217	0.147	0.283		0.231	0.170	
Relatives	0.023	0.115	0.087	0.045			0.077	0.119	0.200
Known	0.313		0.304	0.368	0.348	0.200	0.231	0.288	0.400
Prominent	0.016	0.039	0.174	0.010			0.051	0.034	
Occupational	0.171	0.154	0.044	0.085	0.087	0.067	0.128	0.068	
Ethnic	0.020			0.021		0.067		0.051	0.100
Strangers	0.232	0.423	0.130	0.171	0.283	0.200	0.154	0.203	0.250
Uncertain	0.119	0.077	0.044	0.133		0.200	0.051	0.051	0.050
Dead, imaginary, and metamorphoses	0.013	0.039		0.019			0.051	0.017	

TABLE 4

Proportion of Aggressions by Subclass of Aggression

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
8 Murder	0.06			0.02		0.20			
7 Attack	0.22			0.15	0.06			0.05	0.20
6 Chasing	0.15			0.13	0.06	0.20		0.09	
5 Destruction	0.06			0.04		0.20		0.05	
4 Threat	0.05			0.04					
3 Rejection	0.18	0.25		0.36	0.06	0.40	0.11	0.09	0.40
2 Verbal	0.18	0.50	0.33	0.15	0.25		0.33	0.50	0.20
1 Covert	0.10	0.25	0.67	0.11	0.56		0.56	0.23	0.20
5-8	0.50			0.34	0.13	0.60		0.18	0.20
1-4	0.50	1.00	1.00	0.66	0.88	0.40	1.00	0.82	0.80

TABLE 5

Summary of Aggressive Encounters

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Proportion of dreams with aggression	0.47	0.10	0.50	0.44	0.58	0.43	0.40	0.60	0.23
Reciprocal	0.12	0.75		0.10	0.06	0.20	0.11	0.09	0.40
Mutual	0.05			0.05				0.18	
Self-aggression	0.03			0.01					
Dreamer-involved aggression	0.80	1.00	0.50	0.80	0.75	0.60	1.00	0.91	0.80
Dreamer as aggressor	0.31		1.00	0.45	0.67	0.33	0.78	0.50	0.25
Dreamer as victim	0.48	0.50		0.50	0.33	0.67	0.22	0.20	0.25
Dreamer as reciprocal	0.13	0.50		0.10				0.10	0.50
Dreamer mutual	0.05			0.04				0.20	
Dreamer self	0.04			0.01					
Witnessed aggression	0.20		0.50	0.20	0.25	0.40		0.09	0.20

TABLE 6

Proportion of Friendly Interactions by Subclasses of Friendliness

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
7 Marriage	0.04		0.14	0.08				0.10	
6 Physical	0.09			0.08	0.08	0.14		0.10	
5 Inviting	0.08	0.14		0.15			0.13	0.14	0.11
4 Helping	0.42	0.29	0.43	0.32	0.25	0.43	0.42	0.33	0.56
3 Gift	0.11			0.10	0.08	0.14			0.11
2 Verbal	0.20	0.14	0.29	0.19	0.33	0.29	0.13	0.24	0.22
1 Covert	0.06	0.43	0.14	0.08	0.25		0.33	0.10	

TABLE 7

Summary of Friendly Encounters

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Dream in which friendliness occurs	0.38	0.50	0.75	0.42	0.63	0.57	0.80	0.60	0.54
Reciprocal friendliness	0.02			0.01	0.13			0.05	
Mutual friendliness	0.08	0.14		0.07	0.08		0.04		0.11
Self friendliness							0.04	0.05	
Dreamer involved friendliness	0.90	1.00	0.71	0.84	1.00	1.00	0.83	0.95	0.78
Dreamer as befriender	0.45	0.86	0.80	0.41	0.63	0.14	0.70	0.30	0.43
Dreamer as befriended	0.45		0.20	0.46	0.17	0.86	0.25	0.60	0.57
Dreamer reciprocal	0.03			0.01	0.13			0.05	
Dreamer mutual	0.07	0.14		0.04	0.08		0.05	0.05	
Witnessed friendliness	0.10		0.29	0.16			0.17	0.05	0.22

TABLE 8

Summary of Sexual Interactions

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Proportion of dreams in which sex occurs	0.116	0.100		0.036	0.158			0.05	
Dreamer-involved	0.93	1.00		0.68	1.00			1.00	
Witnessed sex	0.07			0.33					
Dreamer with opposite sex familiar	0.32			0.77	1.00				
Dreamer with opposite sex unfamiliar	0.54	1.00		0.23				1.00	

TABLE 9

Proportion of Activities in Which the Dreamer is Involved

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Proportion of all activities in which dreamer is involved	0.528	0.716	0.550	0.490	0.844	0.654	0.635	0.771	0.793
Verbal	0.016	0.396	0.273	0.019	0.556	0.294	0.424	0.407	0.239
Physical	0.130	0.271	0.273	0.097	0.222	0.118	0.121	0.111	0.457
Movement	0.164	0.104	0.091	0.148	0.074	0.235	0.167	0.148	0.109
Location change	0.059	0.083		0.053	0.037		0.167	0.148	0.065
Visual	0.106	0.104	0.182	0.104	0.037	0.235	0.182	0.111	0.065
Auditory	0.014			0.013	0.037	0.118	0.030	0.037	
Expressive	0.008		0.182	0.012	0.019			0.019	
Cognitive	0.031	0.042		0.044	0.019		0.015	0.019	0.065

TABLE 10

Summary of Failures

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Proportion of dreams in which failure occurs	0.15		0.25	0.10	0.37		0.07	0.05	0.08
Failure for dreamer	0.86		0.50	0.83	0.78		1.00		1.00
Failure for other humans	0.11		0.50	0.17	0.22			1.00	

TABLE 11

Summary of Successes

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Proportion of dreams in which success occurs	0.15	0.10	0.25	0.08	0.16	0.14	0.13	0.30	0.23
Success for dreamer	0.89	1.00	1.00	0.87	0.67			0.67	1.00
Success for other humans	0.11			0.13	0.33	1.00	0.50	0.33	

TABLE 12

Proportions of Misfortunes by Subclasses of Misfortune

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
6 Death	0.08		0.60	0.10					0.50
5 Injury	0.21	0.17	0.20	0.25	0.33	1.00	0.38	0.33	0.50
4 Accident	0.25	0.17		0.19			0.13	0.17	
3 Threat	0.13	0.17		0.13					
2 Falling	0.05	0.33		0.03				0.17	
1 Obstacle	0.28	0.17	0.20	0.30	0.67		0.50	0.33	

TABLE 13

Summary of Misfortunes

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Proportion of dreams in which misfortune occurs	0.36	0.50	0.50	0.33	0.16	0.14	0.40	0.20	0.15
Misfortune to dreamer	0.71	0.67		0.68	0.67	1.00	0.63	0.83	
Misfortune to others	0.29	0.33	1.00	0.32	0.33		0.38	0.17	1.00

TABLE 14

Summary of Emotions

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Dreamer emotions									
Happiness	0.180	0.111		0.151	0.096		0.133		0.462
Sadness	0.075		0.143	0.110	0.194		0.267	0.167	
Anger	0.103	0.111	0.143	0.078	0.161		0.067		0.077
Confusion	0.195	0.333	0.143	0.164	0.065		0.133	0.167	0.231
Apprehension	0.302	0.444	0.143	0.333	0.355		0.133	0.333	0.154
Emotions of other characters									
Happiness	0.014			0.038			0.067	0.167	
Sadness	0.018		0.286	0.019			0.133	0.167	
Anger	0.032		0.143	0.055	0.032				
Confusion	0.043			0.014	0.032		0.067		
Apprehension	0.039			0.038	0.065				

TABLE 15

Modifiers

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Average number of modifiers per dream	2.222	2.70	1.38	2.92	2.68	1.86	3.60	1.65	3.38
Chromatic	0.067	0.074		0.114		0.385	0.167	0.091	0.023
Achromatic	0.039	0.037	0.091	0.046		0.308	0.093	0.091	0.136
Large	0.180	0.296	0.364	0.133	0.039	0.077	0.259	0.061	0.136
Small	0.095	0.037		0.078	0.020		0.074	0.091	0.091
Intense	0.295	0.111		0.300	0.411		0.130	0.121	0.250
Weak	0.051	0.074	0.091	0.038	0.039		0.056	0.030	0.046
Filled	0.016			0.015					0.068
Empty	0.008			0.002					
Straight	0.004	0.111		0.004				0.030	0.046
Crooked	0.012		0.091	0.013	0.020				0.046
Hot	0.005			0.008		0.077			
Cold	0.007	0.037		0.008		0.154		0.061	
Fast	0.036			0.021			0.019		
Slow	0.007			0.007					
Old	0.040	0.037	0.091	0.042	0.157		0.056	0.030	0.046
Young	0.051	0.037		0.042	0.020		0.037	0.030	0.046
Pretty, Good	0.052	0.148		0.071	0.177		0.074	0.182	0.046
Ugly, Bad	0.035		0.273	0.058	0.118		0.037	0.182	0.023

TABLE 16

Number of Negatives Per Dream

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
0	0.282		0.250	0.186		0.143	0.133	0.300	0.308
1	0.290	0.300		0.268	0.105		0.067	0.200	0.077
2	0.222	0.100	0.375	0.234	0.053		0.267	0.200	0.308
3	0.124	0.300	0.250	0.136	0.263	0.429	0.200	0.150	0.231
4	0.040	0.100	0.125	0.086	0.158	0.286	0.067	0.150	
5	0.024	0.100		0.044	0.053	0.143	0.067		0.077
6	0.018	0.100		0.046	0.368		0.200		

TABLE 17

Number of Temporal References Per Dream

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
0	0.656	0.700	0.625	0.598	0.632	0.571	0.600	0.900	0.923
1	0.238	0.300	0.250	0.256	0.263	0.286	0.267	0.100	0.077
2	0.076			0.104	0.105		0.133		
3+	0.030		0.125	0.042		0.143			

TABLE 18

Distribution of Oral Incorporation and Oral Emphasis Scores

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Oral Incorporation									
0	0.840	0.800	0.875	0.830	0.947	1.000	0.533	0.850	0.692
1	0.100		0.125	0.108	0.053		0.200	0.150	0.154
2	0.042			0.044			0.067		
3+	0.018	0.200		0.018			0.200		0.154
Oral Emphasis									
0	0.878	1.000	0.875	0.876	0.947	1.000	0.733	0.900	0.692
1	0.090		0.125	0.106	0.053		0.267	0.100	0.154
2	0.032			0.010					0.154
3+				0.008					

TABLE 19

Distributions of Castration Anxiety, Castration Wish, and Penis Envy Scores

	Male Norms	C5-H	C5-B	Female Norms	C1	C2-S	C2-E	C4	C3
Castration Anxiety									
0	0.798	1.000	0.875	0.908	1.00	1.00	0.800	0.950	0.769
1	0.188		0.125	0.088			0.200		0.231
2	0.012			0.002				0.050	
3+	0.002			0.002					
Castration Wish									
0	0.910	0.900	0.625	0.922	0.895	0.857	0.867	0.950	0.846
1	0.086	0.100	0.375	0.076	0.105	0.143	0.133	0.050	0.077
2	0.002			0.002					0.077
3+	0.002								
Penis Envy									
0	0.950	1.000	1.000	0.974	1.00	1.00	0.933	0.950	0.846
1	0.048			0.026			0.067	0.050	0.154
2	0.002								
3+									

REFERENCES *

Bell, A. & Hall, C. *The personality of a child molester: A study of dreams.* Chicago: Aldine Atherton, 1971.

Berger, R., Olley, P., & Oswald, I. The EEG eye movements and dreams of the blind. *Quarterly Journal of Experimental Psychology*, 1962, 14, 183-6.

Blank, H. Dreams of the blind. *Psychoanalytic Quarterly*, 1958, 27, 158-74.

Hall, C. *The meaning of dreams.* (Rev. ed.) New York: McGraw-Hill, 1966.

Hall, C. & Domhoff, B. The dreams of Freud and Jung. *Psychology Today*, June 1968, 42-5.

Hall, C. & Lynd, R. *Dreams, life and literature: A study of Franz Kafka.* Chapel Hill: University of North Carolina Press, 1970.

Hall, C. & Nordby, V. *The individual and his dreams.* New York: New American Library, 1972.

Hall, C. & Van de Castle, R. *The content analysis of dreams.* New York: Appleton-Century-Crofts, 1966.

Heermann, G. Deotungen und betrachtungen uber die traume der blinden. *Monatschrift fur Medizing Augenbeikunde und Chirurgie*, 1838, 1, 116-80.

Jastrow, J. The dreams of the blind. *New Princeton Review*, 1888, 5, 19-34.

Kimmins, C. *Children's dreams.* London: Unwin, 1937.

Offenkrantz, W. & Wolpert, E. The detection of dreaming in a congenitally blind subject. *Journal of Nervous and Mental Disorders*, 1963, 136, 88-90.

Singer, G. & Streiner, B. Imaginative content in the dreams and fantasy play of blind and sighted children. *Perceptual and Motor Skills*, 1966, 22, 475-82.

Van de Castel, R. *The psychology of dreaming.* New York: General Learning Press, 1971.

Von Schumann, H. *Traume der blinden.* Basel: S. Karger Co., 1959.

*A most exhaustive bibliography on the dreamlife of the blind may be obtained from the library of the American Foundation for the Blind, 15 West 16th Street, New York, New York 10011.

ENERGY RADIATING MOBILITY AIDS FOR THE BLIND: DESIGN CONSIDERATIONS AND A PROGRESS REPORT ON AN EYEGLASS MOUNTED INFRARED AID*

Forrest M. Mims, III**

Part 1. Design Considerations for Ultrasonic and Electro-Optical Mobility Aids

INTRODUCTION

Though many of the technical and man-machine aspects of blind guidance devices have been clearly understood since at least 1949, early devices were too large and cumbersome to provide practical mobility assistance. Nevertheless, test results with early devices provided important experimental verification of the principles of active sonic and electro-optical aids. These encouraging results maintained interest in the field and permitted such technological innovations as semiconductor technology to be exploited in the development of more compact aids.

This report will review the operating principles of current mobility aids research with a view toward identifying the most desirable features of the various approaches. Such topics as sonic and electro-optical ranging, physical configuration, and the man-machine interface will be considered. The report will conclude with a detailed account of the development and preliminary results of an infrared mobility aid mounted in its entirety upon eyeglass frames.

* Preparation of this report was sponsored by a grant from the American Foundation for the Blind, Inc.

** 6901 Zuni S.E. A-12, Albuquerque, New Mexico 87108.

CURRENT MOBILITY AID RESEARCH

Both ultrasonic and electro-optical detection techniques have an active history in mobility aid development. Ultrasonic devices are particularly intriguing since a variety of animals utilize sonic and ultrasonic methods for navigation and object detection and avoidance. The use of sonic navigation techniques by blind travelers is, of course, well known.

Current mobility aids research is primarily centered around devices and concepts promulgated by Kay,[1] Russell,[2] Benjamin,[3] and Mims.[4] Kay and Russell have developed aids employing ultrasonics to detect targets. The operating techniques are similar, but Kay's device provides a complex information content while Russell's supplies a simple signal merely indicating the presence of a target within the detection range.

Culminating research begun in the early 1950's, Benjamin and his co-workers at Bionic Instruments, Inc. have developed a cane equipped with three miniature laser transmitters and receivers. The Laser Cane provides a detection capability for drop-offs, overhangs, and straight-ahead targets. Mims has also employed an infrared source, the light-emitting diode, in an aid which is mounted in its entirety upon eyeglass (spectacle) frames. This aid is described in detail later in this report.

The relative merits and demerits of these four mobility schemes, and several others, will be discussed at length in the body of this report. While this report is limited to *active aids*, those which project a beam of energy into free space and signal the presence of a target when sufficient energy is reflected back to a receiver, it is important to realize there exists extensive research into passive or nonradiating devices which may ultimately have a very distinct role in aiding mobility. Interest in passive devices has increased in recent years, particularly with improvements in semiconductor light detection techniques. Early passive sensors provided but one resolution element and an audible or tactile indication to indicate variable illumination levels at its active surface. Though some of the devices were quite ingenious in design and could even provide range indication, most have been abandoned.[5]

More success was had with a multiresolution element scheme developed by Starkiewicz and embodied in the Elektroftalm.[6] This device has 120 light sensors in a two-dimensional array behind an imaging lens. By activating the appropriate members of a 120-element tactile stimulator array worn on the forehead in response to visual stimuli, the Elektroftalm provides crude information about the shape of illuminated objects within its field of view.

The Elektroftalm concept has been expanded upon by Bliss and Bach-y-Rita. Bliss and Gardiner have developed a passive viewing system employing 144 sensors and stimulators.[7] At the University of the Pacific's Smith-Kettlewell Institute of Visual Sciences in San Francisco, Bach-y-Rita and Collins are developing a system employing 400 sensors and stimulators.[8] In it a solid state self-scanned detector array is utilized; a recent technological development giving the system an advantage over those developed by Starkiewicz and Bliss.

All these multiple-resolution element-passive systems incorporate tactile stimulation. A more radical approach has been undertaken by Brindley and Lewin who have implanted 80 electrodes in contact with the occipital lobe in the brain of a blind subject. Preliminary results have shown electrophosphenes can be created by activation of appropriate electrodes.

There can be no doubt that continued research into multiple-resolution element-passive sensors will play an important role in future mobility aids development. However, the problems which remain before a high-resolution passive system can become practical are immense. Recent reports in the lay press describing one of the sensory systems presently under development have created a false impression of the ease with which a high-resolution passive sensor can create a tactile image of an object. Pictures clearly showing the outline of a cup or telephone, for example, are misleading at best since they are generated by observing the object of interest at an angle which produces a readily recognizable silhouette. Since the device has a two-dimensional output, variations in the viewing angle of three-dimensional objects can make reliable identification difficult or even impossible. Passive sensory aids of this nature, sometimes referred to as *vision substitution systems*, are also troubled by a variety of technical problems. One of the most significant problems concerns variations in the illuminating light for objects being viewed; others include size, weight, and cost.

Though high-resolution passive environmental sensors are at an early level of development, the field bears close watching. These systems come closest to approximating the eye itself, and future developments may permit a close integration of electronic sensors and the brain's visual process.

ULTRASONIC AIDS

A variety of sonic mobility aids has been developed over the years, and the best known models are those contrived by Kay and Russell. Kay has developed both hand-held and head-mounted aids, while Russell's aid is suspended from the neck by a short strap. Kay has abandoned his early hand-held aid for a more sophisticated head-mounted unit. The acoustical sending and receiving transducers are mounted in a modified spectacle frame.

A pocket-carried package contains the unit's electronic circuitry, power switch, and batteries. A flexible cable connects the electronics package to the spectacles, and internally mounted earphones on either temple are coupled to both ears by plastic tubes.

Russell's aid is larger than Kay's, but the entire device is assembled in one package. The output is a pair of small speakers attached to the unit's neck strap. The speakers produce output signals with sufficient amplitude to be heard without ear tubes.

Both aids utilize ultrasonic sound, but their outputs to the blind user are quite different. Kay's aid presents complex tonal signals from which a properly trained user can gain information about the range and surface texture of a target. Russell's device contains limiting circuitry which processes the complex analog signals received by his device and converts them to one of two tones. A clicking sound indicates a target is within two meters of the user, and a second tone with higher pitch indicates a target is within a meter. In this report the former output technique will be classified as *analog* and the latter as *digital*.

The difference in output between the Kay and Russell devices is substantial, and a controversy has arisen over which approach is better suited to actual use with blind travelers. This matter will be treated later in this report.

Both the Kay and Russell aids have been used in tests with blind subjects with varying degrees of success. Kay's aid has probably been evaluated by more blind users than any other electronic mobility aid.[9] Evaluations by blind users, qualified engineers, and mobility trainers have resulted in an interesting set of observations concerning the use of ultrasound in an active mobility aid. There is virtually unanimous consensus, for example, that the relatively slow velocity of sound in air, 344 meters-per-second at 20 degrees Celsius, offers a significant advantage over electromagnetic mobility aids in providing range information.[10] The "round trip" times for a sound wave from a sonic mobility aid to targets one and four meters distant are 5.8 and 23.2 milliseconds respectively; traverse times easily resolved by straightforward electronic circuitry. Electromagnetic waves are propagated approximately 3×10^8 meters-per-second (3 nanoseconds-per-meter). It is exceedingly difficult to design simple, inexpensive electronic circuitry to resolve such rapid time intervals and convert them into a recognizable tactile or audio output.

The slow transit time of ultrasonic systems offers the option of either analog or digital output to the blind user. In fact, it is possible to design one system which provides a choice between the two outputs, thus providing the advantages of each.

While sound's slow transit time enhances simple time-of-flight ranging schemes, the propagated wave is subject to the fluctuations of the transmission medium. Calm air merely absorbs the sound wave, but a turbulent atmosphere can cause significant refraction of a sonic beam with resultant inconsistencies in target detection.[11] Atmospheric turbulence results from convection currents and thermal variations and typical sources include wind, hot pavement, fans, and heaters.

Of even more significance, the relatively long wavelength of a typical ultrasonic aid, 2.5 to 5 mm in the case of Kay's swept-frequency device, causes many targets to appear as specular reflectors. In the visual sense, a specular reflector is a shiny surface which reflects an oncoming beam at the angle of incidence while a diffuse surface scatters the oncoming beam in a distribution approximating pi (*not* 2pi) steradians. At optical wavelengths a typical specular reflector is polished metal, while a typical diffuse reflector is ordinary paper. Many targets have both specular and diffuse reflectance characteristics.

The specularity of a surface is determined by the wavelength of the oncoming beam and the texture of the surface. If the variations in texture are large in relation to the oncoming beam's wavelength, the surface will tend to scatter the radiation in a diffuse fashion. If the variations are small or nonexistent, the surface will tend to reflect the radiation specularly at the angle of incidence.

Specular targets can be difficult to detect with narrow-beam active mobility aids since the oncoming beam will be reflected away from the aid's receiver unless the target is viewed from the normal angle. Since ultrasonic aids tend to have a very wide beam, most specular targets reflect some energy back to the receiver.

Certain nonspecular surfaces are difficult to detect with an ultrasonic mobility aid. High absorption surfaces, particularly those which have sufficient porosity to trap incoming ultrasonic waves, may return little energy to the transmitter. Clothing and draperies can be particularly difficult to detect.

Still another reflectance artifact at ultrasonic wavelengths is echo reinforcement. When an ultrasonic beam is directed into the corner of a room, the waves are retroreflected back to the receiver. The resulting effect causes the corner to give a stronger return than the adjacent walls. Some users of ultrasonic aids have reported this phenomenon assists orientation within a room.

Ultrasonic systems are not immune to ambient interference. Swept frequency devices must be sensitive to a wide range of wavelengths, and, therefore, they will detect such sources of ultrasonics as rustling leaves and vibrating fluorescent lamps.

Finally, by their very nature there is a practical limit to which ultrasonic aids can be miniaturized. Kay's Sonic Spectacles represent the smallest ultrasonic aid yet developed, but the device requires a separate pocket-carried electronics package. More sophisticated electronic circuitry might reduce the size of even Kay's aid, but the volume required by the three sending and receiving transducers will remain a limiting factor.

ELECTRO-OPTICAL AIDS

Electro-optical mobility aids suffer a serious drawback from the outset in that the rapid transit time of the emitted beam makes time-of-flight ranging impractical. However, electro-optical aids permit operation in a pulsed mode with a significant reduction in power consumption. Pulsed operation also permits very high peak powers, up to 15 or more watts in the case of diode laser sources, and improved signal-to-noise ratio. Triangulation techniques can be used to obtain approximate range information.[12,13]

Just as ultrasonic aids are sometimes susceptible to ambient sources of ultrasonics, electro-optical aids are sometimes affected by ambient light sources. Artificial light sources powered by alternating current can produce 60- or 120-Hz output signals and bright continuous sources such as the sun or its reflections can reduce sensitivity of the receiver's detector. Fortunately there are methods to eliminate these kinds of interference. Tuned circuitry or gating the receiver to the transmitter will eliminate modulated interfering sources, while optical filters can reduce the effects of strong continuous sources.

A particularly important feature of electro-optical aids is the ability to vary the transmitted beam divergence with a simple, adjustable lens assembly. A narrow beam provides higher power density at small targets and increases azimuthal resolution, while a large beam increases the chance of illuminating small targets. Some persons may prefer one configuration over the other, and this is easily accomplished with a simple lens adjustment.

The small size of conventional electro-optical sources makes miniaturization practical. Indeed, there are plans which will be described later in this report to fabricate an entire aid inside the frames of modified spectacles much like an eyeglass hearing aid. The complete aid, including batteries, will weigh approximately 100 grams, and will be entirely self-contained.

LASERS VS. LEDS

Through the years a variety of light sources has been employed in experimental electro-optical mobility aids. Incandescent lamps, gas-filled glow-discharge tubes, and strobe lamps have been used with only moderate success.[14] Target detection was achieved, but these sources were hindered by large power consumption or low power output.

In 1962 efficient semiconductor near-infrared emitters were developed, and shortly thereafter these same kinds of emitters permitted the fabrication of tiny semiconductor lasers. In the intervening years development of energy radiating electro-optical mobility aids has centered around semiconductor light sources. The two contenders are light emitting diodes (LEDs) and semiconductor injection lasers. While the latter is merely a specialized configuration of the former, the two sources each have unique characteristics and operating requirements.

A typical LED consists of a slab of gallium arsenide (GaAs) a millimeter or less square. A P-N junction formed in the GaAs in the origin of recombination radiation, as electrons stimulated to higher-than-normal energy levels by a flow of current in the forward direction resume equilibrium by dropping back to their ground state. In GaAs the wavelength of emission is typically centered at 905 nanometers, but the addition of silicon as a compensating dopant increases this figure to 950 nanometers with a substantial increase in power efficiency. Noncompensated diodes have rise times of approximately a nanosecond, while that of silicon-doped diodes is typically 300 times greater, but the latter devices may deliver five or more times the output power for the same forward current.

For most practical purposes the wavelengths emitted by these devices are invisible to the unaided human eye. However, the radiation from GaAs lasers at 905 nm *is* visible as a dim red when the source is viewed directly in subdued ambient light. Gardiner has prepared an interesting report on the visibility of wavelengths beyond the C.I.E. absolute photopic luminosity curve.[15]

The semiconductor injection laser is an LED prepared with two end mirrors to provide the resonant cavity prerequisite to laser action. GaAs has both a high index of refraction (about 3.5) and parallel cleavage zones. If the junction is formed perpendicular to the parallel cleavage zones, it is a relatively simple procedure to create two parallel end mirrors by scribing and breaking the crystal. The high index of refraction gives a reflectance of about 30 percent and this is generally increased to nearly 100 percent on one facet by an evaporated film of gold over an insulating layer of silicon dioxide.

LEDs emit light from all portions of the semiconductor not blocked by electrodes, but the diode laser emits nearly all its radiation from one or both end mirrors. This permits high collection efficiency since a simple f/1 lens can be used to intercept all of the radiation and collimate it into a beam of desired divergence.

LASERS

The relative advantages and disadvantages of LEDs and diode lasers in a mobility aid application are diverse and are discussed in great detail elsewhere.[16,17,18] It is important to note that both sources have been used with varying degrees of success, but electronic and optical considerations are unique for each.

Both the LED and injection laser have a high power conversion efficiency (a few percent or more). Certain specially structured LEDs have about twice the efficiency of injection lasers. These diodes, however, are costly and in a mobility aid application injection lasers generally offer higher power-conversion efficiency. Consider, for example, a typical commercial injection laser capable of delivering 4.5 watts when driven with a 10-ampere pulse, and an efficient and inexpensive LED capable of delivering 6 milliwatts at 100 milliamperes bias. Representative commercial devices with these specifications are, respectively, the RCA SG2002 laser and the General Electric SSL-55C LED.

When driven with a 10-ampere pulse, the LED will deliver about 240 milliwatts, only about 5.3 percent of the 4.5 watts emitted by the laser for the same peak forward current. Equally significant, the LED's power conversion efficiency has dropped from about 5 percent at 100 milliamperes forward bias to only 1.7 percent at 10 amperes. The power conversion efficiency of the laser is an impressive 5.6 percent.

In addition to high peak power and conversion efficiency, the infrared emerging from an injection laser is far easier to collimate than that from an LED. This is because the injection laser emission is directional and emerges from a region on the laser chip only about 0.002 mm x 0.076 mm. Radiation emerging from a source this small can easily be collimated into nearly parallel light with a very small f/1 lens. The Laser Cane developed by Bionic Instruments produces a spot only about 2 cm wide at a range of 3 meters. Even this small divergence can be reduced substantially, and the author has produced a spot only 1 mm wide at 3 meters with an optical system virtually identical with that employed in the Laser Cane. Total dimensions of the spot at 15.25 meters were 5 mm x 120 mm which corresponds to a divergence of only 0.33 mr x 7.87 mr.

The injection laser's small spot size is certainly an impressive characteristic. Indeed, Benjamin has indicated the most important aspect of the injection laser in the Laser Cane is its small size and consequently the small optical system.[19]

Depending on the mechanical structure of the LED, the lens which produces a highly collimated beam for an injection laser gives a minimum divergence of about 3 degrees when used with an LED. Spot size in the far field is consequently larger, and power density on small cross section targets low. At a typical target range of, say, two meters, an injection laser system with a nominal divergence of 10 milliradians will easily cast all of its radiation on a target such as a small diameter twig. This greatly enhances the prospect of the twig being detected by the system. Indeed, an experimental hand-held injection laser aid developed by the author will easily detect a twig only 4 mm in diameter at a range of more than 3 meters. With its comparatively large divergence, however, only a small fraction of radiation from a LED system will illuminate the twig. Combined with the lower power output of the LED, this significantly reduces the chances for detecting the twig at a range of more than 1.5 meters.

These detection considerations must be tempered with the realization that a small-divergence illuminating beam may not even strike the twig. A beam with more divergence offers more opportunity of illuminating the twig and at least presents the prospect of an output signal. The trade-off, then, is that a narrow-beam system will give a stronger return from a small target than a system with large divergence, but there is more likelihood of illuminating the target with the larger beam.

Thus far the laser appears to be a superior radiation source in an electro-optical mobility aid. However, its driving requirements lessen its overall advantages. To fulfill the requirement for sustained laser oscillations, an inversion in the population of stimulated electrons, the injection laser must be pulsed with current levels as high as 100,000 amperes/cm^2. Recently low-threshold double-heterostructure devices have been produced which have reduced required driving current to only a few thousand amperes per cm^2, but these devices have confirmed operating lifetimes of only a few hundred hours when operated at a repetition rate of about 1 kHz. Practical operational current densities for good quality single-heterostructure injection lasers range from 40,000 to 50,000 A/cm^2. In short, to achieve the population inversion prerequisite to laser action, very high current densities must be present in the semiconductor junction.[20]

To reduce the current to practical levels of from about 10 to 100 amperes, injection lasers are made quite small. The RCA SG2002 described above, for example, has a junction area of only 0.076 mm x 0.305 mm. This reduces the required current to about 10 amperes, but the tiny volume of the laser cannot sink this current, if applied continuously, without being destroyed by thermal action. For this reason conventional non-double heterostructure injection lasers must be operated at pulse widths of typically no more than 200 nanoseconds. To avoid a gradual pulse to pulse thermal accumulation, duty cycle (total "on" time) must not exceed 0.1 percent.

When applied to the operating considerations of a mobility aid, these driving requirements mean great care must be exercised in the design of the injection laser driving circuitry. For most practical considerations two options are available to obtain the necessary high current and fast-pulse width.[21] One is to switch a high voltage through a controlled semiconductor switch such as a silicon controlled rectifier (SCR). The other is to switch a voltage through an avalanche semiconductor switch such as a selected transistor or four-layer diode. In both cases the voltage is stored in a small capacitor until being discharged through the semiconductor switch and laser.

The SCR technique has the advantage of simple design and operation, but typical SCRs present a relatively high impedance to the very fast pulse required to operate a laser. For this reason several hundred volts are required to obtain the 20 or 30 amperes required to drive conventional single-heterostructure lasers.

Avalanche transistor circuits can be designed which produce similar current levels for significantly smaller voltage levels. This is because avalanche transistors possess a much lower impedance at fast-pulse widths. In a comparison of practical SCR and avalanche transistor driving circuits conducted by the author, typical SCRs possessed an impedance of nearly 5 ohms for a 75-nanosecond pulse. Typical avalanche transistor impedance was only a third this value.

Obviously, diode laser pulsers require a careful study of trade-offs before selection of a final circuit. Even with great care in circuit design a laser circuit will consume more power than a similar LED circuit.

Injection lasers present other special problems in the design of a mobility aid. For example, the fast pulse width of an injection laser imposes special design requirements on the receiver, and for most practical mobility aid considerations only reverse-biased PIN photodiodes coupled into a wide-band amplifier make for a practical receiver combination.[22] Also, conventional lasers have a limited lifetime, and their degradation is a continual and irreversible phenomenon. Good quality single-heterostructure lasers have demonstrated improved lifetimes, and a study by RCA has shown lasers operated at 1 kHz possess 80 percent of their original output after 1,000 hours operation.[23]

Other disadvantages of injection lasers include temperature sensitivity and beam diffraction patterns. Narrow-beam laser mobility aids will not be troubled by the latter phenomenon, but wide-beam laser systems generally exhibit highly irregular power distribution in the emitted beam. Infrared photographs vividly demonstrate this phenomenon.[24] This may mean targets with small optical cross section will be alternately detected and missed as they are scanned by an aid. Temperature sensitivity is more serious since it directly effects the output of the laser and possibly its degradation rate. Typical injection lasers exhibit significantly lowered current threshold values as temperature drops. Therefore, a system designed to operate a laser at or close to its maximum current level to achieve maximum power output will fail if the laser's temperature is allowed to drop to an extent which causes its maximum permissible driving current level to fall below that delivered by the driving circuit. Depending on the temperature change, the laser may be degraded or even destroyed. In a typical system in which the laser is operated at its maximum current rating, a drop in temperature of only 10 degrees F causes laser failure.[25]

Temperature regulation can be employed to protect the laser, but a simpler procedure is to limit peak current to a safe value for a specified temperature range. The laser simply would not be operated when ambient temperatures exceeded the allowable range.

Other potential difficulties with injection laser mobility aids include electromagnetic pulse (EMP) effects and safety. The EMP phenomenon results from the very fast, high-current discharges required to drive a laser. EMP can cause substantial interference in nearby electromagnetic receivers such as radios and sensitive aircraft navigation equipment. Fortunately the effects are generally minor. In a test, conducted by the author, an injection laser system produced no discernible interference in an AM radio receiver so long as the two were separated by at least 75 cm.

Safety is a less precise area. The high voltage (i.e., several hundred volts) which may be necessary to operate some laser mobility aids poses a potential hazard, but only if the aid's protective housing is opened. Of more concern is the potential ocular hazard to persons within the laser's field of view. That a sensory aid for the blind may have the potential of harming the eyesight of normally sighted persons is, to say the least, ironic.

At the outset of any discussion on laser ocular safety, it is essential to note that the field is controversial. The laser cane has been independently evaluated for safety by five separate institutions. The evaluations included exposure tests with laboratory primates, and no discernible retinal deterioration was noted. These tests were conducted under worst-case conditions with the animals being exposed in one instance for 20 seconds, and in another for 30 minutes,[26] both far longer than the likely exposure times for a person whose eye or eyes happen to momentarily fall within one of the cane's three beams.

Nevertheless, recent reports in the literature indicate laser damage threshold levels may be far lower than previously expected. For this reason and others, the Bureau of Radiological Health of the Department of Health, Education, and Welfare has proposed stringent safety guidelines for most laser products manufactured, sold, and operated in the United States.[27] Optical radar systems are not included in the present standards, but Wilbur F. Van Pelt of the Bureau's Electronic Product Division's Electro-Optics Branch recently stated safety requirements for laser ranging systems will be implemented should their use "become well defined and pose a significant hazard to the general population."[28]

This is not the place for a detailed discussion on the implications of potential injection laser hazards and government regulations. It is likely, however, that the new government regulations will expand the current controversy. A collection of detailed discussions on laser safety, and numerous references, are presented elsewhere.[29,30]

LED

Though the injection laser is superior to the LED in power output and ease of beam collimation, the laser's driving requirements pose a significant drawback. The LED becomes a viable alternative optical source for this reason.

A LED can deliver 100 milliwatts from a 3-ampere current pulse. This represents only about 2.2 percent of the RCA SG2002 laser's peak power, but the LED pulse can be significantly wider than the laser's. A 5-microsecond pulse is far easier to detect and amplify than one only 100 nanoseconds wide.

Of even more significance is the simplicity and compact size of the circuitry required to generate 3-ampere pulses for an LED. A simple regenerative amplifier with but four components and powered by a miniature 9-volt battery will easily fulfill the pulse requirements.[31]

LEDs possess other advantages over injection lasers. They are very economical, a great variety of commercial devices are readily available, and operating lifetimes are orders of magnitude greater than those of injection lasers.

This discussion on the relative merits of injection lasers and LEDs is summarized in Table 1. A careful study of these considerations and both analytical and experimental studies have convinced the author that the LED can be used in a practical mobility aid. While the laser is definitely a practical source, as amply demonstrated by the laser cane and a variety of experimental laser mobility aids assembled by the author, the LED permits very low power consumption and a degree of miniaturization not realizable with any other source.

TABLE 1

Lasers vs. Light Emitting Diodes (LEDs)

Characteristic	Laser	LED
Peak Power	100 W	300 mW
Average Power	15 mW	250 mW
Power Efficiency	6%	10%
Maximum Duty Cycle	0.1%	100%
Rise Time	1-50 ns	1-300 ns
Beam Divergence	20°	10-180°
Spectral Width	3.5 nm	40 nm

Note: These characteristics are representative and may vary significantly.

PHYSICAL CONSIDERATIONS FOR MOBILITY AIDS

Most developers of mobility aids regard the joint goals of small size and light weight as essential to their development effort. Early aids (ca. 1950) frequently weighed more than five pounds and were rather large, even cumbersome, but modern semiconductor technology has made possible considerable reductions in size and weight.

A pleasant cosmetic appearance has also been a design goal, though some blind persons have stated a preference for an easily recognizable device to assist, like the white cane, in identifying the visual deficiency of its operator.[32] In past years engineers frequently were forced to ignore cosmetic considerations just to permit demonstration of a working aid. As a result some devices were quite elaborate in appearance and required the user to manipulate a variety of contrivances for mobility cues with at best questionable value.

Physical considerations divide mobility aids into two broad categories: those which are hand carried and those which are body mounted. Though hand carried aids have a long history, at present only one hand-held aid, the laser cane, is being experimented with actively. The laser cane is itself distinct from previous hand-held aids, since most of these devices have been box-like contrivances. Some of them were found to provide important supplemental information when used in conjunction with a cane or guide dog, but none were capable of providing safe and reliable guidance alone. Consequently, the blind traveler was required to give up both his hands to carry his cane (or guide dog harness) and the mobility aid.

Body-mounted aids have long been suggested as a more practical physical scheme, and Russell's Travel Path Sounder exemplifies such a configuration. The aid is conveniently suspended from the neck by a short strap, much like a camera. An even more flexible approach to body-mounted aids would be exemplified by those worn on the head. This class of aids is becoming so important that a separate discussion of them is warranted.

HEAD-MOUNTED MOBILITY AIDS

Kay,[33] Bishop,[34] del Campo,[35] Starkiewicz,[6] Chardon,[36] Benjamin,[37] Bach-y-Rita,[8] Mims,[4] and others have independently suggested or devised head-mounted mobility aids. Kay was one of the first to achieve a practical embodiment of this one time elusive goal. His device, which is described elsewhere in this report, takes the form of modified spectacles which contain three ultrasonic and two audible transducers. A pocket-carried electronics and battery package is connected to the spectacles with a flexible multicore cable.

Bishop has proposed a simple passive system consisting of a photocell with an aperture to limit its field of view. He has suggested that two of these sensors together with batteries and output devices could be mounted on modified eyeglass frames.

Mims has proposed both infrared LED and injection laser aids mounted entirely to spectacle frames and has fabricated several working models. This approach will be described at length later in this report.

Benjamin has proposed a two-beam laser mobility aid housed entirely in eyeglass frames. One beam would look straight outward while the other would look down.

Bach-y-Rita and Collins are developing a Vision Substitution System similar to that developed by Starkiewicz. Collins' system is more advanced in that it contains 400 resolution elements and makes use of a recent development in semiconductor technology, a self-scanned detector array. The array, in essence a true solid state television camera, is attached together with an imaging lens to conventional spectacle frames. The electronic processing circuitry and an array of tactile stimulators are worn or mounted elsewhere on the body.

Del Campo has developed an experimental passive system mounted in a swimmer's face mask. The device, called the Amauroscope, transmits visual information to five electrodes on the scalp.

The obvious conclusion from this movement toward head-mounted aids is that the head offers a useful mobility aid platform. Both tactile and audio output techniques can be employed and, of course, the head has freedom of movement. In effect, mounting at least the detection system of a mobility aid on the head gives the blind user the potential of a pointing and tracking ability in some ways reminiscent of that possessed by normally sighted persons.

The ideal head-mounted aid would be self-contained to avoid cables or wires leading to electronics and battery packages carried elsewhere on the body. Thus far only the active electro-optical aids devised by Mims have been totally self-contained, but it is possible that improvements in design could lead to a self-contained ultrasonic aid. Kay's device comes closest to this goal, but the electronics package for his Sonic Spectacles contains a good deal of circuitry as well as the system's battery.

THE MAN-MACHINE INTERFACE

Over the years the two primary output mechanisms for mobility aids have remained tactile and audible transducers. Indeed, some aids have used both (i.e., the laser cane).

Tactile stimulation has the obvious advantage of providing an interface to the blind user without blocking useful acoustical cues. Tactile transducers, however, are frequently difficult to maintain, and their power consumption is greater than audible devices.

The primary advantages of an audible interface are improved information bandwidth, simplicity, and low power requirement. Unfortunately audible output techniques can block part or even all of the user's acoustical cues. Blockage can be in the form of earphones, inserts, tubes which physically obstruct all or part of one or both auditory canals, or constant auditory outputs from the aid which mask ambient acoustical cues.

Of course one cannot automatically assume that blockage of ambient acoustical cues by any or all of these methods is automatically unfavorable. The benefits to be gained from the aid which initiates the blockage must first be assessed. Results from tests with blind users, however, tend to confirm the overriding importance of ambient acoustical cues.

Perhaps a more important man-machine interface consideration, and certainly a more controversial one, is the quantity of information transmitted from the mobility aid to the blind user. In the area of active mobility aids, current researchers are divided into two camps: those advocating a relatively high information transfer and those supporting a simpler digital or "go no-go" indication. The relative merits of the two cases can be conveniently compared with a consideration of Kay's Sonic Spectacles and Russell's Travel Path Sounder. Both of these aids are ultrasonic devices with audible output. Kay's aid employs a swept frequency system which provides abundant information about the environment in a binaural output. While interpreting the output signals can be difficult, information regarding target surface texture, range, and general outline is present in the output signal. Range is indicated by the pitch of the audible output, with the frequency decreasing with range. Surface texture is indicated by subtle variations in the output. For example, hard surfaces give a "strong" signal, while porous targets such as draperies give a "fuzzy" signal.

Russell's aid presents far less information to the blind user. Range is indicated by one of two single frequency tones. The first tone is a clicking sound heard when a target is from 76 to 178 cm distant. The amplitude of the clicks increases as the target advances from the outer to inner limit and abruptly becomes a 800-Hz tone as the 76-cm zone is broached.

Though both Kay's and Russell's aids are similar in operating principle, each has a unique information output. Either aid could be adapted to supply the output of the other, but in each case the designer has settled upon what in his view constitutes the most promising output scheme.

Kay has presented intriguing arguments for the acceptance of schemes which supply detailed information to the blind traveler.[38] He has studied the principles of ultrasonic navigation employed by the bat and has concluded that a high-information content supplied in a binaural format will eventually permit properly trained persons to acquire a spatial sense of what lies before them.

Russell takes an opposing viewpoint.[39] He notes that his device receives a complex set of information about the environment within its field of view, but that the device is designed to process this data for the blind person. He notes this approach fails to provide subtle cues about the texture of a target, but questions the value of such information. Referring to the simple two-tone output of his aid as a language system, Russell convincingly argues that his approach saves the blind user from sometimes difficult concentration during the target detection process.

The analog versus digital controversy is not new. Thirty-four years ago Dr. Edward A. Jerome, a psychologist with the Naval Medical Research Institute, noted that an early active electro-optical aid provided an indication of target reflectance by means of amplitude variations in the output tone. He subsequently observed, "It is clearly understood that this responsiveness to reflectivity may give rise to some interesting observations, but it is the deep conviction of the present writer that only the space-occupying characteristics of objects are of importance for the practical travel problem."[40]

Other workers have also noted the relative merits and demerits of analog and digital systems. Chardon summed up the problem nicely when he noted, "Since it is impossible to provide the blind person with all the information in the environment, we must content ourselves with giving him that information which is of vital importance. This means, first of all, giving information about obstacles in his path."[41]

Kay disagrees with those who favor digital output techniques and takes the view that the analog output scheme is more progressive. "There have been many pockets of resistance to this concept, among them several scientific colleagues," he recently wrote. "Even now some keep insisting that a blind person requires only a simple display which is easily learned."[42]

DISCUSSION

These discussions of optical and ultrasonic techniques, physical configuration, and the man-machine interface are necessarily incomplete, but they do illustrate the wide range of possibilities in the design of active mobility aids. They also point out several unsettled and even controversial areas in present design and operational philosophy.

Though a variety of approaches toward the design of mobility aids appears at least potentially practical, there is no overriding need to wait until any particular concept appears superior to the others before widespread testing and even serial production can be initiated. On the contrary, a view expressed by several workers is that no one approach will prove a panacea for all persons desiring an electronic aid to supplement their normal mobility method. While one person may prefer the rich information content of an ultrasonic aid, another may prefer a simpler go no-go indication.

With these thoughts in mind, I shall now proceed to describe my own approach to devising a mobility aid. The design philosophy embodied in the present device, an electro-optical aid mounted on eyeglass frames, is in large part the result of a careful study of the technical considerations presented thus far.

Part 2. An Eyeglass-Mounted Active Infrared Mobility Aid

INTRODUCTION

The author has constructed a variety of active infrared mobility aids since 1966.[4,31,43,44,45] While at least some of the engineering considerations discussed herein were applied to the design of these aids, the man-machine considerations evolved more slowly and after tests with blind subjects.

The first aid was housed in a plastic case measuring 2.6 cm x 2.6 cm x 9.5 cm, and with batteries weighed approximately 100 grams. The aid, which is shown in Fig. 1 during a test session with a totally blind student, employed a beam of pulsed near-infrared from a light emitting diode (LED) to detect targets. The LED was driven by a simple transistorized regenerative amplifier. Some of the infrared striking a target was reflected back toward a sensitive detector on the aid. The detector, a silicon solar cell operated in the unbiased photovoltaic mode, generated a signal proportional to the infrared received from the target. This signal was amplified by a discrete transistor circuit and passed directly to a magnetic earphone.

The output signals from this first crude aid were of limited value. There was no direct ranging information, and the amplitude of the single frequency tone varied as a function of range and target reflectance. This amplitude variation permitted several interesting capabilities. For example, it was a simple matter to locate the position of a door knob on a door by means of the higher amplitude signal provided by the former. But it was not possible to determine the range to the door or, in fact, to be sure the signal thought to be from the knob was not from an object between the door and the aid.

These significant drawbacks notwithstanding, the aid was tested with a large population of blind children and adults with encouraging results. Tests were conducted with blind adults in several cities in the

Figure 1. Miniature hand-held infrared mobility aid; a nonranging aid weighing 100 grams, limited to the role of obstacle avoidance when used with a cane or guide dog.

United States, and students at the Texas State School for the Blind, the Ecole des Garcons Aveugles in Saigon, Republic of Viet-Nam, and the Saigon School for Blind Girls.

In the limited role of an obstacle avoidance device, this aid permitted blind children to navigate their way through mazes of desks, chairs, and other potential obstacles with generally good success. In contrast to aids which supply a more complex output signal, learning time, particularly for children, was short. In a typical case a student would be given the aid, instructed on its operating principles for a few minutes, and assigned a maze task. Manual scanning was readily mastered and the children would invariably complete the assigned task with few, if any, collisions.

The experiment with blind students in Viet-Nam, an informal study involving approximately 30 pupils, was particularly encouraging in view of the dual barriers of language and lack of technical sophistication. A Vietnamese assistant devised a descriptive name for the aid, *May do tieng dong cho nguoi mu di* (literally, machine which makes sound for the blind people to go), which simplified explanation of the device by the experimenter to the pupils and pupils to one another.

These early tests demonstrated that an active infrared mobility aid employing a light emitting diode can detect most targets within a 3-meter range. The tests also demonstrated a convincing need for the provision of at least some range information. Accordingly, a second aid was designed employing an adjustable triangulation base.

The aid shown in Fig. 2, measured 3 cm x 5.5 cm x 8 cm and with batteries weighed approximately 140 grams. The LED was mounted in a lens tube assembly connected to a spring and plunger. Normally the LED lens assembly was parallel to a similar lens assembly housing a phototransistor detector. Depressing the plunger, however, rotated the LED tube and varied the intersection region of the transmitted beam and the receiver field of view. Since the signal from a target would reach an amplitude peak at some point during the rotation of

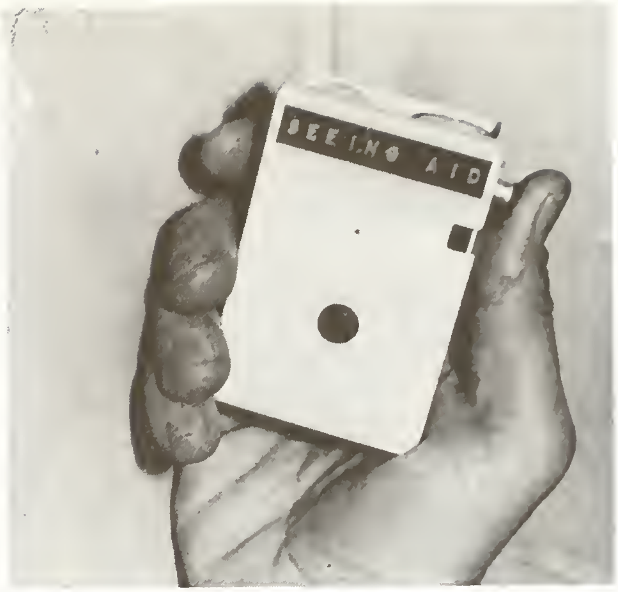


Figure 2. Compact infrared mobility aid with adjustable triangulation ranging feature. Thumb operated plunger controls intersection of transmitted beam and receiver field of view.

the LED assembly, an approximation of target range could be deduced from the position of the plunger. For example, a signal peak which occurred at the midpoint in the plunger's up-down cycle indicated a target approximately 1.5 meters distant.

DESIGN CONSIDERATIONS FOR AN EYEGLASS-MOUNTED AID

While this aid provided substantially more information than the preceding unit, tests with blind subjects revealed that both the requirement for hand-held operation and the earphone cord restricted its practicality. Therefore, still another aid was designed. This new aid was to incorporate two LED transmitters, each pulsed at a different repetition rate, and a single receiver. The aid would be mounted on conventional eyeglass frames and would be entirely self-contained. The output signal would be an audible tone heard in one ear via a thin plastic tube designed to block only part of the external auditory canal.

Triangulation would supply range information. The two LED beams would intersect the receiver field of view at ranges of respectively 1 and 3 meters. The beams would be sufficiently divergent to overlap one another at about 2 meters. As a target was approached, then, the first signal would be the tone from the first LED, the second signal a mixture of the tones from both LEDs, and the third signal the tone from the second LED.

This aid was intended to supplement the mobility cane or guide dog. In this role it would primarily detect targets at shoulder level and above, though slight head movements would permit wider coverage. The go/no-go output of the aid combined with the relatively narrow detection cone would prevent output signals, even in a crowded environment, unless a target was being detected.

To test the improved circuitry and go/no-go output of the proposed eyeglass aid, a single-beam prototype was assembled in a small hand-held housing with a rotating lens tube for the LED. An engineering evaluation of the device and tests against a wide variety of targets were encouraging.

To evaluate the prospects of mounting the proposed aid to eyeglass frames, and to test the man-machine considerations of a head-mounted digital output device, three single-beam prototypes have been assembled and used in both engineering evaluation and preliminary tests by qualified mobility trainers and blind subjects.

OPTICAL RADAR RANGE EQUATIONS

Optical radar range equations were employed in the design of the prototype eyeglass mobility aid.[44] The equations account for factors such as target variations (diffuse or specular nature of target, reflectance, and size of target with respect to the cross section of the transmitted beam), collection area of the receiver optics, transmitter output power, and receiver sensitivity.

Most objects to be detected by the travel aid are diffuse reflectors. The maximum detection range of an optical radar whose beam is completely intercepted by a diffusely reflecting object is expressed as

$$R_m = \sqrt{\frac{P_o A_r \rho \tau}{P_{th} \pi}} \qquad (1)$$

where P_o is the peak power of the transmitter, A_r is the area of the receiver optics, ρ is the reflectance of the target, τ is the transmissivity of the collection optics, and P_{th} is the receiver threshold power.

Some objects to be detected by the aid have a cross section smaller than that of the transmitted beam. Common examples of these objects include small tree branches, narrow poles, and wires. The maximum detection range for such an object which diffusely reflects the transmitted beam is expressed as

$$R_m = \sqrt[4]{\frac{P_o A_r A_t \rho \tau}{P_{th} \pi \Omega}} \qquad (2)$$

where A_t is the illuminated area of the object and Ω is the divergence of the transmitted beam.

The ratio of power output to power threshold is an important factor in both equations. By inserting appropriate values into Eq. (1), for example, it can be shown that a detection range of one meter against an object with a ρ of 0.05 when a 12 mm receiver lens is employed requires a P_o/P_{th} of about 7×10^5.

OPTOELECTRONIC CIRCUITRY

Figure 3 is a block diagram showing the circuitry of a prototype eyeglass-mounted aid. Design of the prototype aid involved choice of an efficient near-infrared emitter, design of a high-gain receiver relatively free from effects of ambient light, and optical considerations. The design possibilities were limited by strict requirements of compact size, economy, and low power consumption.

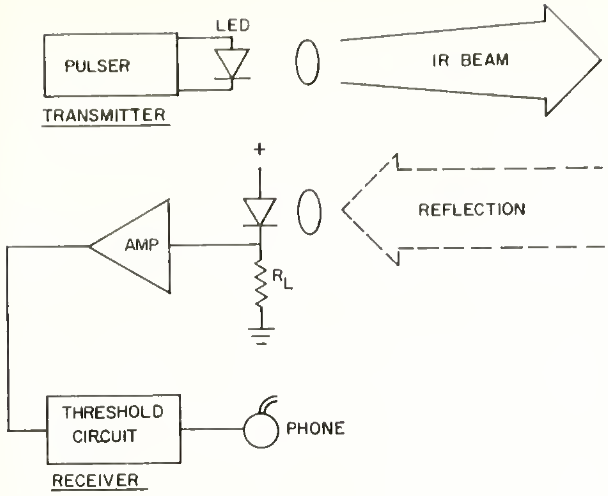


Figure 3. Block diagram for a single-beam, nonranging eyeglass-mounted mobility aid.

TRANSMITTER

Several commercially available light emitting diodes (LEDs) were considered as an infrared source, and an economical unit with a miniature built-in reflector was selected for its high power and optical efficiency. The silicon compensated GaAs LED is driven with 2.7-amp current pulses and emits 53.8 mW as measured with a calibrated silicon solar cell. The 20-μsec pulses are delivered at a rate of 130 Hz by a simple two-transistor modulator. A detailed description of the transmitter circuitry, power measurement techniques, and other factors affecting LED operation is given elsewhere.[31,45]

Some of the flux from the LED is collected by a 12-mm f/1.2 lens and collimated into a beam whose central component can be adjusted to a minimum of 70 milliradians. When adjusted to 130 mR (7.5°) the central beam contains 10.5 mW of the 53.8 mW emitted by the LED; 32.1 mW of the loss is due to radiation not reaching the lens and lens losses. The remaining 11.2 mW is contained in a diverging halo surrounding the primary beam and having a half angle of 1 radian. The halo originates from reflections within the LED mounting package.

RECEIVER

The receiver consists of a silicon PiN photodiode, a high-gain integrated amplifier, a threshold circuit, and an audio transducer. A wide variety of photodetectors is available, some with more sensitivity than the type used here. However, the PiN diode's linearity significantly reduces the saturation effects of ambient illumination and permits the receiver to operate in bright sunlight without an optical filter.

In operation the photodiode signal is amplified approximately 80 dB by the integrated amplifier and passed on to a monostable multivibrator threshold circuit. When the amplified signal exceeds a preset, adjustable threshold value set to be above the noise level (typically 0.15 volts), the multivibrator issues a stretched output pulse. The pulse is converted to an audible signal by a subminiature receiver identical to those employed in eyeglass hearing aids.

The combined voltage gain of the amplifier and threshold circuits is about 110 dB. With the threshold circuit adjusted for a signal-to-noise ratio of 2.5 (bright sunlight conditions), the receiver will detect a minimum signal of 12 nanowatts, and when the ambient light is subdued the receiver can be set to detect 6 nW.

PACKAGING

The transmitter and receiver are each housed in 13 mm x 90 mm brass tubes. Each housing includes two internal acrylic bulkheads for centering the LED and photodiode and holding the circuit boards in place. The bulkheads also serve as battery retainers and eyeglass mounting fixtures.

The receiver circuitry is more complex than the transmitter's and two circuit boards, both of which are shown in Fig. 4, are required. The receiver's audible transducer is mounted to the battery retainer bulkhead. Output to the ear is provided

Figure 4. Receiver circuit boards for the prototype eyeglass-mounted mobility aid. At left is the high-gain integrated amplifier; at right the monostable multivibrator threshold discriminator.

by a removable plastic tube inserted through the housing and into a receptacle in the bulkhead. The transmitter and receiver, including optics, electronics, battery, housing, and switch assembly, weigh about 38 grams each. The transmitter and receiver have a tested battery life of 32 and 62 hours respectively. By way of comparison, both the laser cane and the sonic glasses operate only 4 hours before requiring recharging of their batteries. Operating cost is approximately 7.5¢ per hour. Fig. 5 is an internal view of a prototype aid. Fig. 6 is a view of an assembled prototype on eyeglass frames.

Figure 5. Disassembled view of the prototype eyeglass-mounted infrared mobility aid; transmitter left, and receiver right.

TEST PROCEDURES AND RESULTS

The completed prototype aid was tested in a variety of controlled and subjective experiments. In addition to quantitative evaluation of detection range capability, the tests were designed to check the possibility of establishing a maximum detection range so that the blind user would have some range information about a detected object. Accordingly, both transmitter and receiver were aligned so that the former's beam intersected the latter's field of view at an adjustable distance from the aid, for example, 3 meters. The optical triangulation format for the prototype aid is shown in Fig. 7.

QUANTITATIVE TESTS

The aid was tested against a variety of diffusely reflecting targets with a cross section larger than that of the transmitted beam. The resultant detection ranges were plotted on a computer-generated graph of Eq. 1 showing detection range vs. target reflectance for several values of P_o/P_{th}. Target reflectance was measured with a calibrated reflectometer assembled for the purpose. The P_o/P_{th} values used for computer processing ranged from 5×10^5 to 3×10^6 and were selected on the basis of what reasonable P_o/P_{th} values might be achieved in a prototype aid.

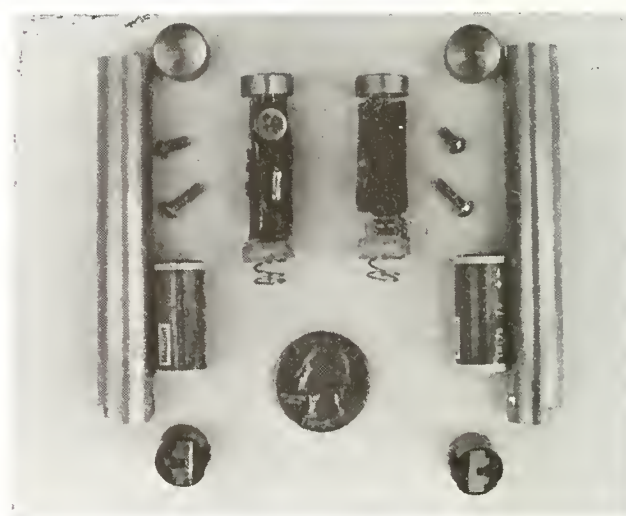


Figure 6. Completed prototype nonranging eyeglass-mounted infrared mobility aid, completely self-contained and requiring no supplemental battery or electronics packages.

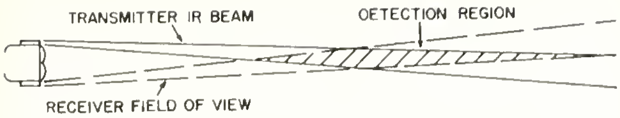


Figure 7. Triangulation scheme for the prototype eyeglass-mounted infrared mobility aid.

As shown in Fig. 8, the experimentally measured detection ranges most closely agree with a P_o/P_{th} of 9 x 10^5. Since the power within the central beam of the transmitter is 10.5 mW, the P_{th} is about 12 nW. The aid was tested against a variety of common objects, some of which are given in Table 2.

A knowledge of P_o/P_{th} is important in predicting the aid's performance against many common objects. Some objects, however, have a specular reflecting component or a cross section smaller than that of the transmitted beam and make detection range predictions more difficult. Glass, smooth unpainted metal, and other specular reflecting targets severely limit the aid's detection range. While these objects can be detected at considerable ranges when their surface is normal to the oncoming beam, their off-axis detection range is nominal at best.

Detection of most diffusely reflecting objects is characterized by an output signal from the time the object is initially detected to a

TABLE 2

Detection Ranges for Targets with a Variety of Reflectances

Target Material	Reflectance (%)	Predicted R_m* (cm)	Measured R_m (cm)
Fabric	1.5	64	65
Paper	5.0	116	119
Wood**	12.0	180	195
Fabric	31.0	289	287
Stucco**	40.0	329	312
Concrete**	62.0	409	381
Fabric	64.0	416	396
Stucco**	77.0	456	437
Stucco**	88.0	487	498
Wallboard	91.0	496	504

* where P_o/P_{th} is 9 x 10^5, A_r is 0.36 π cm^2, τ is 0.8, and the target is a diffuse reflector (Eq. 1).

** painted

point only a few centimeters from the eyeglasses. While Fig. 7 shows a near detection range cut-off point somewhat farther from the aid, sufficient off-axis infrared from the transmitter is scattered back to the receiver to give a broader detection capability.

One of the aids has been tested in environmental extremes which might be expected to alter its performance. Detection range is reduced when the target is illuminated by direct sunlight. Fog caused no measurable change in detection range, and snow, rain, and hail caused an occasional false return in the form of solitary clicks. Storage at -23 degrees Celcius for eight hours produced only a slight detection range reduction and storage at 46 degrees Celcius for three hours produced no reduction in detection range. Operation in humidities ranging from 10 percent to 95 percent (relative) resulted in no noticeable detection range reduction. The aid successfully withstood drop and vibration tests. (Note: Though the circuitry of the aid is unaffected by high humidity, and the aid has been successfully operated in the rain, it should be noted that the reflectance of many materials is reduced by either a surface layer of water or water absorption which can reduce the aid's detection range.)

SUBJECTIVE TESTS

The author has tested the aid with several blind subjects in limited preliminary tests and the Prosthetics and Sensory Aids Service of the Veterans Administration is informally evaluating two additional aids. Though limited in scope, tests conducted by the author have proved encouraging. Subjects have used the aids to detect overhanging branches, open doors, hallways, poles, pedestrians, and other objects. The aid has proved useful in tracking a partner in a conversation and standing in line.

A formal evaluation of an earlier electro-optical aid, the hand-carried G-5 Obstacle Detector developed by Bionic Instruments, Inc., concluded that of a variety of specified obstacles narrow openings (doorways) and "low" obstacles proved the most

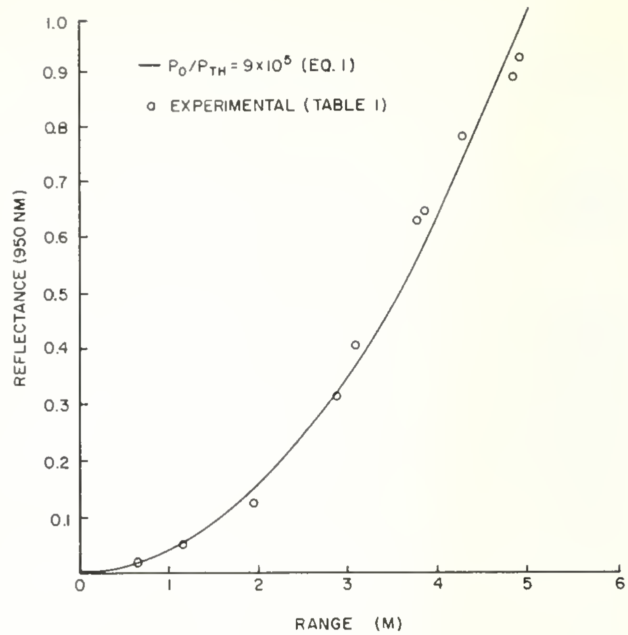


Figure 8. Detection range vs. target reflectance for the prototype eyeglass-mounted aid. Note close agreement of theoretical prediction (solid line) and experimental results (circles).

difficult to detect.[46] These preliminary tests with the eyeglass aid have shown doorways can be easily entered without collision by merely scanning the head once or twice to assess its azimuthal position.

It is illustrative to compare this task as performed with the eyeglass infrared aid and the Sonic Glasses. The ultrasonic system has such a wide beam (60 degrees) that the door opening cannot itself be resolved. Instead, the operator receives signals from all sides of the opening even when gazing directly at the aperture. By means of head movements the user can discern subtle variations in the binaural output and deduce the existence of the opening. The narrow beam infrared aid with digital output provides a far simpler detection scenario. The aid only signifies targets within its field of view, so that when the user gazes at the opening no output signal is present. The high resolution provided by this scheme permits the user to readily ascertain the shape and approximate dimensions of the opening by a simple scanning process. In contrast to the ultrasonic aid, little training or concentration is required for this operation, and blind subjects frequently walk directly through the center of doorways during their first trial with the infrared instrument.

Thus far two important recommendations have come out of the preliminary testing. One is that the aid should be considered a supplement, not a replacement, for such traditional guidance devices as the mobility cane and guide dog. The other is the addition of a second channel whereby a target will trigger three tones as it is approached is essential for providing range information.

A RANGING EYEGLASS AID

The single-beam prototype eyeglass aids have demonstrated that an LED can be used as a source of near-infrared in a mobility aid. Since the prototypes provide no range information, tests with blind subjects are inconclusive at present. But the technical success of the aid and its small physical size have encouraged further work.

Accordingly, I have approached the Southwest Research Institute in San Antonio, Texas with the suggestion they undertake the final design, assembly, and testing of an eyeglass aid with a ranging capability. The Southwest Research Institute is well known for its work in bioengineering.

Following a favorable recommendation from Arkansas Enterprises for the Blind, based upon an informal evaluation of one of the prototype eyeglass aids, the Institute has recently formulated a detailed proposal for developing and testing six eyeglass aids which will provide range information.[47] The aids will be housed inside cosmetically pleasing, hollow eyeglass frames much like eyeglass hearing aids. There will be a single transmitter and two receivers. A simple optical arrangement will cause the receiver's fields of view to intersect the transmitted beam in two zones about 1 and 3 meters from the aid. An overlap of the two fields of view would provide a central detection zone.

The output to the blind user will take two forms. Three of the aids will employ an audible transducer and three different tones will indicate in which of the three detection zones a target is located. The remaining three aids will employ a miniature tactile stimulator on each temple of the eyeglass frames. Vibrations from either or both stimulators will provide the outputs for the three detection zones.

The proposal includes an evaluation program to measure the technical specifications of the aids and to test them with blind subjects. All six aids will be delivered to Arkansas Enterprises for the Blind for independent testing.

The Southwest Research Institute is presently seeking funding for this development effort. If funding is forthcoming and if tests results warrant, the eyeglass aid will be further improved and serial production considered.

LASER EYEGLASS AIDS

Earlier in this report a comparison of LEDs and injection lasers concluded that the injection laser offers superior optical power output, but that the LED is less costly, easier to operate, and consumes less power. Accordingly, LEDs have been employed in most of the electro-optical mobility aids designed and assembled by the author.

In April 1971, however, an experimental injection laser transmitter measuring 1.2 cm x 12 cm including a self-contained battery and suitable for use in a mobility aid configuration was designed and assembled. The transmitter, which is described in detail elsewhere,[8] projected a 2.3 mR beam which produced a spot approximately 2 cm in diameter at a distance of 4.3 meters. The divergence could be varied by a simple lens adjustment. At a pulse repetition rate of 2.5 kHz, this system consumed about 23 mW and therefore operated approximately 80 hours from the stack of 18 1.3-volt mercury cells contained within the cylinder.

This laser transmitter was mounted on eyeglass frames for an informal evaluation in a mobility aid configuration by a blind subject. The most significant finding was the exceptional resolution provided by the transmitter's narrow-beam width. For example, a pencil could be easily resolved at a range of several meters. There was some question from the subject, however, concerning the possibility of missing small targets with the system.

Further development of this laser eyeglass aid has not been pursued due to the weight of the transmitter (approximately 75 grams including the mercury cells) and the success of the LED approach. Nevertheless, the injection laser may yet find a practical role in an eyeglass mobility aid. Low-threshold large optical cavity (LOC) double-heterostructure diode lasers have recently been made commercially available. One typical laser of this type, an RCA developmental type C30025, has a threshold current of only 1.2 amperes and delivers 730 mW at a forward current of 5 amperes. This is nearly five times the power available from a conventional (nonhemispherical structure) LED for the same forward current. Furthermore, *all* the radiation from the laser can be easily collected with a simple lens. Considering the difficulty in collecting more than 20 percent of the radiation from the LED into a central beam, the laser offers a potential power output advantage of more than 25:1.

This new laser can be driven by simple, low-voltage circuitry very similar to that employed in the prototype LED eyeglass aids described in this report. Receiver design, however, would have to be modified somewhat to accommodate the laser's very fast pulse width. Assuming a receiver sensitivity of 100 nW and a laser output of 500 mW, a P_o/P_{th} of 5×10^6 is possible. This gives a detection range of about 4 meters against a diffuse target which has a reflectance of only 10 percent and intercepts all the transmitted beam.

The conclusion from these experiments and studies of a laser eyeglass aid is that while the LED is preferable from a cost and weight standpoint, new injection laser developments bear close watching. High-duty cycle double-heterostructure injection lasers which have already been developed, for example, could be directly substituted for the LEDs in the prototype eyeglass aid with no transmitter or receiver circuit revisions.[49] Lasers now at a laboratory stage of development would typically provide more than 120 mW, all of which could easily be collected by a simple lens. This configuration would provide a power advantage over the LED it replaced of at least 12:1 and a P_o/P_{th} of at least 1×10^7. This value of P_o/P_{th} is higher than that for the 500 mW laser cited earlier, since the first laser must be operated at a much faster pulse width (e.g., 75 nanoseconds) with reduced receiver sensitivity.

ONGOING WORK

Pending the outcome of the Southwest Research Institute proposal, no work on developing more advanced eyeglass mobility aids is presently under way. However, there is a comprehensive ongoing program to further quantify the aid's electro-optical specifications, refine the optical radar range equations, and gather data about target reflectance.

Measuring the electro-optical specifications is hindered by a necessity for calibrated standards and accurate test equipments. Though the data presented herein are believed to be reasonably accurate, there is a continual effort to update them as appropriate.

The optical radar range equations used to calculate various detection ranges for diffuse targets larger and smaller than the oncoming beam have been experimentally verified and are correct. The equations, however, need to be refined to take into account such factors as signal-to-noise ratio, targets with both diffuse and specular reflectance characteristics, solar background illumination, and others.

Target reflectance studies are particularly important, and present plans are to identify the reflectance of the "average" target for a variety of outdoor and indoor environments. This study involves direct measurements with two reflectometers, one which measures diffuse reflectance over a large (3 cm^2) surface area and one which measures total reflectance over a small surface area. The design, construction, and operation of these reflectometers are described in detail elsewhere.[50] This study also involves image conversion techniques to record various scenes for later evaluation. Both color and black and white infrared film are employed, as is an image-converter tube. Image conversion permits any desired scene to be recorded at the wavelength of interest by means of a suitable optical filter over the camera lens. Densitometry permits the relative infrared reflectance of objects recorded on the image to be measured. For quick checks, a calibrated reflectance target containing a grid of various reflectances and placed within the area of the scene being photographed permits subjective determinations of reflectance. This same technique can be used to gather real-time results with a filtered image-converter tube.

TECHNOLOGICAL SPIN-OFFS

The development of this series of active infrared mobility aids has resulted in several interesting technological spin-offs. To evaluate the aid quantitatively, for example, the reflectance of a great variety of common materials had to be measured. This kind of data is not readily available in the literature, and that which has been published cannot always be applied in a practical case due to possible variations in the reflectance of similar and even identical targets. Commercial reflectometers are available, but they are costly. Therefore a simple reflectometer was designed utilizing an LED of the same type used in the mobility aid. The entire device cost less than $10. When calibrated against a smoked magnesium-oxide reflectance standard prepared in accordance with National Bureau of Standards instructions, reflectance data obtained with the instrument agreed quite closely with published data.

An interesting application of the reflectometer has already been found. The near-infrared reflectance curve for most vegetation is relatively flat, so the monochromatic near-infrared reflectance measurements obtained with the instrument can be applied to the entire photographic infrared. This kind of data is very useful in the field of environmental remote sensing.

Of course the instrument is ideal for measuring the reflectance of targets for electro-optical mobility aids and optical radars in general. These applications, construction of two kinds of simple reflectometers, and typical results are explained in detail elsewhere.[50]

Another interesting technological spin-off has been the application of the eyeglass aid in a pulsed, frequency-modulated voice communications system. Amplitude modulated optical communicators are easy to design, but their performance is impaired by a reduction in receiver output as the distance between transmitter and receiver is increased. A pulsed system which employs a threshold circuit at the receiver output will provide a constant signal output within the specified communicating range.

Since the existing eyeglass aids incorporate receivers with a threshold stage at the output, they are well suited for use in pulsed optical communications. A simple voice-modulated pulsed transmitter which will fit in the mounting tube occupied by the aid's existing transmitter (including miniature microphone) has been designed and tested in a bread-board configuration by the author with good results. An eyeglass optical communications system such as this could provide covert, interference-free communications between individuals a few hundred meters apart. A book has been prepared describing in detail the design, operation, and circuitry of several optical communications systems which have evolved from this work in electro-optical mobility aids.[51]

There have been several other technological spin-offs from the infrared eyeglass aid, particularly in the area of miniaturized injection laser systems. The two described here illustrate possible commercial applications whose development might defray some of the expense of the mobility aid itself. Optical communicators, intrusion alarms, and other electro-optical systems directly resulting from this mobility aid research are described in detail elsewhere.[16,17,18,51]

ACKNOWLEDGEMENTS

Several individuals have made important contributions to the development of the eyeglass infrared mobility aid. Noel Runyan, an electrical engineer, has tested each of the aids described in Part 2 of this report and provided important evaluations. He has also provided important information about cane travel and acoustical cues.

James P. Miller, chairman of the Southwest Research Association, has provided valuable discussions regarding optical radar range equations and assistance with the computer generation of range equation results. Important discussions on active electro-optical aids have been provided by J. Malvern Benjamin, Jr., president of Bionic Instruments, Inc. J. J. Whitehead and L. W. Farmer of the Veterans Administration's Central Blind Rehabilitation Center have dispensed helpful advice and consultations concerning the prototype non-ranging eyeglass aids.

I am grateful to the American Foundation for the Blind (AFB) for funding the preparation of this report. Mr. Louis Goldish, director of the Foundation's Sensory Aids Analysis and Development Program, has provided information about the design philosophy, potential user population, and encouragement. Dr. Milton Graham, Director of AFB's Department of Research has contributed valuable discussions on the general subject of sensory aids. I am particularly indebted to Leslie L. Clark, Editor of the *Research Bulletin*, for making the preparation of this report possible.

Finally, I wish to acknowledge the patience, understanding, and enthusiastic support of my wife, Minnie.

1. Kay, L. Ultrasonic mobility aids for the blind. In L. L. Clark (Ed.), *Proceedings of the Rotterdam Mobility Research Conference*. New York: American Foundation for the Blind, 1965, 9-16.

2. Russell, L. Travel path sounder. Ibid. 73-8.

3. Benjamin, J. M., Jr. A review of the Veterans Administration blind guidance device project. *Bulletin of Prosthetics Research*, 1968, 10(9), 63-90.

4. Mims, F. M., III. An infrared eyeglass mobility aid for the blind. *Proceedings of the Southwest IEEE Conference*, April 1972.

5. See, for example: Bliss, J. C., Crane, H. D., and Gardiner, K. W. An ambient-light object detector and its potential extension to convey object shape information. In L. L. Clark (Ed.), *Proceedings of the Rotterdam Mobility Research Conference*. New York: American Foundation for the Blind, 1965, 61-71.

6. Starkiewicz, W., and Kuliszewski, T. Progress report on the Elektroftalm mobility aid. Ibid. 27-38.

7. Bliss, J. C., and Gardiner, K. W. *A mobility aid for the blind to supplement the cane*. (Final report, Project No. 4213) Stanford Research Institute, 1966.

8. Bach-y-Rita, P., Collins, C. C., Saunders, F. A., White, B., and Scadden, L. Visual substitution by tactile image projection. *Nature*, 1969, 221, 963-4.

9. See, for example: McClung, R. R. Short term field evaluation of Type 8A9 ultrasonic aid for the blind. *Bulletin of Prosthetics Research*, 1968, 10(9), 91-8.

   Also see, Kay, L. Sonic glasses for the blind. *Research Bulletin Number 25*, 1973, 37-50 (Appendices A and B).

10. Benjamin, J. M., Jr. Op. cit., 65-6.

11. Ibid., 66.

12. Cranberg, L. Sensory aid for the blind. *Electronics*, March 1946, 116-19.

13. Hannan, W. J. Application of injection lasers to communication and radar systems. *RCA Lasers*, 1972, 95-9.

14. Benjamin, J. M., Jr. Op. cit., 67-72.

15. Gardiner, F. J. Effectiveness of IR covert illuminators. *RCA Lasers*, 1972, 178-81.

16. Campbell, R., and Mims, F. M., III. *Semiconductor diode lasers*. Indianapolis: H. W. Sams & Co., 1972, 75-136.

17. Mims, F. M., III. *Light emitting diodes*. Indianapolis: H. W. Sams & Co., 1973, 24-38.

18. Mims, F. M., III. *Light emitting diode projects*. Indianapolis: H. W. Sams & Co., 1973, in press.

19. Benjamin, J. M., Jr. Op. cit., 81.

20. Campbell, R., and Mims, F. M., III. Op. cit., 25-39.

21. Ibid., 75-110.

22. Ibid., 111-36.

23. Ibid., 74.

24. Mims, F. M., III. *Light emitting diodes*. Indianapolis: H. W. Sams & Co., 1973, 142-3.

25. Schlisser, G., and Insler, J. Portable optical communicator rides laser for secure voice transmissions. *Electronics*, March 16, 1970, 96.

26. Bionic Instruments, Inc. *The Bionic C-4 Laser Cane*. (brochure) Bala Cynwyd, Pa.: Bionic Instruments, Inc.

27. The complete regulations will appear in a future edition of *The Federal Register* and are expected to take effect in late 1974.

28. *Laser Focus*, May 1973, 16.

29. *Archives of Environmental Health*, February 1970, 20(2), 156-211.

30. *Laser health hazards control.* Air Force Manual, April 1968, 161-8.

31. Mims, F. M., III. Use LEDs, not lasers, in rangefinders. *Electronic Design*, May 25, 1972, 48-50.

32. Benjamin, J. M., Jr. Op. cit., 63.

33. Kay, L. Ultrasonic spectacles for the blind. In R. Dufton (Ed.) *Proceedings of the International Conference on Sensory Devices for the Blind*, London: St. Dunstan's, June 1966, 275-92.

34. Bishop, W. Passive environmental sensors and their transducers. In L. L. Clark (Ed.), *Proceedings of the Rotterdam Mobility Research Conference.* New York: American Foundation for the Blind, 1965, 51.

35. *Product Engineering*, March 25, 1968.

36. Chardon, G. A mobility aid for the blind. In L. L. Clark (Ed.), *Proceedings of the Rotterdam Mobility Research Conference.* New York: American Foundation for the Blind, 1965, 79-81.

37. Benjamin, J. M., Jr. Op. cit., 89.

38. Kay, L. Sonic glasses for the blind. *Research Bulletin Number 25*, 1973, 29-33.

39. Russell, L. Op. cit., 77-8.

40. Zahl, P. A. (Ed.) *Blindness, modern approaches to the unseen environment.* Princeton, N.J.: Princeton University Press, 1950, 486.

41. Chardon, G. Op. cit., 79.

42. Kay, L. Sonic glasses for the blind. *Research Bulletin Number 25*, 1973, 33.

43. Mims, F. M., III. Eyeglass mobility aid for the blind. *Journal of the American Optometric Association*, June 1972, 673-6.

44. Mims, F. M., III. An active infrared mobility aid for the blind. *Proceedings of the Electro-Optical Systems Design Conference*, 1972, 14-18.

45. Mims, F. M., III. *Light emitting diode projects.* Indianapolis: H. W. Sams, in press.

46. Deatherage, Bruce H. The evaluation of the Haverford-Bionic Instruments obstacle detector. In L. L. Clark (Ed.), *Proceedings of the Rotterdam Mobility Research Conference.* New York: American Foundation for the Blind, 1965, 214.

47. Laenger, C. J., Sr., et al. *A proposal for a mobility aid for the blind.* Southwest Research Institute, April 11, 1973.

48. Mims, F. M., III. Relaxation oscillators provide compact drive for injection lasers. *Electronics*, July 19, 1971, 88-90.

49. Kressel, H. *Semiconductor lasers: Devices.* (Technical Report PRRL-71-TR-012) RCA Laboratories, 1971. Page 43, Fig. 2.5.32.

50. Mims, F. M., III. *Light emitting diode projects.* Indianapolis: H. W. Sams, in press.

51. Mims, F. M., III. *Optical communication.* Indianapolis: H. W. Sams, in press.

PSYCHOLOGICAL ASPECTS OF LONG CANE ORIENTATION TRAINING

Jennifer C. F. Peel*

In the following series of five papers, which will appear under the above general title, important difficulties and problems associated with long cane training will be examined, and experimental attempts at overcoming them will be described. The first is a critical examination of the standard teaching method, and five specific areas of weakness in that method are discussed from a psychological point of view. These are: difficulties relating to information overloading, selective attention away from crucial aspects of the task, negative transfer of training, and a general paucity of feedback.

The second paper reports on experimental training techniques which sought to overcome the first four of these problems and how they fared in a practical setting. The third paper reports on an experiment which arose out of methodological problems associated with performance evaluation, aimed to discover (a) what the psychological threshold for drop detection is, and (b) whether it could play a useful part in a battery of tests. The fourth paper reports on the effect of providing augmented feedback during the first week of indoor training, and will describe a technique for taking daily objective performance measures.

The fifth and final paper assesses how the whole experimental training technique, including an attempt to augment feedback concerning case handling, fared in a real life situation.

The first four papers appear in this issue of the *Research Bulletin*; the last one will appear in a subsequent issue.

---

*Blind Mobility Research Unit, Department of Psychology, University of Nottingham, England.

PART I

Critique of Standard Long Cane Orientation Training from a Psychological Point of View

Techniques for training people in long cane orientation have been in use for the past thirty years, since Hoover (1950) began his pioneer work during World War II. During those years many suggestions for modifying the traditional training method have been made and successfully put into practice (cf. Campbell, 1971). These modifications have always had to do with specific areas of the training, such as increasing the instructor/student ratio, providing crash courses, etc., but have rarely looked at the standard training method as a whole. This paper will critically analyze some basic assumptions of the training scheme from a psychological point of view and make practical suggestions for improvement.

A specifically psychological approach was adopted not to denigrate the experience of practitioners and cane users, as this discussion is based on the author's practical experience in using the long cane and in working as a mobility instructor. There is however much to be gained from combining practical experience of problems and the kinds of insights that can be gained from applying the psychologist's body of knowledge.

THE STANDARD LONG CANE TRAINING METHOD

Although the exact training methods used by individual instructors and in use at different institutions will obviously vary,* in general the basic principles of the training are these: the training is part progressive in nature. One aspect of the skill, such as the touch technique (the basic factor in cane handling), is taught and practiced first, then other aspects of the skill such as the use of orientation cues is added. Thus the progression is from practicing single skills in simple environments to using difficult multiple skills in more complex environments with the speed of progression being determined by the ability of the trainee.

Progression is encouraged by stressing the universal nature of whatever is taught, so that a skill or technique taught in a simplified situation is shown to be applicable to another, more complex one. Orientation taught early, so that a client can see that he is using a set of principles capable of dealing with a number of events.

Verbal instructions are the largest source of information throughout the training for both tactical procedural techniques (such as road crossing) and precise motor skills (such as cane handling). Thus, the only augmented or artificial feedback a trainee gets comes from his instructor. This information tends to be massed early in the training period and at specific parts of the lesson, so that the client is briefed to perform a task and debriefed on its completion (Fitts and Posner, 1967). In the early stages of training much verbal feedback concerning cane handling is being given. It is generally done a short time after the completion of a response rather than concurrently with it. The instructor's aim is to phase himself out of the lessons gradually, at first providing repeated information about arc width, and later allowing his client to learn by experience that a narrow arc width may result in a bumped shoulder.

TRAINING DIFFICULTIES

Building upon this very brief account of the basic principles of standard long cane training, I now

*"Standard training method" refers to the method currently used in Great Britain, brought here from the Veterans Administration Rehabilitation Center, Hines, U.S.A.

want to discuss how it works in practice, and to point out major problem areas. In fact, this analysis will focus on the teaching of cane handling, for this is at the same time both the central feature of this particular mobility technique and a particularly difficult skill to acquire. An instructor's aim is so to train his client to use the cane as if it were an extension of his body. Thus, by having the correct arc width and the correct amount of cane contact with the floor, he is both protected from and given information about his environment.

Problems in long cane teaching arise because the difficulties involved in learning *any* motor skill are compounded by the lack of vision. Therefore it is necessary to describe the task immediately confronting the long cane trainee.

First, in any learning situation the trainee must work from a clear description of the skill he is attempting to learn. For the blind trainee this prerequisite is particularly difficult to achieve because his ability to receive, interpret, and use information that is intrinsic to the task is curtailed. Instead of using clear visual feedback he has to appreciate and use esoteric proprioceptive, kinesthetic, and tactual sources. When the task requirements are described verbally by the instructor there is the added difficulty of translating words into feelings, and it may be that the task requirements remain unclear for a long time.

A second problem is that through inexperience the learner is unable to anticipate, weigh, and categorize items of information correctly. When presented with a stimulus the learner has to try to recognize it, assess what has to be done with it, and try to perform the correct response. If at any of those stages he makes a mistake there is little chance to go back and correct because new sets of stimuli requiring different responses may have come along in the meantime. Thus, most novices generally face an information overload at the beginning of training.

Overloading leads many learners to attend selectively to only certain parts of the task. They may filter out certain aspects of the information they are receiving; or they may allow stimuli to wait for attention and so build up an increasing time lag between the arrival of a stimulus and the attempt to cope with it; or, they may work too fast and commit more errors (Miller, 1964). This selective attending may lead to poor cane handling or to a concentration on, say, orientation rather than cane handling.

The blind are particularly prone to information overload because they generally have to monitor information at higher levels of awareness. They have, for instance, the problem of consciously synthesizing information from several sources rather than, as the sighted might do, unconsciously analyzing what they see (Leonard, 1970). Also in mobility they have less time for making decisions: for example, they cannot see that they may be approaching a step or curb.

In motor learning, another major problem is that of actually being able to hit upon the correct response, and recognizing those characteristics that distinguish it from an incorrect one. The learner's aim is to be able to correct his own errors, for if they go uncorrected and are practiced they may be learned, become habitual, and prove difficult to unlearn at a later stage (Kay, 1953). Again, blindness as such makes the self-detection of errors difficult. In addition, in cane handling, few warnings of error come via intrinsic feedback. For instance, a traveler may walk a whole block with a narrow arc width without bumping his shoulder, and therefore not receive warning that his technique is faulty.

Finally, cane handling itself is a difficult skill. On the one hand, information tends to be distorted because it is received at the cane's tip (at a distance from the body), while on the other, there is a considerable difference between the extent of the controlling wrist movement and the resulting sweep of the cane's tip. Furthermore, the basic requirements of cane handling (an accurate arc width and sensitive reactions to the tip's contact with obstacles) are exacting, for they imply nothing less than that the user must learn to project his body image forward to the tip of the cane--

obviously difficult when you cannot see where the tip is (Cratty and Sams, 1968).

OVERLOADING AND SELECTIVE ATTENTION

Looking at problem areas particularly associated with standard long cane training, we will see that one of them seems to arise from the instructors' stress on the importance of teaching cane handling and orientation together. While it is true that a client may spend a while simply practicing cane handling, orientation is normally introduced the moment he begins to make short simple journeys; after about four lessons (not counting training in "pre-cane" mobility skills). From then on orientation and cane handling tend to receive almost equal amounts of attention from the instructor.

From my own experience as a trainee and instructor it appears that orientation training is introduced long before the skill of cane handling has been mastered. These two facets of the training are competing for the client's attention. The competition appears to be unequal, for extraneous factors direct attention towards orientation often at the expense of cane handling.

The most significant factors contributing to this situation are: first the stresses and anxiety experienced by the blind traveler (Locke, 1972) will inevitably encourage him to use cues and techniques which appear to him to maximize his safety. For instance, at this stage in training he is unlikely to feel sufficiently sure of his cane handling to trust it completely. So if he has been taught the orientation cues which give him prior warning, say about stairs, he is going to want to watch out for these. Then, when he has spotted the cue his anxiety will mount and so too will the temptation to use old and tried methods of drop detection (such as foot shuffling). Thus at each stage attention is directed away from cane handling and at crucial moments (detecting a step down) the cane may not be properly used at all (Knapp, 1963, p. 121).

Second, for many there may be unequal amounts of intrinsic interest in these two aspects of mobility. The requirements of cane handling are difficult and exacting, and the reward for improving, say hand position, may not be obvious, let alone significant. Yet, the solution of orientation problems may have some of the excitement of good detective work so the need to achieve in that sphere may become associated with the need to demonstrate that one is intelligent, bright, and alert.

Finally, the cues associated with orientation are in large measure easier to perceive and recognize than those that are intrinsic to cane handling. For instance, it is easier to recognize footsteps than it is to pick up the proprioceptive cues associated with an incorrect arc width.

In sum, the learner's attention may be directed away from cane handling before he has mastered it. Instead of concentrating on establishing good techniques and eradicating bad ones, he tends to practice his errors and allows them to become habits.

Perhaps the most crucial point, however, is that through the addition of orientation at this stage there is added yet another load for the learner's already stretched capacity to cope. This overloading may have a number of detrimental effects, varying from inflexible behavior (Fitts and Posner, 1967, p. 37) to states of anxiety and confusion (Wechster, 1945), all of which may result in taking longer to acquire the skill.

TRANSFER OF TRAINING

A second problem arising from the standard training technique becomes apparent during that frustrating and troublesome period when the trainee first tries to travel outdoors. Very often the situation develops as follows. By lesson 19, when the changeover often takes place, the trainee will already be performing well indoors. His handling of the cane will have become more automatic and will be showing a rhythmic, firm, and regular touch. Instead of having to struggle with and concentrate on his cane technique he will be largely unaware of that; rather, he will be paying attention to his environment and quickly and efficiently completing his journeys. The contrast between his last performance indoors and his first performance outdoors consequently will be most marked. First of all, in the new environment he may no longer feel safe. The dangers of outdoor travel where there are cars, side curbs, overhanging trees, etc., are obviously more numerous and more significant than those faced indoors. Furthermore, he may feel less secure because outdoors things are on a much larger scale. Walls from which noises rebound are further away and the general noise level is much higher and more confusing.

It is not just the novel aspects of the new environment that are burdensome to the trainee. A far more serious impediment is the fact that the skill he equipped himself with indoors no longer functions as well outdoors. The reason is that when the cane is used on smooth floor surfaces (found indoors), the tip's contact with the floor can be quite extensive--as much as 15 cms. On rough surfaces, such as pavements, the tip tends to jam in cracks if there is a slide phase to the movement.* Therefore the correct technique in these circumstances is to touch the tip to the floor and lift it off immediately. Though clients always have this explained to them, in my experience they find it very difficult to put their instructions into practice. It normally happens that every few yards the client finds that the cane has jammed in a crack, and with infuriating frequency he has to stop, pull his cane out, realign himself, and start again. Frustration mounts to a disheartening level, often resulting in an alarming deterioration of skill.

This is another occasion when a problem that is met with in many training situations, namely that of progressing from the simplified training environment to the testing real-life setting is, in the case of long cane training, augmented by difficulties peculiar to cane handling.

This time the primary source of the difficulty seems to be the need to modify the touch technique. Other parts of the skill, such as hand position, grip, etc. remain the same in the two situations and are positively transferred from one to another (Seymour, 1957). The disruption comes about because there is negative transfer between the two touch techniques.

Various reasons can be put forward why the transfer is negative. Bruce (1933) pointed out that where task stimuli (i.e., floor texture) and responses differ in two situations no transfer should be expected. But going beyond this, it looks as though the learner simply forgets to make the right response, and because the old response is inappropriate finds himself in difficulty (Holding, 1965).

Another reason is that there might be interference between the old and the new response. Such interference tends to occur when similar skills have not been overlearned (Siipola and Israel, 1933) and tends to be greatest when the learning of the first task is at an intermediate stage (Mander, 1954). Thus, the amount of time devoted to cane handling indoors appears to be crucial.

A third reason for the poor transfer of training may be that the skill acquired during training on the easy task (cane handling indoors) cannot be transferred to the harder task (cane handling outdoors) because it lacks some of the necessary skill components used in the latter (Holding, 1962). Thus it appears as though the indoor training not only encourages the client to acquire a skill different from that he is going to be required to use outdoors, but also fails to teach him much that will be of use. It could be true that in orientation the cues and techniques used in the two situations are so different that rather than expecting a transfer from one to another, instructors should, to a certain extent, approach them separately. Lawrence, (1954) who has shown that where simulators differ slightly from the final task these differences may be important and produce negative transfer.

Therefore there is a case for saying that a client should tackle the complex task of outdoor travel as soon

---

*This problem may be less severe in America where the floor texture of the sidewalk is apparently smooth, but it is certainly met with in Europe where paving slabs tend to be used.

as possible, for having acquired the difficult skill he could then expect it to transfer positively to the simpler situation, and would have avoided the frustrations and disappointments that at present accompany the first few weeks of outdoor travel.

FEEDBACK

The third problem arising out of the standard training scheme is one that affects it throughout. Unlike the problems already discussed, it is not limited to a particular situation or portion of the training, though like them its effects are most apparent in the early stages of learning. The problem centers on the difficulty of supplying the blind client with adequate information concerning his cane handling.

Again we see a situation in which the difficulties created by blindness itself render conventional teaching techniques inefficient (for a fuller account of these difficulties see Leonard, 1970). In this case the conventional method of supplying verbal descriptions of the skill and verbal feedback about it is at fault. For by these means it is impossible to give the blind person a clear idea of what he must do.

The drawbacks involved in using words as the primary source of augmented feedback are these: First, it is very difficult to avoid giving descriptions in visual terms; terms that may mean very little to blind people. Second, there is no way in which words can draw attention to the skills' intrinsic cues (i.e., proprioceptive, kinesthetic, and tactual) that the client must learn to recognize.

Third, it is difficult to give the verbal information at the right time. Take the example of correcting a client's arc width. The best that an instructor can manage is to give the information a short while after the response has been made. This means that there is a delay between the response and the feedback, during which distracting stimuli may break the response-feedback link (Brackbill and Kappy, 1962).

The instructors' alternative is to give the feedback concurrently with the response, but this also has its drawbacks. It may cause the client to attend to the artificial feedback, rather than the intrinsic cues, with the result that when the former is taken away (the "crutch" is withdrawn) there is a sudden drop in performance (Annett, 1959). Or the client may find it confusing and difficult to associate a particular piece of feedback with a particular response. This is especially noticeable if the concurrent feedback begins to lag, as it may well do during a sequence of responses (Lee, 1950).

Thus, there is a clear case for replacing words as a source of feedback with something more in harmony with the body's intrinsic feedback systems. For blind clients perhaps the most flexible and easily controllable method for augmenting feedback is to provide it tactually. Teaching aids could be designed which would provide the client with a concrete description of the task's requirements and present information about errors in such a way as to direct attention to intrinsic rather than extrinsic sources of feedback.

SUMMARY

The major problems associated with the standard long cane training scheme appear to be these:

1. The emphasis on teaching long cane handling together with orientation from a very early stage generally causes an overloading of the learner's capacity to cope and attend. As a result, he will selectively attend to things other than cane handling.

2. In the indoor environment, with its smooth surfaces, the trainee appears to learn a technique that is inappropriate to outdoor travel. Transfer between the two environments and techniques is difficult.

3. There is a general paucity of feedback regarding cane handling, most feedback being given in the form of words which are difficult to relate to the task's intrinsic feedback and do not draw the client's attention to it.

AN ALTERNATIVE TRAINING SCHEME

Because the difficulties following upon the problems described can be so damaging, a new training technique which seeks to avoid them has been developed. Briefly, the principles out of which these new techniques grew were these: First, it appeared that the burden of overloading which results in selective attention for aspects of the skill other than cane handling could be avoided if the learner was allowed to spend his first weeks of training concentrating on cane handling alone. Then when cane handling had been largely mastered and had become a habit rather than a conscious process the teaching of orientation could safely begin. Second, the training scheme sought to avoid the difficulties of transferring the skill of cane handling from the indoor to the outdoor environment. Here the suggestion was that if the transfer was made as easly as possible, say within the first fortnight, then the client might still be in the right frame of mind to concentrate on his cane handling and not feel so much resentment and frustration with the difficulties of using a cane on rough pavements.

Third, to increase the amount of information available concerning the skill of cane handling, a piece of apparatus was devised which augmented the learner's tactual feedback in relation to arc width and extent of cane contact. This, it was hoped, not only defined the task more clearly, but encouraged the learner to concentrate on the tasks' intrinsic cues so that he could become more self-critical of his performance.

All these techniques were tested in both experimental and practical teaching situations. How they fared and how they came to form part of a new teaching method will be reported later in this series.

REFERENCES

Annett, J. Learning a pressure under conditions of immediate and delayed knowledge of results. *Quarterly Journal of Experimental Psychology*, 1959.

Brackbill, Y. & Kappy, M. Delay of reinforcement and retention. *Journal of Comparative Physiological Psychology*, 52, 14-18, 1962.

Bruce, R. W. The conditions of transfer of training. *Journal of Experimental Psychology*, 16, 343-61, 1933.

Campbell, D. W. A vacation course in long cane orientation mobility. Mimeograph, Department of Psychology, University of Nottingham, 1971.

Cratty, B. J. & Sams, T. A. *Body image of blind children.* State of the Art Report, New York: American Foundation for the Blind, 1968.

Fitts, P. M. & Posner, M. I. *Human Performance.* Belmont, Cal.: Brooks/Cole, 1967.

Gagne, R. M. & Bolles, R. C. A review of factors in learning efficiency. In Holding, D. H. (Ed.) *Experimental psychology in industry.* Harmondsworth, Eng.: Penguin, 1959.

Holding, D. H. *Principles of training.* Oxford: Pergamon Press, 1965.

Holding, D. H. Transfer between difficult and easy tasks. *British Journal of Psychology*, 53, 397-407, 1962.

Hoover, R. E. The cane as a travel aid. In Zahl, P. A. (Ed.), *Blindness*, Princeton, N.J.: Princeton University Press, 353-65, 1950.

Kay, H. *Experimental studies of adult learning.* Unpublished Ph.D. thesis, University of Cambridge, 1953.

Knapp, B. N. *Skill in sport.* London: Routledge, 1963.

Lawrence, D. H. The evaluation of training and transfer programmes in terms of efficiency measures. *Journal of Psychology*, 38, 367-82, 1954.

Lee, B. S. Effects of delayed speech feedback. *Journal of the Acoustical Society of America*, 22, 824-6, 1950.

Leonard, J. A. The concept of the minimal information required for effective mobility and suggestions for future non-visual displays. Mimeograph, Department of Psychology, University of Nottingham, 1970.

Locke, P. M. *Stress in blind pedestrians.* Unpublished Ph.D. thesis. University of Nottingham, 1972.

Mander, G. Transfer of training as a function of degree of response overlearning. *Journal of Experimental Psychology*, 41, 329-35, 1954.

Miller, J. C. Adjusting to overloads of information. In Rioch, D. McK., and Weinstein, E. A. (Eds.), *Disorders of communication*, research publications, Association for Research into Nervous Mental Disorders, 42, 87-100, 1964.

Seymour, W. D. Transfer of training in engineering skills. *Occupational Psychology*, 31, 243-7, 1957.

Siipola, E. M. & Israel, H. E. Habit interference as dependent upon stage of training. *American Journal of Psychology*, 45, 205-27, 1933.

Wechster, D. R. H. The clinical measurement of anxiety. *Psychiatric Quarterly*, 19, 618, 1945.

PART II

An Experiment on the Effects on Long Cane Mobility of Reducing the Length and Content of the Indoor Training Period

Criticisms of the standard long cane training method have been made above which suggest that in its present form it creates several very serious difficulties for the learner. The standard insistence that orientation and cane handling are taught together from a very early stage led to an overloading of the learner's capacity to cope and caused him to direct his attention away from cane handling to orientation. Similarly, the indoor training environment was thought to be inappropriate in the sense that it allowed the trainee to acquire a cane handling technique which he would not be able to use outdoors and which would interfere with the more useful outdoor technique.

In this paper an experiment will be described which set out to test whether these defects are present in the standard training scheme and whether an alternative training method might eliminate them.

EXPERIMENTAL DESIGN

Control Group

Group 1A was trained for four weeks. Throughout they received standard long cane training in both cane handling and orientation. They spent the first two weeks indoors followed by two weeks outdoors.

Experimental Groups

Group 1B was trained for three weeks. They also received the standard training throughout in both cane handling and orientation. However, they spent only a week indoors before going outdoors for two weeks.

Group 11A was trained for four weeks. For the first two weeks they concentrated on cane handling alone, and trained indoors. In the second two weeks they trained outdoors combining orientation and cane handling.

Group 11B was trained for three weeks. During the first week they learned only cane handling and were indoors. During the following two weeks they were outdoors and combined cane handling with orientation.

It was hypothesized that the effects of overloading and selective attention would be avoided by Groups 11A and 11B because they had concentrated on cane handling alone during initial training. By contrast, these effects would be apparent in the performances of Groups 1A and 1B who, from the beginning, had combined cane handling with orientation.

Similarly, regarding the effects of training in an "inappropriate" environment, Groups 1B and 11B were expected to adapt more readily to the rough outdoor surfaces, because they had spent only one week indoors. On the other hand, Groups 1A and 11A were expected to experience greater difficulties in making the transition to outdoor travel, because they had trained for two weeks on smooth indoor surfaces.

SUBJECTS

Twenty-four paid volunteers, drawn from a university population, acted as subjects. There were an equal number of both sexes and the age range was from 18 to 24 years. There were 6 subjects to a group and all were sighted.

METHOD

Subjects were blindfolded before lessons and not allowed to see the place where the lessons were held. They had an hour's training on four consecutive days in each week, and one hour's testing on the fifth. Except where the design of the experiment called for a difference, lessons followed the standard teaching procedure.

TESTING PROCEDURE

Subjects' performances were evaluated at the end of the three

TABLE 1

Experimental Design

Group	Indoors	Outdoors	Test
1A	Two weeks Cane handling and orientation	Two weeks Cane handling and orientation	Familiar and unfamiliar routes
1B	One week Cane handling and orientation	Two weeks Cane handling and orientation	Familiar and unfamiliar routes
11A	Two weeks Cane handling only	Two weeks Cane handling and orientation	Familiar and unfamiliar routes
11B	One week Cane handling only	Two weeks Cane handling and orientation	Familiar and unfamiliar routes

or four weeks of training. For this evaluation, subjects were observed and filmed as they negotiated two routes in quiet residential areas. Both routes were approximately half a mile long, and subjects were familiar with one, but not the other. The familiar route was simple in shape and had been met once before. The unfamiliar route was more demanding, having an unusual shape, narrow cluttered pavements, and the novelty of a gradient.

Subjects negotiated two different types of route so that the varied conditions might reveal diverse qualities in subjects' performances. Whereas optimum performances could be maintained on the familiar route, any weaknesses in skill were expected to be revealed on the more difficult route (Armstrong, 1968).

Objective scores were gathered at the end of training. However, objective performance measures cannot at present cover all the aspects of training experience and performance that are of interest; in this study qualitative judgments were also recorded.

For the objective scores Leonard and Wycherley's method of using a "flow chart" type of assessment form was used (Leonard and Wycherley, 1967). Briefly, this form divides a route into street blocks and lists all the subtasks that the traveler should perform (detecting up-curbs, clearing on up-curbs, etc.). Subjects are then scored according to whether they performed the subtasks or not. Scoring was done by a qualified and experienced long cane instructor.

This type of flow-chart scoring misses many of the more subtle aspects of a performance because it only records whether or not the subtask is performed, and says nothing about how it is carried out (Brown, 1966). This gap was filled by having two observers record independent, simultaneous commentaries on how subjects were faring on the routes. These were done by the author and another experienced observer using pocket tape recorders. Finally, subjects were filmed performing all subtasks.

TRAINING RECORD

Throughout the training individual daily records of subjects' progress were kept. Particular attention was paid to how they reacted to their training programs, and how and when they developed the ability to cope with different situations.

RESULTS

The groups' mean scores for each item on the rater's score sheet is shown in Table 2. This table presents a profile of the mean of the group's ability. The main point of an analysis of this data is that at the time of the evaluation there were no major differences between the performances of the four groups. The judgments of observers supported this conclusion.

The data also shows that all subjects were able to perform most of the subskills most of the time. Again, the observers' judgments supported this, though they went on to say that there were differences in the *way* subskills were performed.

Finally, it is clear that a number of subjects reached a comparatively high level of competence after a relatively short period of training. The rater and observers agreed that 11 of the best performers could have traveled safely by themselves in familiar, quiet residential areas. In unfamiliar areas they might have got lost, but probably would not have hurt themselves (Table 3).

The following conclusions are based on the daily training record:

1. Subjects who concentrated on cane handling only during their indoor training became bored and careless.

2. It was easier to teach subjects who had only trained for one week indoors how to adapt to the outdoor environment.

3. Difficulties which emerged early in the training were ironed out by the time of the final evaluation.

TABLE 2

Groups' Percent Mean Scores and Standard Deviations for the Test Items

	Familiar Route								Unfamiliar Route							
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Test Item	Group 1A		Group 1B		Group 11A		Group 11B		Group 1A		Group 1B		Group 11A		Group 11B	
Detects down curb	75.0	16.1	62.5	31.5	72.9	29.2	72.9	23.3	76.7	24.3	56.7	24.3	56.7	21.3	70.0	22.3
Falls off down curb	81.3	15.7	56.3	35.2	60.4	30.9	72.9	24.4	80.0	16.3	50.0	34.2	73.3	9.43	56.7	13.7
Squares up	46.7	29.8	40.0	36.5	56.7	17.9	66.7	22.1	50.0	40.8	58.3	44.9	58.3	34.4	91.7	18.6
Listens	63.3	29.3	58.3	23.4	53.3	27.5	83.3	13.7	75.0	22.8	75.0	38.2	58.3	34.6	83.3	23.6
Crosses straight	60.0	16.3	43.3	21.3	56.7	31.5	60.0	23.1	66.7	23.6	75.0	25.0	58.3	30.1	75.0	25.0
Detects up curb	76.7	17.9	73.3	14.9	76.7	26.9	86.7	14.1	91.6	18.6	75.0	25.0	75.0	25.0	91.6	18.6
Stumbles on up curb	76.7	21.3	90.0	10.0	93.3	14.9	100.0	0	100.0	0	91.6	18.6	100.0	20.4	91.6	18.6
Clears	63.3	39.0	41.7	36.7	60.6	28.3	66.7	47.1	66.7	47.1	50.0	40.8	83.3	52.7	50.0	40.8
Travels straight	80.9	15.8	76.2	25.4	81.0	10.7	81.0	10.7	63.3	13.7	60.0	16.3	43.3	19.2	56.7	13.7
Pavement position	47.6	29.4	42.9	30.9	45.2	31.3	69.1	22.5	46.7	27.5	36.7	29.3	20.0	36.5	46.7	24.9

TABLE 3

Raw Scores for the Eleven Best Performers: Familiar Route

			Possible Score									
			8	8	5	5	5	5	5	5	7	7
			Test Item*									
Subject	Rank, familiar route	Rank, unfamiliar route	1	2	3	4	5	6	7	8	9	10
Group lA												
1	1	1	8	8	4	5	4	5	5	5	7	7
2	5	3	7	7	4	5	4	5	5	5	5	5
3	15.5	6.5	6	7	3	3	2	3	4	1	7	2
Group lB												
1	8	11	7	7	5	4	4	5	4	4	7	1
2	10	2	7	8	3	3	2	4	5	2	6	5
Group llA												
1	4	8.5	8	8	3	4	5	4	5	4	7	5
Group llB												
1	10	18.5	8	8	2	4	2	4	5	5	5	3
2	10	15	6	7	3	4	4	4	5	0	5	3
3	2.5	6.5	6	6	5	5	4	5	5	5	7	7
4	2.5	6.5	7	7	4	4	3	4	5	5	5	6
5	6	5	6	4	5	4	5	5	5	5	6	6

*Test items correspond to those shown in Table l.

DISCUSSION

Evaluation Methodology

A first reaction to the data obtained is disappointment that the method of evaluating performance used turned out to be so inadequate. On the positive side it did show, in agreement with the observers' judgments, that by the end of training there were no major differences between the groups and that nearly all subjects were able to perform the subskills. However, the quantitative scores failed completely to record differences in the efficiency with which subskills were performed, and also differences in performance which occurred during the training program.

This implies that improvements in the current methods of evaluating performance need to be made, especially in the following areas. First, one evaluation only at the end of training is not enough, for it misses many of the differences in training experience that are coped with and eliminated by an expert instructor. Instead, daily performance measures need to be taken. Second, scores should say something about the efficiency and economy of the performance. (This was in fact done in later experiments in which daily measurements were taken and an objective measurement of the smoothness of performance was used--see below.)

The inadequacies of the final evaluation apart, a wealth of information was obtained from the daily training records. The justification for using this sort of information is simply that it is the only source currently available, and thus is commonly used among trainers and instructors. Therefore, until better evaluation techniques can be developed, training experiences arising from one set of circumstances should be clearly and fully described so they may be compared with the experiences of others elsewhere.

Overloading and Orientation Training

The experimental hypothesis regarding relationship between orientation training and overloading turned out to be more complicated in practice than the theory predicted. In the daily training record it was noted repeatedly that when subjects were relieved of the necessity of finding their own way round a building, or of the challenge of completing a route on their own, they became bored and lost interest in the task. Thus, instead of taking advantage of their greater freedom to concentrate on cane handling, they became slack and lazy and were careless and sloppy about their performances.

The effects of this teaching method reflected on the teacher in a similar way. She too found the lessons boring and frustrating. She was constantly having to exhort subjects to improve their performances, and yet had none of the normal incentives (such as the challenge of an interesting orientation problem) to offer them. In addition, subjects' conversation related to the task tended to diminish, so that cues and items of interest that are normally remarked on by trainees were not mentioned by these subjects. It seemed that the development of a full professional relationship between client and instructor could be impeded by such a consequence. The trainee might lose interest in the task and fail to see the potentialities of long cane mobility, while the instructor might find this a frustrating and unrewarding stage of training.

In fact these comments apply mainly to Group 11A, who spent two weeks indoors learning cane handling only. Those who spent only a week in similar circumstances (Group 11B) did not seem to suffer from boredom. They were still at a stage in which the attainment of skill in cane handling was sufficiently novel, difficult, and intriguing to command their attention. This suggests that the notion that overloading usually occurs during training may still be true, and that in the case of Group 11A the beneficial effects of reducing overloading were overshadowed by harmful effects of boredom.

In sum, it seems that the problem of overloading is secondary to the importance of proper motivation. It may still be disheartening for a trainee to be stretched beyond his capacity, but it is obviously far worse if he loses interest through not being stretched at all. Thus there is a critical level to be sought involving a balance between challenge, interest, and overloading on the one hand, and a clear, unimpeded chance to receive information and to practice, with the risk of boredom, on the other. The happy experience with Group 11B seems to indicate that for some the balance is achieved when orientation is kept out of the first week of training, but is upset if indoor training under these circumstances is continued for too long.

Inappropriate Training Environment

The suggestion that transfer between indoor and outdoor environments is made easier if it is done at an early stage of training rather than later received support from the experimenter's experience with the subjects in this experiment, and from the objective data. The latter demonstrated that those who spent only one week indoors fared the same as those who spent two weeks. However, the daily training notes recorded a definite difference, in that those who had only spent one week indoors were easier to help during the transfer period. It seemed as though subjects from Groups 1B and 11B, at an earlier stage of training, were therefore more prepared to listen to the instructions on how to cope with the situation. The others, subjects in Groups 1A and 11A, preferred trying out their own strategies. It appeared as though those who had had more training at this stage had got used to operating on their own and were reluctant to return to dependency on detailed verbal instructions.

The Level of Competence Achieved

The primary reason for embarking on this type of training experiment is to try to improve the cost effectiveness of long cane teaching. Thus the question, "What level of competence did the subjects achieve by the end of training?" is of crucial importance in assessing the effectiveness of the experimental training methods.

The first aspect of this question to be described should cover those tasks that subjects could not accomplish. A number of subjects would not have completed both of the test routes if they had not been given occasional, additional orientational tips as they negotiated them. A third of the subjects fell into this category. Regarding safety, two subjects would have had a major collision with an obstacle but for the intervention of the safety man; the rest would have completed the routes without having hurt themselves.

On the positive side, all subjects could perform the subskills, such as clearing on the up-curb; differences lay in the efficiency and smoothness with which they were performed. Of the 11 best performers we found that they could negotiate an unfamiliar route in a quiet residential area without getting lost, without injuring themselves, and having performed fairly skillfully and efficiently with their canes.

Thus, we have an indication of what useful levels of competent mobility can be achieved after only 12 or 16 hours of training. By comparison, under the traditional training method, trainees who had had an equivalent number of hours would only just have started work outdoors. While it is dangerous to extrapolate too far on evidence based on experience with young, healthy, intelligent blindfolded subjects, the implications of these results is that some blind people will profit from shortened or "crash" courses and need not be taught at the leisurely pace of the standard teaching method.

CONCLUSIONS

This experiment revealed the inadequacies of the flow-type score sheet for this particular situation. Where detailed comparisons between training schemes are to be made, the performance measures must not simply record the more obvious features of a blind traveler's performance (such as pavement position), but finer aspects of the skill as well. Thus, in later experiments use of the flow-type score sheet was supplemented by measurements of the accuracy with which the cane was used, the smoothness of the performance, and the distribution of time relative to the various subtasks performed on a test journey.

On the training side, overloading turned out to be of secondary importance to boredom in these particular circumstances. Though the possibility that overloading may occur was not ruled out, it appeared more important to establish a balance between the opposing factors of boredom and overloading. Such a balance seemed to have been struck for some subjects when training in cane handling only was restricted to the first week. This fitted in very nicely with the conclusion that subjects who stayed indoors for only one week made the best transfer to outdoor conditions. This was because they were still in a receptive frame of mind so far as listening to instructions and concentrating on cane handling were concerned.

The overall conclusion drawn from this experiment is that clients who have characteristics similar to the subjects used in this experiment could be trained effectively in a shorter time than the standard teaching method suggests. However, a further implication is that where time and money are so precious that crash or shortened courses are necessary, then every moment of the training must be scrutinized to see that it is being used to provide the optimum amount of information and the best opportunity for practice. At present it looks as though that valuable one week of indoor training could be better used. Thus, subsequent experiments in this series were designed to test methods for doing so.

REFERENCES

Armstrong, J. D. A report on the visit to Nottingham of Miss J. Woodcraft and Mr. John Williams 15th-16th November, 1968. Mimeograph, Department of Psychology, University of Nottingham, 1968.

Brown, I. D. A subjective and objective comparison of successful and unsuccessful trainee drivers. *Ergonomics*, 9, 1, 46-56, 1966.

Leonard, J. A. & Wycherley, R. J. Towards the measurement of performance of travel skills. Proceedings, Conference for mobility trainers and technologists, 27-45, Sensory Aids Evaluation Development Center, Massachusetts Institute of Technology, 27-45, 1967.

PART III

An Experiment to Determine a Long Cane User's Ability to Detect a Drop Below Ground Level

The present experiment was designed to determine a typical long cane user's threshold for detecting drops below ground level and to discover whether this particular test of ability could distinguish among different subjects' performances. The information is potentially important. An instructor should know what level of skill it is reasonable for him to expect of a client; just as he should know when it is impossible for the blind person to travel alone and when it is best for him to seek sighted assistance. Both examples cited have a direct relevance to practical problems (such as detecting down-curbs on pavements) and both raise the question of the psychological threshold for detection. The second function of the experiment underscores the ever-increasing need of those studying and teaching blind mobility to be able to evaluate accurately and objectively the performances of people and aids. In this case it was predicted that as peoples' ability to detect drops varied, it would be reflected in a wide range of scores achieved in the test.

SUBJECTS

The blind long cane user population of the City of Birmingham and its vicinity were asked to take part in the experiment. Twenty-three people volunteered of whom four were rejected for having too much residual vision.

APPARATUS

Subjects walked along a platform 32 feet long, 6 feet wide, and 6 inches above ground. Along its length the platform was bounded by a wall 10 inches high which prevented subjects falling off.

The depth of the drop was limited by a smaller platform (6 feet 8 inches by 3 feet) which could be raised and lowered to give drops ranging from 1 to 9 centimeters (cm) deep.

Safety

When subjects failed to detect the drop at the end of the long platform they were supported by an experimenter. No one said he felt afraid.

The Elimination of Additional Cues

Noise cues were eliminated by having the subjects wear earphones on top of malleable wax ear plugs. The remaining sounds were drowned by the experimenter striking a board similar to the two platforms. The position of the noise board was varied.

Vibrations set up on the long platform by the subject's cane were increased and prolonged by an experimenter striking the long platform in time with the subject's steps.

Subjects were asked not to try to judge the distance to the drop, and were prevented from doing so by being led back by circuitous routes to different starting points on the long platform. They were also asked not to use a "slide technique" to detect the drops, but instead the touch technique normally used for outdoor travel on rough pavements (Suterko, 1967).

PROCEDURE

Subjects examined the apparatus and had all of its aspects explained to them. They were asked to detect the depth of the drop at the end of the long platform without stepping off. Also, it was explained that if they detected the edge of the platform rather than the drop itself the trial would not be scored, but would have to be rerun.

Following each run the height of the small platform was adjusted, with the different depths presented in random order. The range of depths was from 1 to 7 cm, with each depth being given six times, subjects making 42 trials.

Modifications to the Procedure

When the experiment had got under way it was discovered that some subjects were physically incapable of complying with all requirements. Due to fatigue, seven subjects were unable to attempt all 42 trials, and the procedure was modified for them. Efforts were concentrated on discovering what depths they could detect 50 percent and 80 percent of the time. This meant they made fewer attempts at the smaller drops (i.e., 1 and 2 cm) and more towards the middle and end of the range.

Criteria for Scoring

Subjects were deemed to have successfully detected a drop if they stopped before stepping off the long platform; a fail was recorded if they stepped onto the small platform. The trial was rerun if subjects detected the edge of the platform rather than the drop. False positives were recorded if a subject indicated that he thought he had detected a drop before he had in fact reached the end of the long platform. However, so few false detections were made that they were not included in the results.

Results

Because seven subjects were unable to attempt six trials at each depth, the results for the whole sample have been divided into two groups. Group 1 includes those who were able to fulfill all the experimental requirements; Group 2 includes the seven who were not.

The experimental results are shown in Table 1.

Group 1

Subjects in this group appeared to become more reliable in their ability to detect drops at a depth of 4 cm. Eight subjects were able to detect this depth 50 percent or more of the time, with the median score 58.4 percent correct detections. At 5 cm they were able to detect the drop significantly more often than not, with the median score at 83.3 percent correct detections; eight of them achieved this level or better.

Group 2

The results for this group seem to be inferior. The median for 4 cm was only 40 percent with three subjects making 25 percent or fewer correct detections, while at 5 cm it was 66 percent; with six subjects making 60 percent or more. However, at 6 cm the median was 100 percent with five subjects scoring 85 percent or more correct detections.

TABLE 1

Depth of Drops and Median Score for Whole Sample and Sample By Groups

	CM	Whole Sample	Group 1	Group 2
Main Platform	1	0	0	0
	2	0	16.7	0
	3	33.3	33.3	0
	4	50.0	58.4	40.0
	5	83.3	83.3	66.7
	6	100.0	91.7	100.0
	7	100.0	100.0	100.0
Full Scale		N = 19	N = 12	N = 7

Differences

In spite of what seem to be differences between the two groups a Mann-Whitney U test (Siegal, 1956) showed that they were not in fact significant.

DISCUSSION

The Measured Ability to Detect Drops as a Measure of Cane Handling Ability

The results of this experiment were not as clearcut as one would have liked. Though it was reasonable to assume that older subjects and those in poor health--in other words, those who made up Group 2, would show abilities inferior to the comparatively young and fit people in Group 1, this did not in fact appear in the results. Nevertheless, there is evidence that there are quantifiable differences between peoples' skills in this area. For example, the experiment has shown that whereas some people were accurately responding to a drop of 4 cm (two responded correctly every time at that height) others could only do so when the drop reached the 6-cm mark. Thus, though the two groups in this study were not significantly different from one another, it can safely be suggested that given large enough samples this particular test will be of use in future evaluations.

The Validity of the Test

The problem of assessing the validity of this test rests upon the question of how far the laboratory situation in which it was carried out matches up to the long cane user's day-to-day situation and requirements. In other words, has the stringency of the experimental procedure left us testing a totally artificial skill? It is true for instance that in a real life setting long cane users detect drops, such as down-curbs, as much by auditory and tactual cues as they do by proprioceptive cues. For example, they will hear a car crossing the line of travel, or feel the pavement sloping towards the road. Nevertheless, it is reasonable to expect people to be able to detect drops in circumstances in which proprioceptive signals are the only ones available (e.g., the unguarded manhole), and furthermore the majority have been taught during training to cope with this eventuality.

Thus, though the laboratory setting for the test may have been an unusual one, the skill tested is authentic.

The Ability to Detect Drops as a Pyschophysical Measure

The importance of these experimental findings does not lie so much in the information they give us about a blind person's ability to detect certain signals, but rather in defining circumstances in which the blind traveler can be expected to operate safely and efficiently. The fact that over half of the present sample could detect 4-cm drop 50 percent of the time, and 5-cm drop 80 percent of the time, should therefore be related to real travel requirements. In the general conditions prevailing in Great Britain this can be done fairly simply. For example, the average drop off the pavement to the road in a typical suburb is about 10 cm, a depth that we now know the majority of long cane users should be able to detect easily. However, there is cause for alarm in towns and cities because the average drop from the pavement to the road is between 3 and 4 cm. Since these particular drops have to be detected against a background of noise and distraction it is clear that the chances of a blind pedestrian unwittingly stepping into the road are high.

Nevertheless, it is pleasing to observe that even the less skilled people in the present sample were able to detect a 6-cm drop reliably, and so by using the long cane have managed to avoid a considerable number of jolts and shocks. Furthermore, if some people can reliably detect drops as small as 3 and 4 cm, then the long cane has been demonstrated to be a very effective mobility aid in this respect.

REFERENCES

Siegal, S. *Nonparametric statistics for the behavioral sciences.* New York: McGraw-Hill, 116-27, 1956.

Suterko, S. *Long cane training. Its advantages and problems.* Proceedings conference for mobility trainers and technologists, Sensory Aids Evaluation and Development Center, Massachusetts Institute of Technology, 13-18, 1967.

PART IV

An Experiment to Determine the Effect of Providing Augmented Knowledge of Results on the Acquisition of the Skill of Cane Handling

The results of previous experiments made it clear that certain people might well be given adequate training in long cane mobility through a shortened or "crash" course. This possibility increases the need to scrutinize current training practices to ensure that they allow maximum use to be made of every moment of the training.

One area which does not match up to such scrutiny is the initial one or two weeks of training. In the author's experience the difficulties encountered in this period center on the standard method of teaching cane handling, which includes methods of describing the task of cane handling, and of specifying the correct arc width and extent of cane contact.

A primary difficulty is the standard practice of giving a verbal description of the cane handling technique. As a result, the learner does not have his attention directed to the proprioceptive, kinesthetic, and tactual cues which will form the foundation of his skill, but instead has to pick these up for himself (see Part I). Therefore, it seemed wise to seek an alternative way of describing the skill, one which would avoid the pitfalls of verbal, visually oriented descriptions, and at the same time would give maximum information about the task.

Although it is not possible to provide the learner with enough information that is intrinsic to the task through feedback, the form of extrinsic or augmented feedback used ought at least to direct the learner's attention to those natural sources of information. Two methods of providing augmented feedback were chosen to do this.

The first was an adaptation of Holding and Macrae's (1964) response restriction technique. This was a form of motor guidance whereby a subject's movements are forcibly terminated by a barrier.

A variation on this guidance technique was also tested in which information about arc width and cane contact was given tactually by way of the floor surfaces which the subject touched with his cane. In this way he could distinguish a correct from an incorrect placement of the cane by the feel of different floor textures.

These two teaching methods were thought to have advantages over the standard technique. First, they provided concurrent feedback, and so avoided the confusion that usually results when delayed feedback is given about a repetitive task (Lee, 1950). Second, because such feedback comes after the subject has committed himself to the task, it could not be used to modify the current movement, but must be referred forward to future attempts. Thus, some of the problems involved in the use of action feedback are avoided (Macpherson, Deese, and Grindley, 1949).

Such are the general advantages of providing nonverbal extrinsic feedback, but there are others which relate more specifically, either to the use of response restriction techniques, or to methods of providing tactual Knowledge of Results (K-R). However, these will be examined in the "Discussion" section.

With these two techniques as a basis, certain modifications were tested to find out how much information the learner could profitably use. In one experimental setting, information concerning the lateral and medial placement of the cane was given. In another, only the lateral placement was identified and subjects were expected to pick up from the standard verbal description an idea of how much cane contact was necessary and where such contact should finish.

SUBJECTS

Thirty paid volunteers, six to a group, acted as subjects. Their characteristics were the same as those described in Part II of this series, the only difference being that they were given a half hour's training followed by 15 minutes of testing for five consecutive days.

Training

The five groups of subjects were given identical training (following the standard procedure), except where experimental variables called for a difference. They followed the same schedule regarding training environment. For the first three days they were restricted to moving in a large laboratory, while in the last two lessons they traveled about in a large building.

All subjects were given verbal instructions which included verbal K-R. However, the control group was the only one that was given K-R concerning arc width. For example, response restriction groups were told to strike the barriers softly and low down. The tactual K-R groups were told to let their canes touch only the smooth sections of the floor. On aspects of the skill other than those relating to arc width and cane contact all six subjects were given verbal instructions.

During the time the experimental groups spent in the laboratory their movements were restricted to walking up and down a constructed pathway. They left it only to rest or to be tested.

Group 1. The Control Group

Subjects in this group were given the standard training and as a consequence were taught almost wholly verbally. During their time in the laboratory they moved about the whole floor space.

Group 2. Tactual Knowledge of Results (TKR 1)

Augmented feedback was provided for this group in the form of tactually discriminable differences in the surface texture of the floor of the pathway. The floor was made up of five strips of two types of texture. The central strip on which the subjects walked was roughly textured. On either side of this were smooth sections in which the subject was told to land his cane. The cane was supposed to land at the outside edge of the smooth section and slide into the center until it lifted off just before touching the central rough strip. Outside the right- and left-hand side smooth sections were rough sections which, if the subject touched them with his cane, warned him that his arc had been too wide (Fig. 1).

Group 3. Response Restriction (RR 1)

A pathway for Group 3 was built to provide a double restriction. A wall of plastic bricks (25 cm high) restricted the outward swing of the cane, while the edge of a hardboard strip (one cm high) restricted its inward swing. The hardboard was 25 cm wide and provided the surface on which the subjects walked (Fig. 2).

Figure 1. Apparatus used by TK 1.

Groups 4 and 5

The training techniques used for Groups 4 and 5 were simply modifications of those used for the previous two groups. These subjects were given no information about the medial extent of the arc, except in an initial verbal description that was given to everyone.

Group 4

Instead of walking on a central rough section, Group 4 walked on a path that was continuous with the two sections in which the cane was supposed to land, i.e., a smooth surface. Hence, though they contacted a rough section if the cane was swung too far outwards, they received no warning if they slid the cane too far medially.

Group 5

The training conditions for this group were identical with those of Group 4 except that the lateral extent of the cane's swing in this case was restricted by the wall of bricks.

THE PATHWAY

The apparatus enabled subjects to walk straight and relieved them of the fear of colliding with obstacles by the use of two metal handrails which ran along either side of the subject. The rails projected out over the pathway so that they did not interfere with the movement of the cane.

The dimensions and characteristics of the floor of the pathway are shown in Fig. 3. For the purposes of this experiment the "correct" arc width and extent of cane contact was defined as follows:

Figure 2. Apparatus used by RR 1.

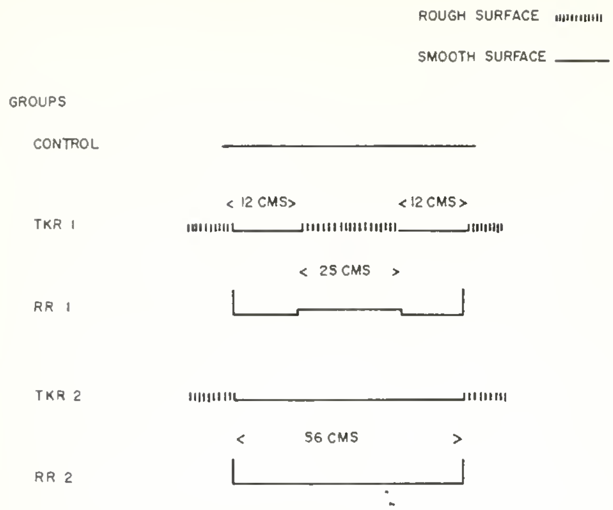


Figure 3. Dimensions and Characteristics of Floor of Pathway.

1. Lateral limit of the cane's swing: half of the mean of the male population's shoulder width plus 5 cm (i.e., 27 cm from the center of the pathway).

2. Medial limit of the cane's contact with the floor; the above minus 15 cm (i.e., 12 cm from the center of the pathway).

3. Extent of cane contact with the floor: 15 cm.

These measurements correspond to the instructions usually given to trainees during indoor training.

The control group was told to land the cane 5 cm wider than the shoulders and to slide it medially 15 cm.

METHODS OF TESTING AND SCORING

After each training session subjects were tested as they walked the length of the room unaided. During the walk they tried to perform exactly the same movements they had under training conditions. Data were obtained by having the subject walk down a continuous sheet of paper with ink pens attached to his feet, and another ink pen inserted into his cane tip. Thus, the extent of the cane's contact with the floor, and foot prints, were marked.

From this an indication of the direction of travel and a measurement of the dynamic base (Scrutton & Robson, 1968) was obtained by linking successive foot prints by a straight line. The accuracy with which the cane had been placed was then scored by measuring from the center of the dynamic base to the lateral and the medial points of the arc. Extent of cane contact was also measured.

The measurements obtained were:

1. Distance from the center of the dynamic base to the most lateral point of the arc;

2. Distance from the center of the dynamic base to the most medial point of cane contact with the floor;

3. The extent of cane contact with the floor.

Finally, throughout the training, daily records of each subject's progress were kept.

RESULTS

The data obtained from the daily test walk were recorded in the form of error scores. To do this, the actual position at which the cane landed, or the actual extent of cane contact with the floor, was recorded as a plus or minus score, according to whether it was too wide or too narrow, too long or too short. Thus, accurate positioning or movement of the cane gave scores of 0. Most of the results are presented in this form as signed mean error scores (see Tables 1, 2, and 3; Figs. 4, 5, and 6).

An alternative method of analyzing the data was also used, in which an absolute error score was obtained by ignoring the sign of the error. In this form, the data do not give a detailed picture of how subjects performed, and so blur possible differences between groups; nevertheless, the form does concentrate more stringently on the size of the errors.

The data were first analyzed to see whether the various training conditions had caused the groups to perform differently. For this the

TABLE 1

Lateral Point of the Arc

Day	Controls Mean	Controls SD	TKR 1 Mean	TKR 1 SD	RR 1 Mean	RR 1 SD	TKR 2 Mean	TKR 2 SD	RR 2 Mean	RR 2 SD
1	14.22	14.94	-5.17	9.53	6.31	13.38	1.06	10.91	-1.3	11.03
2	12.91	14.09	-5.70	11.04	0.74	16.7	1.24	11.33	-3.74	8.55
3	9.58	12.39	-6.32	7.99	0.24	14.2	1.81	8.7	-4.64	8.13
4	13.26	9.09	-5.94	9.29	-2.24	15.92	3.27	11.24	0.81	10.75
5	13.78	11.44	-6.33	12.22	-3.16	15.98	-3.16	15.98	1.26	7.55

TABLE 2

Medial Point of the Arc

Day	Controls Mean	Controls SD	TKR 1 Mean	TKR 1 SD	RR 1 Mean	RR 1 SD	TKR 2 Mean	TKR 2 SD	RR 2 Mean	RR 2 SD
1	17.25	15.17	6.36	10.14	13.74	14.78	7.74	12.1	0.96	14.74
2	15.92	15.26	3.77	10.32	5.14	19.12	7.96	13.4	-0.52	13.24
3	20.82	13.33	6.62	12.16	3.31	14.30	4.88	9.67	1.19	13.13
4	14.33	14.37	3.38	10.55	0.68	14.97	8.77	10.61	2.77	12.86
5	15.11	16.33	1.7	12.06	-3.26	13.27	7.34	10.88	-0.48	12.83

TABLE 3

Cane Contact

Day	Controls Mean	Controls SD	TKR 1 Mean	TKR 1 SD	RR 1 Mean	RR 1 SD	TKR 2 Mean	TKR 2 SD	RR 2 Mean	RR 2 SD
1	6.49	13.49	-4.68	7.34	0.22	12.0	-1.83	10.07	9.09	8.81
2	7.0	11.48	-0.03	7.86	2.36	9.68	1.70	12.27	8.71	6.85
3	-2.87	12.43	-0.84	9.74	8.87	11.59	2.90	13.47	12.84	11.59
4	7.89	19.56	2.01	12.26	6.48	16.94	7.81	19.75	16.57	13.27
5	9.23	19.14	0.0	11.91	11.75	15.71	8.85	18.77	14.86	14.87

Kruskal-Wallis one-way analysis of variance, and the Mann-Whitney *U* Test were used (Siegal, 1956). Only the Groups' data for days 1, 3, and 5 were analyzed. The former test was applied to the data for all groups together, and the latter test to specific pairs of groups. The significance levels quoted for these analyses relate to two-tailed tests.

When data, in the form of signed means, were analyzed according to the Kruskal-Wallis test, there were significant differences between the groups on all three days on all measurements. The significance level ranged from 0.05 to 0.001.

The more detailed analysis of the Mann-Whitney *U* Test showed that the only really consistent differences were that the control group tended to have a wider arc (i.e., wider lateral and medial cane placements) than all or most other groups. Extent of cane contact was more extensive than that for two other groups on day 1 only. There were some differences between the experimental groups, but these were few and showed no consistent pattern.

A Kruskal-Wallis analysis of the absolute mean error scores showed fewer significant differences. For the data on lateral placement there were significant differences on days 1 and 5, and for medial placement on days 1 and 3. Here the significance levels ranged from 0.05 to 0.02. The data on the extent of cane contact revealed no differences between groups.

Again, the Mann-Whitney tests showed that the significant differences revealed by the Kruskal-Wallis test were caused by the fact that the control group's performances tended to be inferior to those of the other groups. Differences between experimental groups were so few as to have no significance.

The standard deviations from the means for all three categories of data (i.e., extent of cane contact; lateral and medial placement) showed so few significant differences between groups that it seems fair to conclude that the different training conditions had little effect on the variability of an individual's performance.

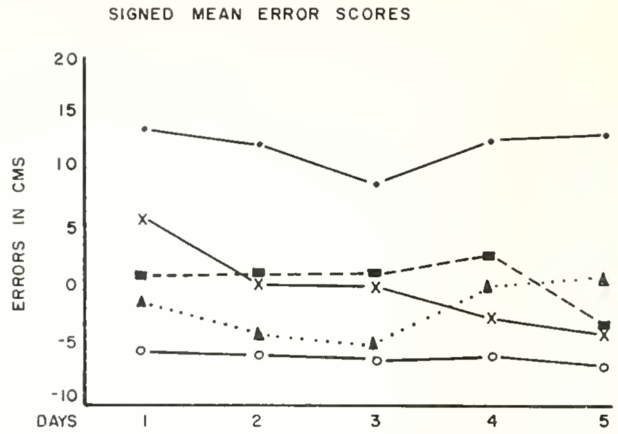


Figure 4. Lateral Point of the Arc.

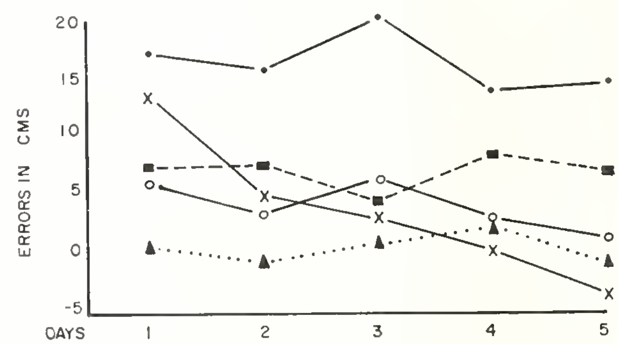


Figure 5. Medial Point of the Arc.

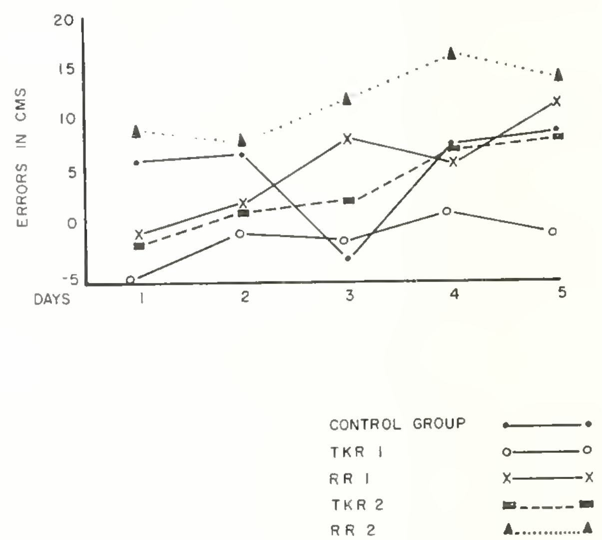


Figure 6. Extent of Cane Contact.

CORRELATIONS BETWEEN PERFORMANCE MEASURES

The only significant correlations between performance measures were as follows:

Day 1. lateral with medial placement:

Signed means $r_s = 0.532$, $p > 0.01$ (one-tailed test);

Absolute mean error $r_s = 0.578$, $p > 0.01$.

Day 3. extent of cane contact with medial placement:

Signed means $r_s = 0.615$, $p > 0.01$;

Absolute mean error $r_s = 0.385$, $p = 0.05$.

Day 5. extent of cane contact with lateral placement:

Signed means $r_s = 0.397$, $p > 0.05$;

Absolute mean error $r_s = 0.126$, p is not significant.

COMMENTS FROM THE DAILY TRAINING RECORD

Control Group

This group's greatest difficulty was that of concentrating on cane handling. Other things distracted them and made their progress generally slower and more difficult than that of the others.

KR 1 (......______......______......)

At first this group found it difficult to discriminate the different textures. By the second day they were reasonably competent at this, and from then on appeared to be careful and precise in their performance.

R 1 ()

These were the least impressive of the Experimental Groups. Their task at first seemed to be too confusing (their movements were frequently being stopped by the restrictions) and later too easy (all they had to do was to move the cane and let the restrictions do the rest).

KR 2 (.....______.....)

This group was, like TKR 1, careful and sensitive towards the skill. It looked as if they had to take care to make maximum use of the apparatus.

RR 2 ()

By the end of the first day RR 2 had lost the carelessness which characterized RR 1. Henceforth, though, some of them had difficulty with the wrist movement and the shape of the cane's movement on the floor; they generally tried to use the apparatus well by striking it gently and low down.

GENERAL COMMENTS ON THE EXPERIMENTAL CONDITIONS

From the instructor's point of view it was useful to have the training environment controlled and simplified. Experimental subjects were almost immediately sure of their safety, while the controls remained inhibited and distracted by their fear of collisions.

By the third day of training the experimental setting became very boring for the instructor, though none of the subjects found it so.

DISCUSSION

The results of this experiment will be examined in two sections. In the first, the differences between the Control and Experimental Groups will be discussed. The second will contain an assessment of the comparative merits of the experimental techniques.

Two of the three objective measurements which were recorded daily throughout the experiment show quite clearly that the Control Group's performance was, in general, qualitatively different from the performances of the Experimental Groups. For lateral and medial cane placement the Control Group consistently overestimated the width of the movement, and in general made larger errors. However, their training conditions did not affect their ability to learn the correct extent of cane contact. Here they performed equally as well as the Experimental Groups.

The comments contained in the daily training record make clear the reasons why these differences occurred. Here the consistent theme was the contrast between the comparative simplicity of the experimental situation and the complexity of the Control Group's training setting. This contrast was produced solely by the effect of the training apparatus on reducing the number of distractions that normally plague both client and instructors.

In the experimental setting no one had to worry about overbalancing, bumping into obstacles, or veering. Instead, after one or two attempts, subjects could easily walk up and down the apparatus. In other words, they had immediately attained a level of mobility within the apparatus that usually comes only after a number of lessons in "pre-cane" skills. Thus, with these Groups, cane handling could be taught immediately so that when the time came to walk outside the apparatus they had developed enough skill and confidence to avoid the normal difficulties. Therefore, if cane handling can be taught first, in the absence of other difficulties, then the skill itself will provide the learner with the ability to cope with these difficulties when he has to. In this way the difficulties may never seriously interfere with his performance.

Subjects in the Experimental Groups had therefore an initial advantage which other characteristics of the apparatus enabled them to capitalize upon. The main point in their favor was that from the first they had an especially clear description of the task, which from then on acted as a constant regular source of feedback. This meant that from the beginning they were able to monitor their own performances. Consequently, while subjects in the Control Group tended to *ask* whether they were making the right movements, those in the Experimental Groups made such pronouncements for themselves.

This constant supply of feedback helped in another way, by making it easier for subjects in the Experimental Groups to shift attention to different aspects of the skill. It is a common experience among instructors that, when they have taught the client to perfect one part of the skill (e.g., hand position), and they then try to correct something else (e.g., arc width), performance of the first part often immediately deteriorates. Though this happened for the Control Groups, the Experimental Groups did not seem to have such trouble. For them, instructions regarding cane placement were always concretely present so that they were free to concentrate on other features of the skill without running the risk of forgetting the primary features.

DIFFERENCES BETWEEN EXPERIMENTAL GROUPS

The results of the statistical analysis of the data show that there were no consistent differences between the Experimental Groups. Therefore, it seems fair to conclude that on a general level it does not matter which of the experimental techniques is used in training. However, since a choice does have to be made, and since the daily training record did suggest that the groups had different experiences according to their particular circumstances, it is worthwhile considering the information obtained during the course of the experiment.

The main emphasis of the training record was always on the difference between the tactual K-R groups and the response restriction groups. The first appeared to have a lighter, more sensitive touch with the cane, and to perform other aspects of the skill (such as hand position) with greater care and precision. The response restriction groups either never developed these qualities (e.g., RR 1 never did) or did not develop them as early as the others.

The source of these differences may be found in the contrasting demands made on the subjects by the differences in construction of the training pathway. Now while both types of experimental training situation gave experimental subjects the advantage over the controls of always being aware of their errors (as far as cane movement was concerned) there were differences in the amount of active control that subjects were required to exert to avoid errors. For the tactual K-R groups an active involvement was demanded. Though the apparatus warned them when they had made an error, the responsibility for controlling their movements and for avoiding mistakes was left entirely with them. What is more, if the cane tip was put down on the wrong spot, then it had to be dragged across the rough section on to the smooth. This can be regarded as a form of punishment, because it was mildly difficult to do, and so irritated them. Consequantly, to avoid the punishment, subjects had to concentrate on the skill's intrinsic feedback.

By contrast, the R-R groups were able to abrogate responsibility for their movements. Though as is general in a response restriction training situation (Holding and Macrae, 1964) they had to adopt their own movement pattern for carrying out the response; they could rely entirely on the restriction to ensure that the response was correct. Hence, as there was nothing forcing them to attend to intrinsic cues, it began to look as if the effect of relieving them of motor demands was to relieve them of the need to concentrate on perceptual demands as well. In other words, though they had the double advantage of being prevented from making errors while having error information made available to them, they seemed to respond by relying on the former and ignoring the latter.

These factors seem to have affected the subject's general attitude to learning the whole skill. For instance, it was difficult to motivate the R-R groups to maintain such things as a correct hand position, because to them these requirements did not appear essential. Their task, of walking up and down the apparatus, could be performed quite well without that.

On the other hand the tactual K-R groups had to maintain these features of the skill in order to avoid the "punishment." But they also became quite involved in their own progress, and so tried very hard to walk the length of the apparatus without touching the rough sections.

Previous experience (Gordon, 1968) has shown that it is the off-target character of such feedback which contributes to subjects' interest. This is because subjects know when their performances are improving, because as they do so they receive less and less warning of having missed the target.

When we come to consider whether it is necessary to give a learner information concerning the point at which the slide phase of the movement should be halted, the objective data obtained from this experiment shows that it does not matter whether such information is given or not. (There were no consistent differences between the groups for the data on medial cane placement.) All that could be said is that it seemed to be one of the factors which made subjects in Group TKR 1 take great care over the skill, and which gave them pleasure when they got it right.

CONCLUSIONS

The results of this experiment demonstrated that a subject's progress in acquiring some aspects of the skill of cane handling can be affected by the type and amount of augmented feedback which he is given. Subjects trained according to the standard method (in which they are given only verbal instructions) consistently overestimated the extent of the required movement, and in general made larger errors than those who were given either tactual K-R or who were trained according to a response restriction technique.

The advantages of the experimental training environments seemed to be that they provided controlled, simplified settings in which subjects gained a useful level of "instant" mobility. Thus subjects easily acquired a sufficient skill at cane handling to enable them to cope with some of the difficulties that usually upset the learner. The constant supply of feedback that was available also helped them to gather information about the task for themselves, and to attend to more than one aspect of the skill at a time.

Though the differences between the experimental groups were not evident according to the objective measurements, the trainer came to the conclusion that the setting which required the most active involvement on the part of subjects produced the more skilled cane users. The response restriction method, which allowed subjects to abrogate responsibility for their movements, was therefore considered less successful than the technique for providing subjects with tactual K-R. However, it did not appear to matter whether subjects were given information about both lateral and medial cane placement or simply the former.

On the basis of this study it does seem fair to suggest that better use could be made of the initial training period than is usually the case. However, before any really firm conclusions can be reached it is necessary to test these findings in a less artificial atmosphere--that is to say with blind trainees who are set to undertake a full course in long cane mobility, rather than with blindfolded volunteers undergoing a short training experiment. A full-scale evaluation of this sort has been undertaken, and the results will be reported in a forthcoming paper.

ACKNOWLEDGEMENTS

This study was carried out at the Blind Mobility Research Unit at the University of Nottingham under the auspices and financial assistance of the Medical Research Council. I would like to acknowledge the supervisory help given by the late Dr. J. A. Leonard and the practical assistance given by Miss E. Leigh and Mr. R. Crouse.

REFERENCES

Gordon, N. B. Guidance versus augmented feedback and motor skills. *Journal of Experimental Psychology*, 77, 24-30, 1968.

Holding, D. H. & Macrae, H. W. Guidance restriction and knowledge of results. *Ergonomics*, 7, 289-96, 1964.

Lee, B. S. Effects of delayed speech feedback. *Journal of the Acoustical Society of America*, 22, 824-6, 1950.

Macpherson, S. J., Deese, V., & Grindley, G. C. The effect of knowledge of results on learning and performance: 111 the influence of the time interval between trials. *Quarterly Journal of Experimental Psychology*, 1, 167-74, 1949.

Scrutton, J. & Robson, P. The gait of fifty normal children. *Physiotherapy*, 54, 1968.

Siegal, S. *Nonparametric statistics for the behavioural sciences.* New York: McGraw-Hill, 1956.

TWO INSTRUMENTS FOR THE BLIND ENGINEER

John A. Phillips
Peter M. Seligman*

Department of Electrical Engineering
Monash University
Clayton Victoria Australia

PART 1

A Braille-Reading Digital Multimeter**

Abstract

Hitherto, multimeters for use by blind persons have been of two types:

1. Conventional moving-coil type, with a mechanical locking device which enables a follow-up pointer to be brought up to the meter pointer in order that the reading may be taken against a braille scale;

2. Potentiometric type, with an auditory null. The reading is taken by moving a pointer across a braille scale until null is achieved.

Both types of instrument make the taking of readings a more complex procedure for the blind person than for the sighted person. Recognizing that it would be desirable to make the process simpler rather than more complicated for the blind person, the design and construction was undertaken of a braille-reading digital multimeter.

An instrument with a tactile digital output necessarily gives information in sampled rather than continuous form. For this reason, and also in order to keep the user's hands as free as possible, the instrument has a supplementary auditory output. This output is a continuous tone of frequency proportional to the digital output, and enables the user to appreciate quickly the order of magnitude of the quantity being monitored and also its time dependence. He can, for instance, tell whether the quantity is increasing, decreasing, oscillating, or varying erratically as would be the case with a poor connection. When an accurate reading is required, this is read in braille on depression of a press-to-read panel. The panel is strategically placed so that it can be reached by the left (braille reading) hand, leaving the right hand free.

The instrument has a three-digit, solenoid-operated readout and has ranges and accuracy similar to those of conventional multimeters. It is battery operated and portable, weighing 8 1/2 lb. and measuring 4" x 8" x 11".

---

*Now at 146 The Boulevard, Essendon, W.5, Victoria, Australia.
**Designed by P. M. Seligman, supervised by J. A. Phillips, for a final year project (1967) in Electrical Engineering at Monash University.

INTRODUCTION

The requirement for the instrument described here arose when a blind student was enrolled in the degree course in Electrical Engineering at Monash University. The instrument was designed and built within the Electrical Engineering Department and was successfully used by the student in his laboratory work for the latter two and a half years of the course.

It must be pointed out here that the design is a prototype and should not be considered to be a final version of the instrument. Improvements which could be implemented in a final version will be included in this paper.

Description

A block diagram of the scheme used is shown in Fig. 1. The instrument consists of two linear voltage-controlled oscillators (VCO), one of which is fed with the input voltage and the other with a reference voltage so that it runs at a frequency of one hundredth of that at which the first oscillator runs at full scale. Both oscillators run continuously, the first oscillator is gated by the second and the pulses within the fixed intervals are counted. The final value of the counter is displayed in braille by the readout unit. Since both the counter and the readout unit draw a fairly heavy current, a push-to-read arrangement is used to conserve battery life. The sequence after the press-to-read panel is operated is as follows:

1. Power is applied to all logic circuitry and after waiting for contact bounce to cease, the reset pulse to all flip-flops is removed.

2. A gating circuit operates on the first pulse from the reference oscillator to arrive after the press-to-read panel has been pressed.

3. After reception of this pulse, the gate is open and the counter counts input VCO pulses.

4. On reception of the next pulse from the reference oscillator, the gating circuit closes the gate and sends out an "end-of-count" signal.

5. The "end-of-count" signal closes a switch which applies power to the readout, allowing it to display the reading at which the counter stopped.

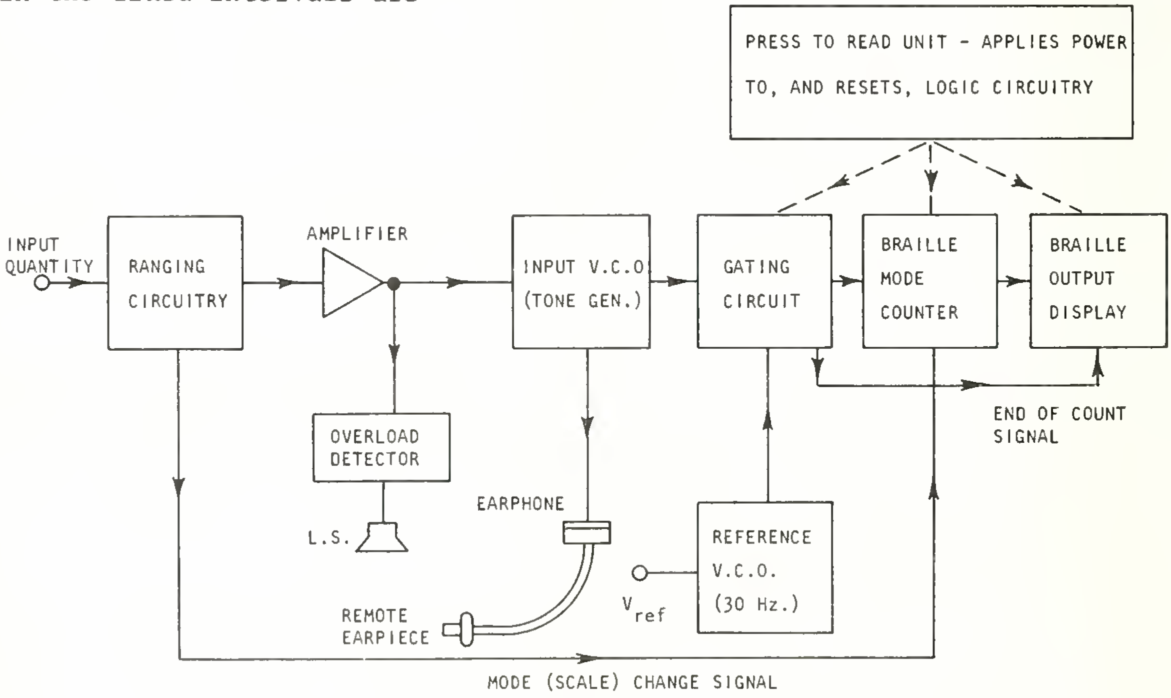


Figure 1. Block Diagram: Braille-Reading Digital Multimeter

6. On releasing the panel, all power is removed from the circuitry and the system is returned to its "dead" state.

Further operation of the panel resets the counter and the sequence 1 to 6 is repeated. A graphical representation of the sequence is shown in Fig. 2.

An auditory monitoring signal (sawtooth wave) is taken from the input VCO, or tone generator, to a transducer which consists of a dynamic-type, miniature earphone. Because the circuitry of the multimeter is floating and can be at a potential of several hundreds of volts above ground, it is essential to have good electrical insulation between it and the user. The transducer is therefore placed *inside* the instrument, the sound being piped out via a flexible plastic tube. The tube is fitted at its remote end with the plastic earpiece from the earphone.

A further function with which the multimeter is fitted is an overload alarm. This alarm produces a loud beeping from a separate transducer and is heard without the earpiece. It operates with inputs in excess of 140 percent of full scale and also with reverse polarity inputs. The alarm however does not afford any protection when the instrument is switched off.

Lastly, a pushbutton is provided for checking the calibration of the multimeter. Its operation should produce a full scale reading on the digital display. A failure to do so usually indicates that the batteries need replacing.

DESIGN

The lines along which the instrument was designed will now be described. Since the discrete circuitry in many places could be replaced by integrated circuitry, and since the logic circuitry is based on now obsolete RTL devices, full circuit diagrams will not be given here.

Ranging Circuitry and Input Amplifier

The ranging circuitry used in the instrument is very similar to that used in commercial multimeters having ac and dc current and voltage ranges. The difficulty of the nonlinearity of ohms ranges would have resulted in a high degree of extra complexity, thus these were excluded from the design. The ranging circuitry is of a type which has common linear scales for all ranges. The ranging circuitry is passive and makes use of a current transformer.

The dc-input amplifier following the ranging circuitry serves two purposes: first, it acts as a buffer to ensure that no signal generated within the instrument itself can appear at its terminals (such effects are most disturbing); and second, it provides gain. The linearity of the VCO circuit used, depends to a large degree on the voltage level from which it is fed. The full-scale

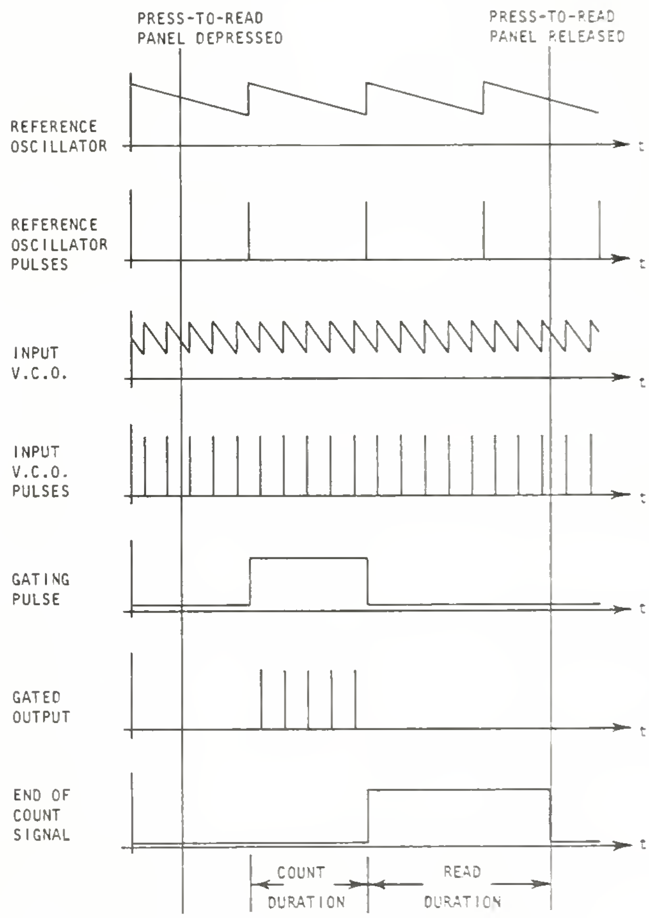


Figure 2. Operating Sequence

voltage derived directly from the ranging circuitry is 125mV--insufficient to achieve the accuracy required. The amplifier consists of an IC operational amplifier (709c) with shunt feedback and provides a voltage gain of 30. Its input resistor replaces the meter movement plus swamp resistance of a conventional multimeter.

Because the interval over which the counter gate is open is of the same order as the period of mains power frequencies, it is essential that the output of the rectification circuitry for the ac ranges of the instrument be well smoothed. A time constant approximately equal to that of a mechanical meter movement was used. The same effect could also have been achieved, however, by placing a capacitor in parallel with the shunt feedback resistor of the operational amplifier, limiting its frequency response to a few Hz.

The operational amplifier is protected against overload by two silicon power diodes connected back-to-back across its input. Power diodes, rather than light current diodes are used because of the low-source impedance from which the circuit is driven.

Voltage Controlled Oscillators

The reason that a VCO is used for the reference oscillator as well as for the input, is partly a matter of design convenience. With the exception of the values of the timing components, the circuits for both oscillators are the same. There is an additional advantage in that any slight instability (due to battery voltage variation or temperature) in the frequency of one oscillator, approximately tracks with the instability of the other. Thus the overall accuracy of the instrument is significantly higher than the accuracy of either of the VCO's.

The oscillator design itself consists of a miller-integrator which is reset by a form of large-backlash schmitt trigger. The output of the integrator ramps down, at a rate proportional to input voltage, until it reaches the lower limit of the backlash, when resetting is initiated. This is performed by a transistor which charges the integrating capacitor from the supply rail while a diode holds the input end of the amplifier at near earth potential. When the output reaches the upper limit of the backlash, resetting is terminated and the integrator-output voltage begins to ramp down once again. A pulse output is obtained from the resetting circuit, the tone output for auditory monitoring being taken directly from the integrator output. Each VCO uses three NPN and two PNP silicon transistors.

A constant voltage source is required to stabilize the frequence of the reference VCO. To provide this, two constant current sources are used to develop fixed voltages across zener diodes. Each of these voltages acts as a reference for the other current source. The circuit provides excellent stability against variation of supply voltage and continues to operate when the supply has fallen to within a fraction of a volt of the reference level. It also does not suffer from the disadvantage of single-zener diode references, i.e. high current consumption with nominal supply voltage.

Braille-mode Counter

The braille-mode counter consists of three separate sections, one for each digit; units, tens, and hundreds, with each digit counting directly in the braille numeric code and operating a separate solenoid-actuated display. This is in contrast to other braille readout schemes in which digits must be read sequentially from one unit.

In this multimeter, as in many multimeters, for the measurement of voltage, interdecade ranges are provided. The range sequence is 10-25-100 etc. For 1-percent resolution therefore, the most significant digit needs only to be able to read 0, 1, or 2 and is simpler than the units and tens digits. The units digit on the other hand, is designed to count in either mod 10 or mod 4 and is slightly more complicated than the tens digit which counts in mod 10 only. This aspect of the design will be discussed at a later stage, the design of the basic mod 10 counter will be dealt with first.

Basic Mod 10 Braille Counting Stage. Braille numerals are produced by a four-bit code of raised dots in the braille positions 1, 2, 4, and 5, in the following manner:

Four J-K flip-flops are used, one per-dot-position. The counter is synchronous; i.e. its bistable elements change state simultaneously on a clock pulse applied to all trigger inputs; and it could be described as a shift register with multipath feedback.

Figure 3 outlines the braille numeric code, with 1 representing a dot present and 0--no dot present.

Numeral	A	B	C	D
1	1	0	0	0
2	1	0	1	0
3	1	1	0	0
4	1	1	0	1
5	1	0	0	1
6	1	1	1	0
7	1	1	1	1
8	1	0	1	1
9	0	1	1	0
0	0	1	1	1

← Carry = $D\bar{A}$

A ● B ●

Dot Positions

C ● D ●

Figure 3. Braille Numeric Code

Figure 3 can be transformed into the general Karnaugh map Figure 4. The Xs indicate nonexistent states for the code.

Figure 5 represents the characteristics of the J-K flip-flop, Q_n being the state of an output before a clock pulse and Q_{n+1} the state after a clock pulse, with the J and K input states shown. X here indicates that the state of a particular input is immaterial.

CD \ AB	00	01	11	10
00	X	X	3	1
01	X	X	4	5
11	X	0	7	8
10	X	9	6	2

Figure 4. General Braille Map

The procedure for drawing up the Karnaugh maps for each input of each flip-flop is as follows:

1. Find the existing state of pin A when the digit is indicating the numeral 1 from Fig. 3.

2. Look in the row below, to see what the state of pin A must be when the numeral is 2.

3. Note that pin A is 1 in both cases; i.e., pin A must be 1 and must not change on the next clock pulse.

4. Look in Fig. 5 to see what conditions on the J and K inputs are required for pin A to remain 1 after the clock pulse. The table shows that the input on J is immaterial, but the input on K must be 0.

5. Take the general braille map, and form a map for each input A_J and A_K by substituting X for state 1 in the map for A_J and 0 for state 1 in the map for A_K.

Q_n	Q_{n+1}	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

Figure 5. JK Flip-flop

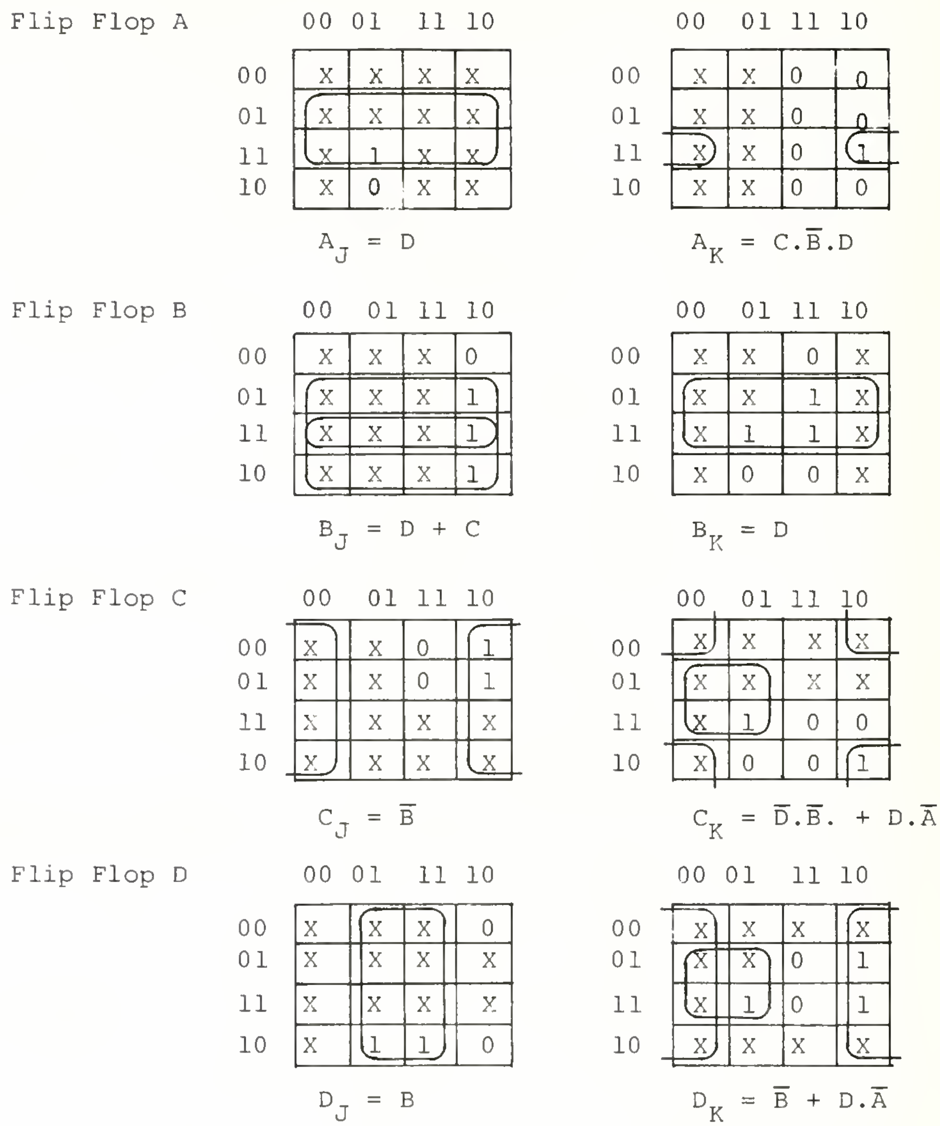


Figure 6. J and K Inputs

Flip Flop	J	K
A	D	$C.\bar{B}.D.$
B	D	D
C	$\bar{B}$	$\bar{D}.\bar{B} + D.\bar{A}$
D	B	$\bar{B} + D.\bar{A}$

Figure 7. Input Summary

6. Continue down Fig. 3 in this manner until 0 is reached. The following state is then 1.

Figure 6 gives the maps for all eight inputs of the four flip-flops. If loops are drawn around the largest possible areas containing no zeros according to the usual rules, the minimised boolean functions for each input are obtained. These functions express what each input of each flip-flop must be in terms of the outputs of all the other flip-flops, in order that the input conditions are those that are required to shunt it into its next state on reception of a clock pulse.

The inputs to all the flip-flops are summarized in Fig. 7. It remains then only to produce the boolean functions using "nor" gates and apply them to their appropriate inputs. A schematic diagram for this is given in Fig. 8.

From Fig. 3 it can be seen that the digit 0 can be detected by the boolean function $D.\bar{A}$. This function can therefore be used to produce a "carry" signal for the next digit. Figure 8 shows that $\overline{D.\bar{A}}$. is available already; it only remains to invert it to get $D.\bar{A}$.

Modification to Bi-modal Operation. The method that was used to achieve a full scale count of 250 instead of 100 was to arrange the units stage of the counter to count not in ten steps-per-cycle but in *four* steps-per-cycle. The steps were 0-3-5-7-0, this being the sequence involving least modification to the basic mod 10 design. The modification was implemented using one "nor" gate and two changeover switches, formed by wired switch wafers ganged to the range change switch.

Alternative Ranging Schemes. A simpler method of achieving the same effect as described in 2.3.2. would have been to increase the period of oscillation of the reference oscillator to 2.5 times the period on the decade ranges, allowing the counter to count to 250 rather than 100 with a full scale input. This would have resulted in a saving of switch wafers and wiring effort.

A more elegant solution would have been to simply use a full 3-digit display and dispense with inter-decade ranging altogether. A VCO of ±1/2-percent instead of ±2-percent linearity would be required, but

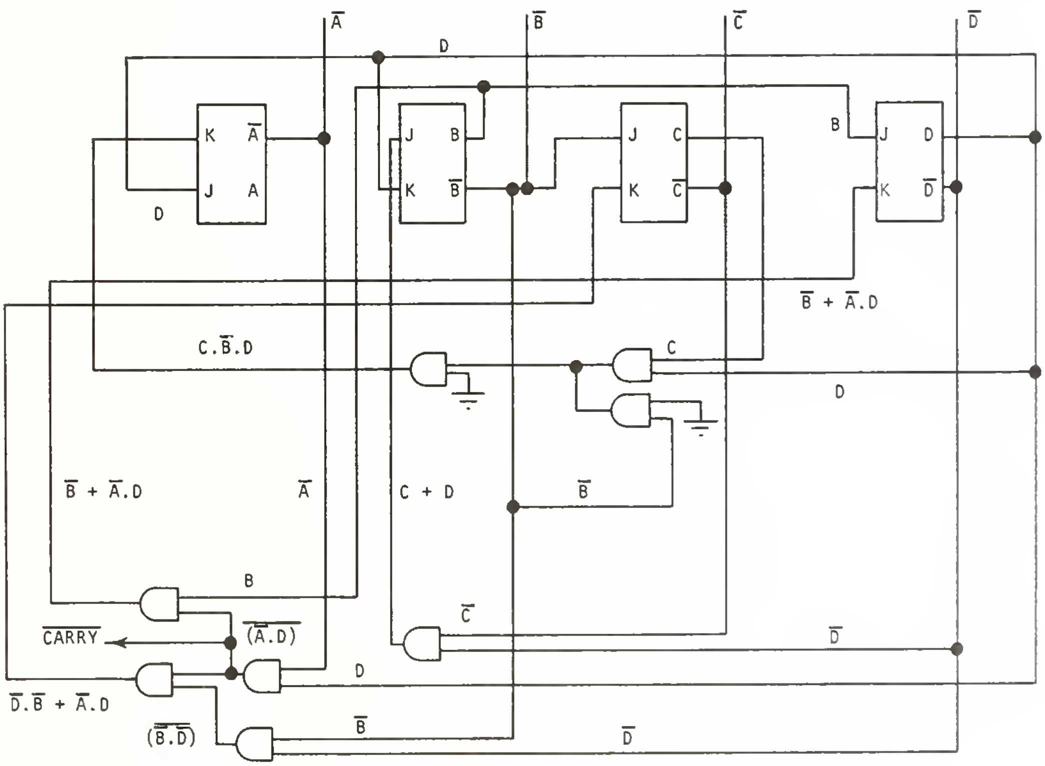


Figure 8. Basic Mod 10 Braille Counting Stage

this would be perfectly realizable and the result would equal or exceed the specifications of our instrument in every respect, with the added advantage that fewer range switch positions would be required. The scheme would require a larger number of components, but since the three digits would have identical counter circuits, some economy could be realized in design and assembly.

Design of "Short" Numeral. The hundreds digit in the braille display needs only to be capable of reading 0, 1, and 2. This represents a twofold simplification in that pins A and C only, are required to indicate the numerals 1 and 2. The numeral 0, since it is always a leading 0, needs never to be displayed and hence a saving of two braille pins can be made. Figure 9 gives the sequence for pins A and C in this "short" numeral.

The simple scheme shown in Fig. 10 provides the function required.

Gating and Resetting

Resetting. After application of power to the counter all flip-flops must be reset in order that counting may begin. It is essential, however, that the last contact bounce is over before the resetting pulse is removed. This delay is achieved by means of a logic buffer amplifier and a capacitor charging circuit as shown in Fig. 11. When the amplifier input reaches a threshold of one base-emitter junction voltage, the reset pulse is removed.

Gating. The arrangement which provides the gating of the counter, has three states:

1. Reset and ready to receive pulse from reference oscillator to turn gate on.
2. Triggered and ready to receive pulse from reference oscillator to turn gate off.
3. Blocked, after reception of second pulse to prevent any further opening of gate.

Numeral	A	C
0	0	0
1	1	0
2	1	1

Figure 9. Sequence of Hundreds Digit

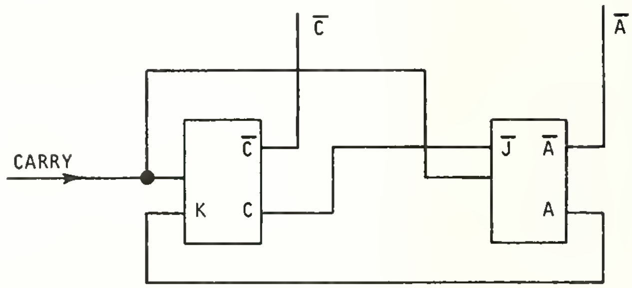


Figure 10. "Short" Numeral

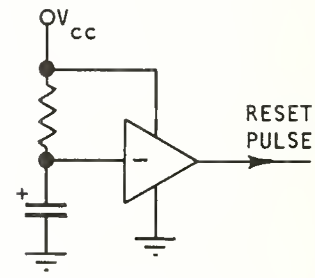


Figure 11. Resetting Circuit

Since there are three different states, two flip-flops are required to perform this function. The circuit given in Fig. 12 is a binary counter with a facility to block itself when it reaches 2 (sequence is 00, 01, 10). It does this by applying 0 to both the J and K inputs of the first flip-flop.

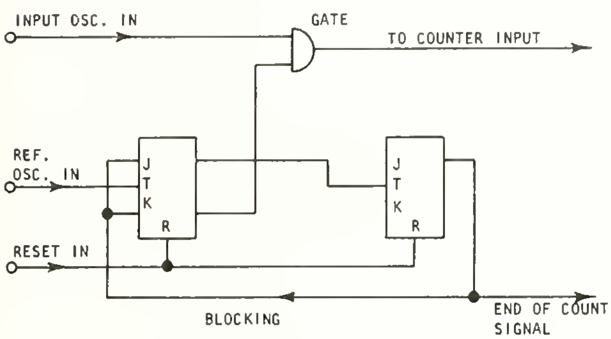


Figure 12. Gating Circuit

This circuit is reset together with the counter at each operation of the press-to-read panel.

Power Supplies

Two separate power supplies are required for the instrument; one, a low-voltage high-current supply for the logic circuitry and readout unit, and the other, a higher voltage low-current supply for the VCOs, overload alarm, etc. In an improved version of the instrument, the two supplies could be obtained from one source, the higher voltage being derived via an inverter from the low voltage. Balanced, regulated, positive and negative voltages could then be used allowing greater flexibility in the design of the VCOs.

In the instrument described here, however, two sets of batteries are used and the VCOs must work using a single unregulated 9-V source. A medium size Eveready type 2362 transistor radio battery is used.

The voltage tolerance for the IC logic used is 3.6 V ±10 percent, i.e., 3.2 to 4.0 V. This circuitry draws approximately 400 mA at 3.6 V, which together with the readout current gives a total consumption of 700 mA in some cases. Ordinary zinc-carbon dry cells are somewhat inadequate for this application, their voltage being a little too high for three to be used in series, but mainly because their internal resistance is too high for such a heavy current. Manganese batteries are much more suitable. These cells have an open circuit voltage of 1.35 V so that if three are used in series, the total voltage is 4.05 V. The cells have a very low internal resistance; the short-circuit current for the "D" size being approximately 10 A. This gives a total voltage drop of only 0.3 V at 700 mA, bringing the voltage down to 3.75 V on load. Since the cells also have an essentially constant voltage discharge characteristic, they can be used for a considerable time before falling to 3.2 V on load.

The capacity of both sets of batteries is sufficient to supply power for several months' normal operation. It was found that the low-voltage supply lasted somewhat longer than the 9-volt supply.

Electromagnetic Braille Readout

Figure 13 shows a cross-section of the readout solenoids. These consist of coils of 1800 turns of 44 B&S enameled wire, wound on brass tubular formers of 2.5-mm OD and 2.0-mm ID. The coils are inserted into a common mild steel block which has been drilled with ten 6-mm diameter flat-bottomed holes, 6 mm deep. The block provides the outer path of the magnetic circuit while the mild steel plungers which slide within the brass formers, form the inner path. A variable air gap is formed between a steel cover plate and the tops of the plungers. The air gap at the base of the plunger is kept constant over the full movement by allowing the plungers to pass through clearance holes in the bottom of the block. Brass pins are used to transfer the motion to plastic caps which form the braille dots.

Two problems were encountered in the design. The first was one of achieving a high degree of reliability with the low power available. When the plungers are at their lowest position, the force is low, and this combined with the effects of dust and dirt between the plunger and former sometimes resulted in a failure to operate. In the up position the air gap is very small and the holding force large, presenting no problem. It was thus decided that some additional force must be made available initially only to overcome the static friction at a time when the plunger is in its least favorable position. This was done by supplying the solenoids momentarily with a high voltage and then transferring to a lower voltage for holding only. The circuit is shown in Fig. 14 and operates as follows:

While the instrument is switched on, the 1000-μF capacitor C, is charged to the sum of the voltages of the two battery supplies, through the resistor R. When the press-to-read panel is depressed, the counter is activated and begins to count. On finishing, an end-of-count signal, via the transistors Tr1 and Tr2, switches the 12.6 V or so held on C

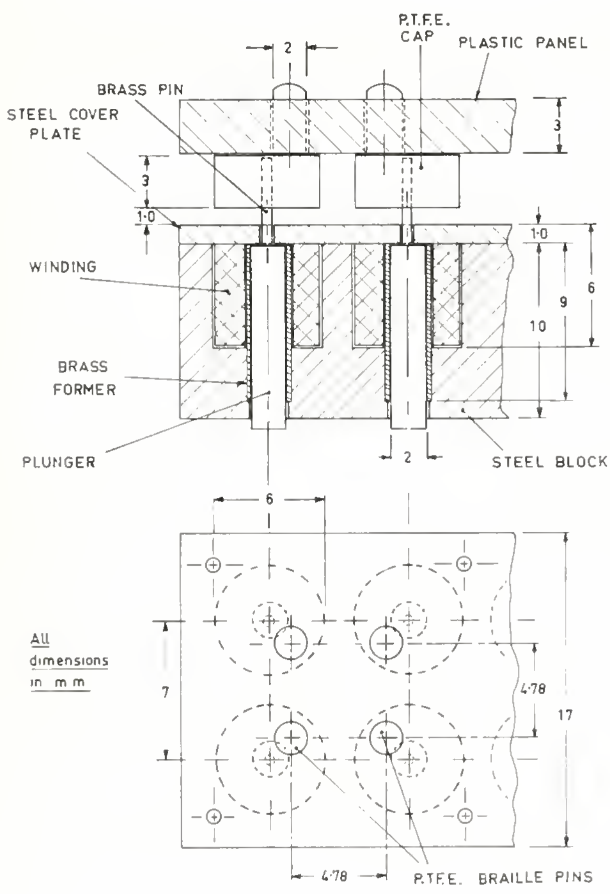


Figure 13. Electromagnetic Braille Readout

onto the solenoid supply line, operating the appropriate solenoids. When C has discharged to the lower supply voltage (approx. 3.6 V) the heavy-current diode D begins to conduct and the low-voltage supply takes over to supply the holding current. The display is then read. On release of the press-to-read panel, the capacitor charges up again and after approximately two seconds is ready for further operation.

The second design problem was one of size. The spacing of the dots of standard braille is small (2.3 mm) and to build solenoids of the dimensions necessary to achieve it directly would be exceedingly difficult. A scheme using larger solenoids with remote actuation of the pins would be bulky and complicated. A compromise was reached here by the use of offset pin caps, together with a dot spacing of 4.78 mm, approximately twice that of standard braille. Although a short familiarization period was required, the large size braille was found to be satisfactory in use. The offset pin caps were turned from PTFE and in their raised position protrude about 1 mm through holes in a perspex cover. This provides complete electrical insulation between the instrument and the user. Photographs of the braille readout before its installation in the instrument can be seen in Fig. 15.

CONSTRUCTION

Figure 16 illustrates the layout of the instrument inside and out. The positions of the circuit boards, current transformer, shunts, and batteries can be seen in the upper illustration. The plastic tube which pipes the sound from the auditory monitor transducer to the outside of the case is also visible. The lower illustration shows the front panel with the hand in the reading position, the range switches, on-off-reverse switch and full-scale check button.

Screening and Insulation

The multimeter is housed in a wooden box which is lined with aluminum foil to form an electrical shield.

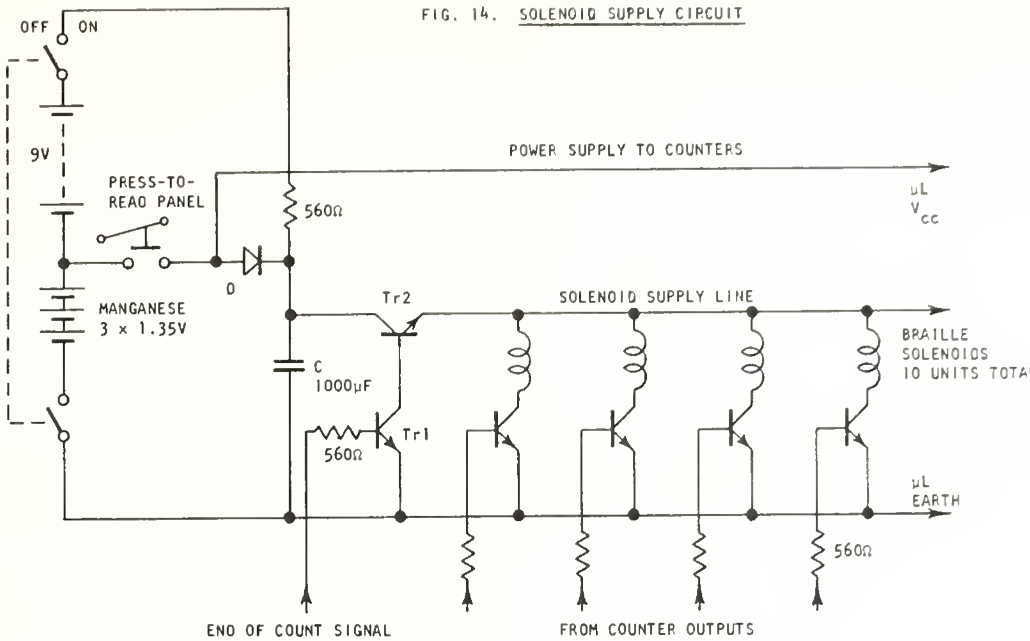


Figure 14. Solenoid Supply Circuit

This shield is connected to the common terminal via a 0.001-μF, 2-kV capacitor in parallel with a 1-MΩ resistor, providing the electronic circuitry with an environment which is at a similar potential to itself. This is essential in an electronic instrument in which the whole circuitry can be swinging at 50 or 60 Hz through hundreds of volts. The complete instrument is mounted on a 3/8-in. thick perspex front panel which is also backed with aluminum foil. No metal parts except the terminals protrude through this panel. It is thus completely safe for making "floating" measurements. In the unlikely event of the case electrically breaking down or being penetrated by a conductor, the current would be limited to a very low value by the resistor-capacitor connection between the screen and common.

Since the readout unit is fairly close to the input terminals and there is the danger that the user's fingers may stray too close to them, a substantial perspex barrier has been provided between the two.

Press-to-Read Panel

A large button was originally used for this function but later was replaced with a hinged panel approximately 3-1/2" x 6", operating on a microswitch. The advantage of the panel is that it enables the user to operate the instrument from almost any angle, using one hand only. The ball of the thumb, palm, or lower wrist can be used to hold the panel down while the reading is being taken. An array of fixed dots representing the braille numeral symbol " ⠼ " is placed immediately before the electromagnetic display to allow the user to quickly locate the active display area.

Range Change Knobs

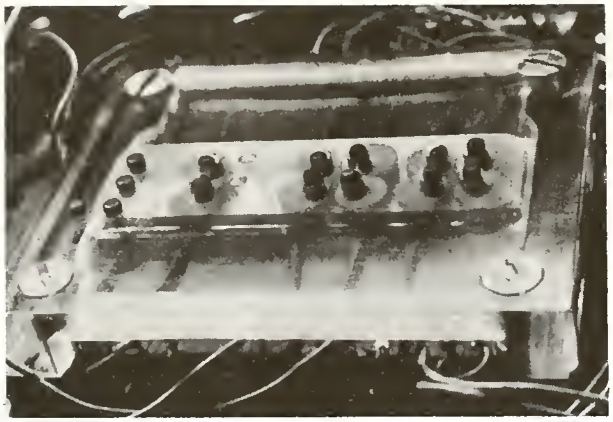
Three features were considered necessary in the design of these:

1. For convenience of reading, they should be flush with the panel;

2. They be arranged so that the reading position is fixed and near the electromagnetic display;

3. They should be totally insulated from the switch shafts.

The design adopted consists of a plastic disc with two 1/4-in. deep D-shaped depressions for the finger



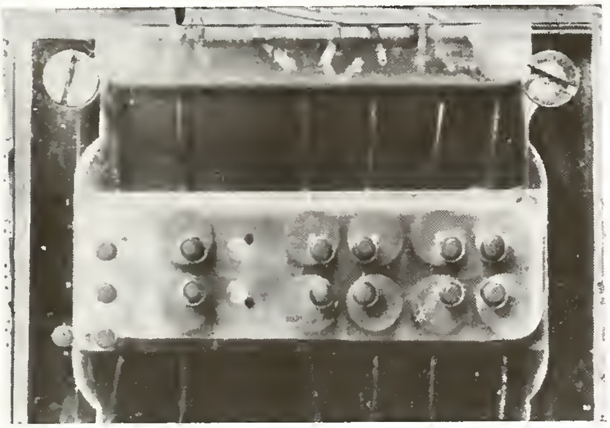


Figure 15. Braille Readout Before Installation

and thumb. The disc is let into the panel so that it does not protrude. On the circumference of the disc are the braille markings which are read opposite a fixed reference indentation. These markings were added by glueing vacuum-formed sheet plastic face plates to the knobs.

Overvoltage Protection

At an early stage in the testing of the instrument in use, measurement was made of the field voltage of a dc generator. When the field of this machine was switched off, a substantial voltage spike was produced, arcing between adjacent contacts on a range change switch, demolishing both the switch and the components mounted on it. We therefore consider it important, if the voltage ratings of the range switches used are not as high as might be desirable, that the input terminals be bridged with a gas discharge tube or some other form of overvoltage protecting device.

CONCLUSION

Brief Specification

Ranges. AC: 2.5 V, 10 V, 250 V, 1,000 V, 10 mA, 100 mA, 1 A, 2.5 A, 10 A. DC: 2.5 V, 10 V, 25 V, 100 V, 250 V, 1,000 V, 100 μA, 1 mA, 10 mA, 100 mA, 1 A, 10 A.

Accuracy. ±2 percent of full scale between 10 percent and 100 percent of full scale with a resolution of one on the 0-100 scale and three on the 0-250 scale. Usable readings can be made to 50 percent overscale on the 0-100 ranges and up to the reading 300 on the 0-250 ranges.

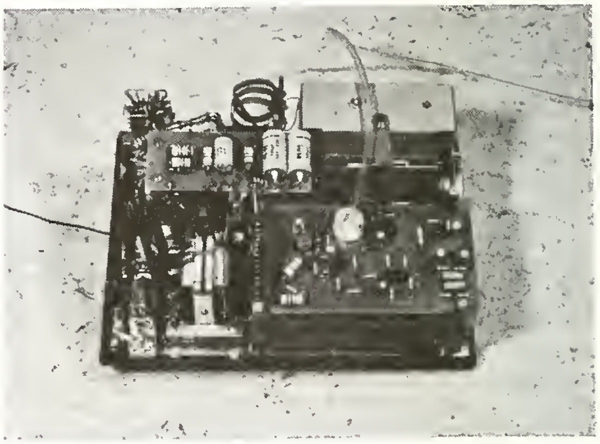


Figure 16. The Completed Instrument

User's Comments

So far we have simply described the engineering involved in this instrument from the designer's point of view. In conclusion it would perhaps be fitting to hear a word from the user, Tony Brown:

Over several years, I have used this instrument in many situations, especially for studying the behaviour of experimental electronic circuitry. I have also used other instruments for this task. These have produced tactile readout either by sensing the position of the meter pointer with a probe, or by nulling an audible signal with a graduated potentiometer.

I have found the digital meter the easiest of these to use. It also provides more information than other meters of my experience.

Only the digital meter does not require effort and judgment on the part of the operator. When the readout button is pressed, the measurement is made, and displayed in braille, on the panel.

The audible monitor is extremely useful. It obviously provides information continuously about the parameter being measured. Any change is immediately noticed, even if a measurement is not being made at the time. When some change is made in the circuit under test, the audible monitor provides immediate feedback about the effects of that change.

The audible alarm also has the advantage of immediate feedback to the operator when the parameter is out of range, or of the wrong polarity.

Thanking you for your continued interest in the development of equipment with braille read-out.

APPENDIX

The following appendix to Part 1 contains circuit diagrams of the prototype braille-reading digital multimeter as it was built in March 1968.

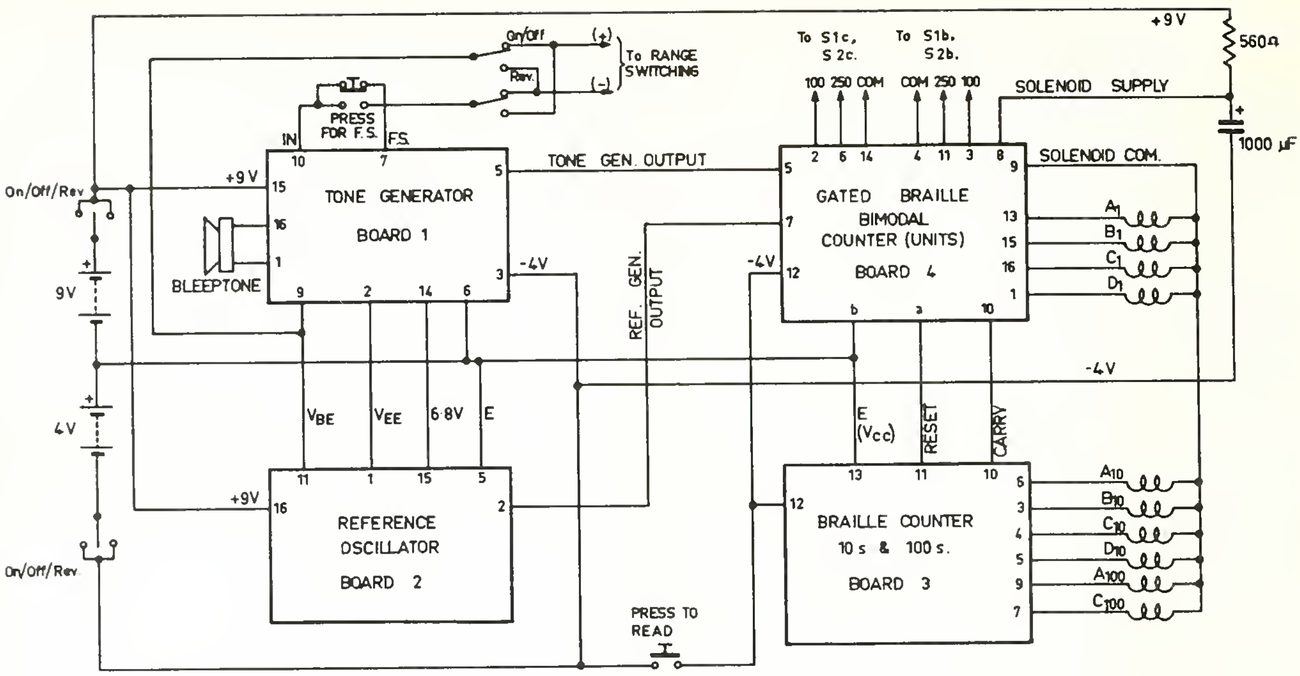


Figure 17. Interconnection Diagram

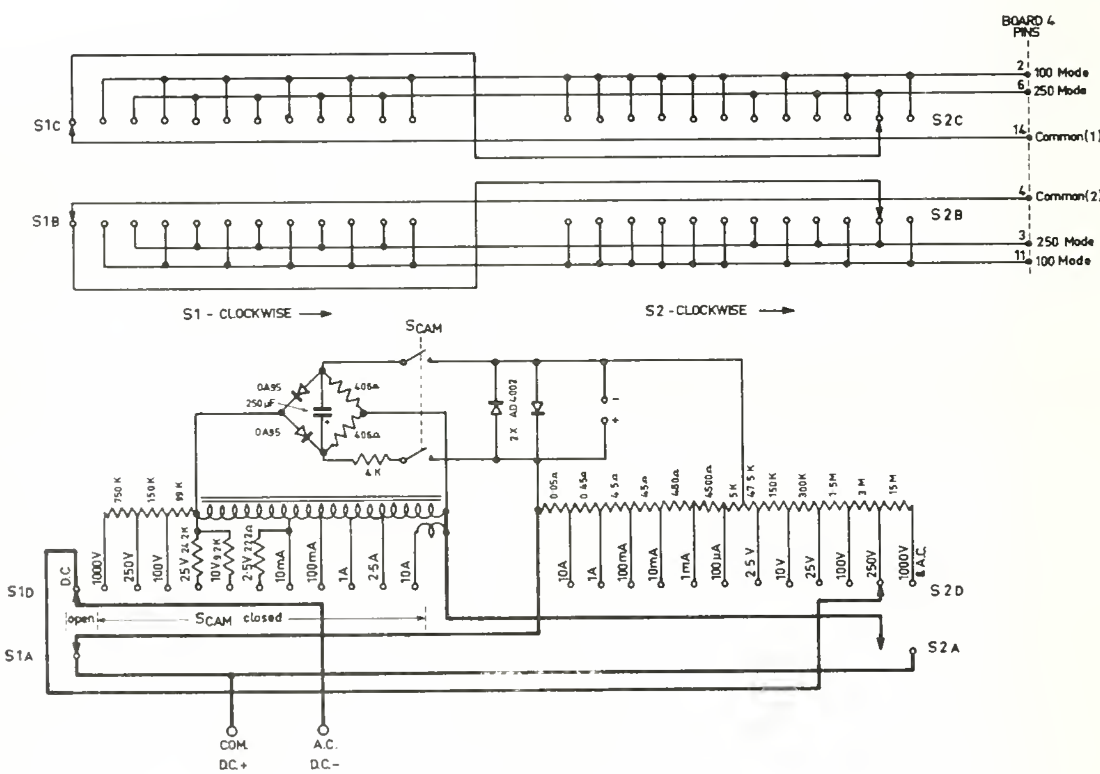


Figure 18. Range Switching

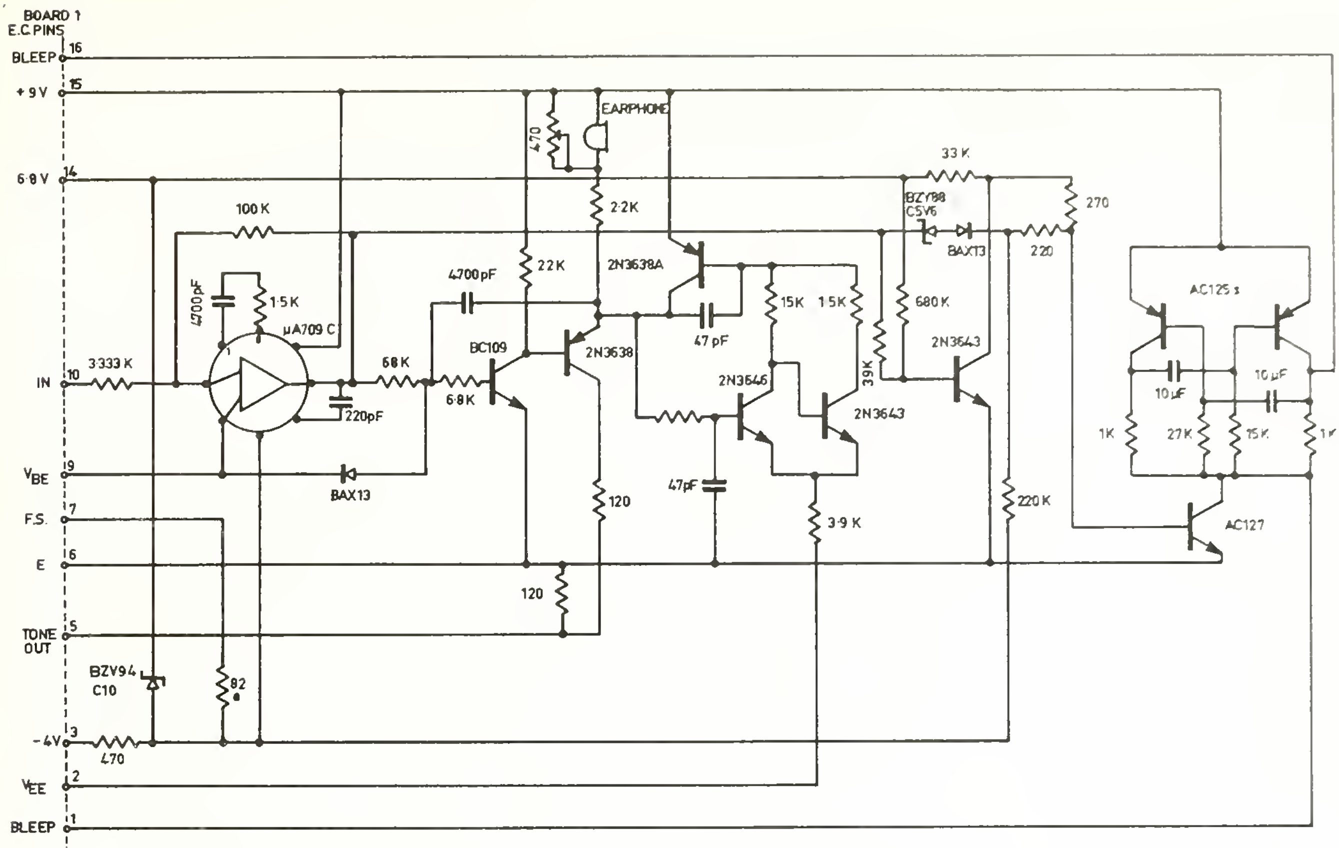
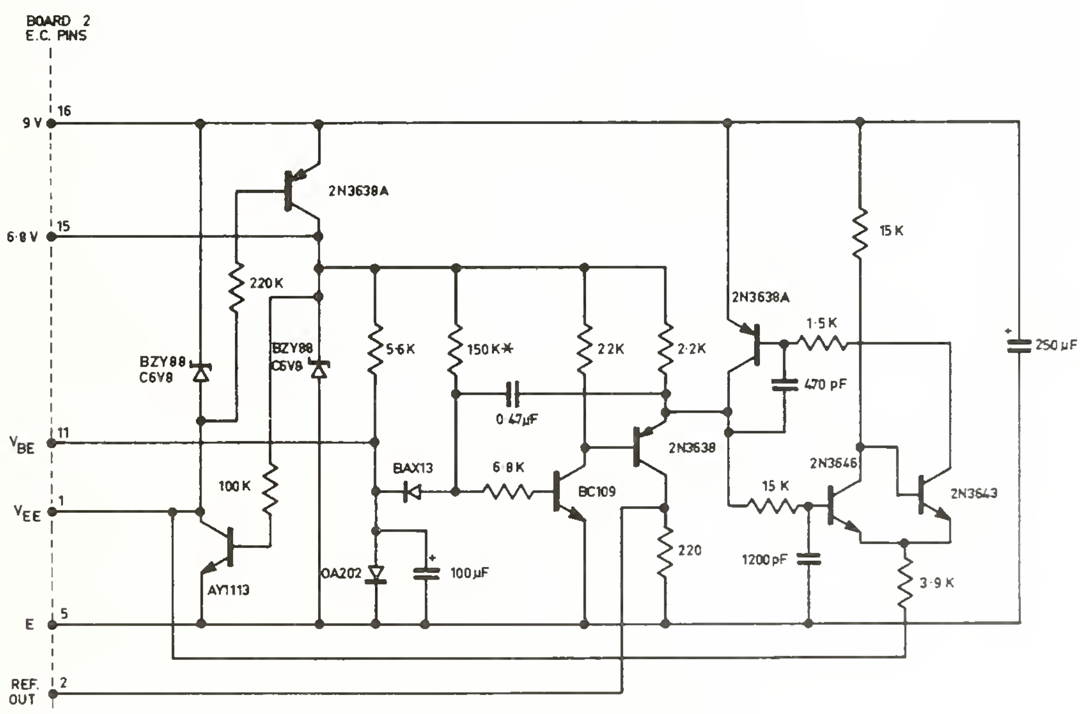


Figure 19. Tone Generator: Board No. 1



* ADJUST FOR CORRECT F.S. READING

Figure 20. Reference Oscillator Board No. 2

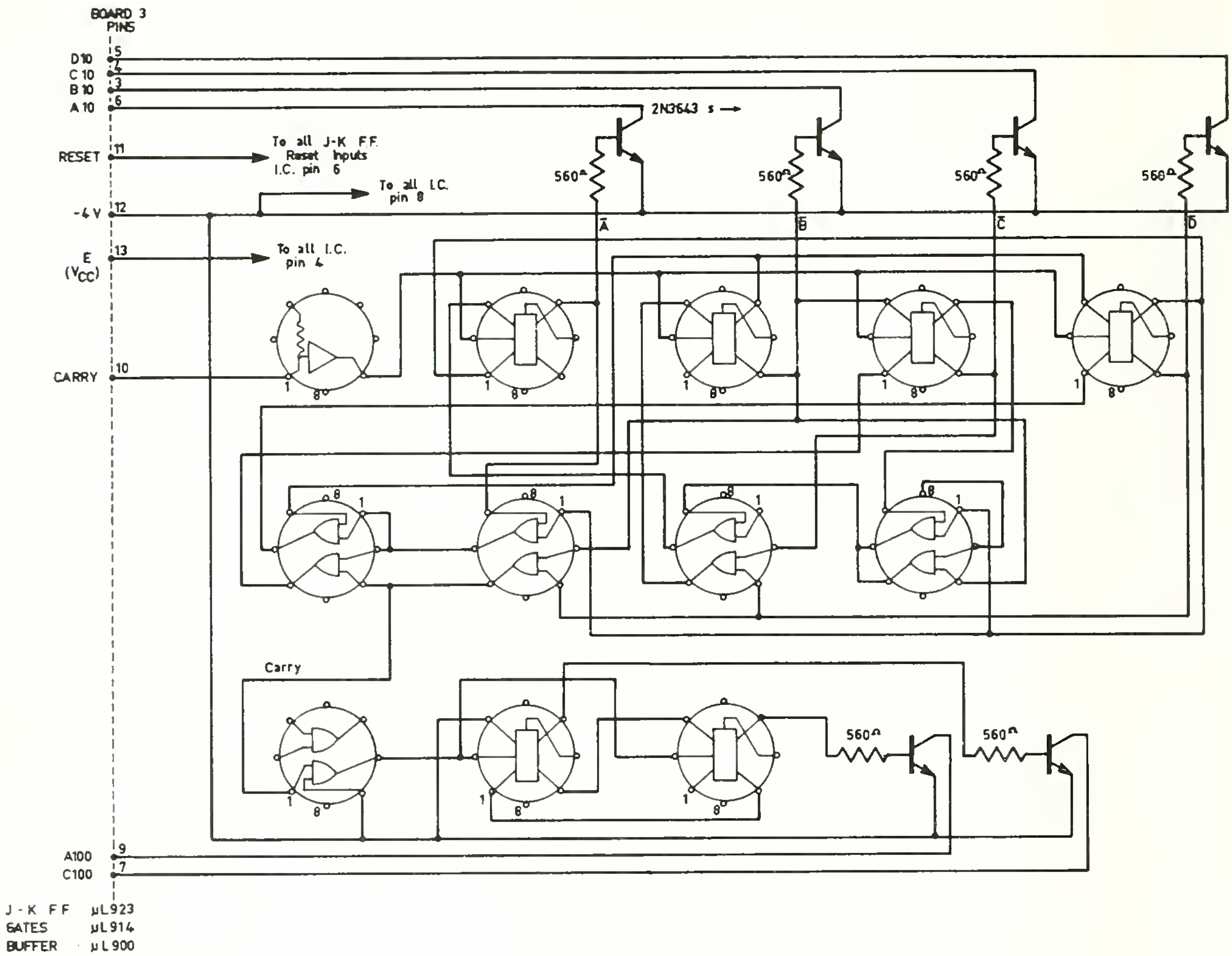
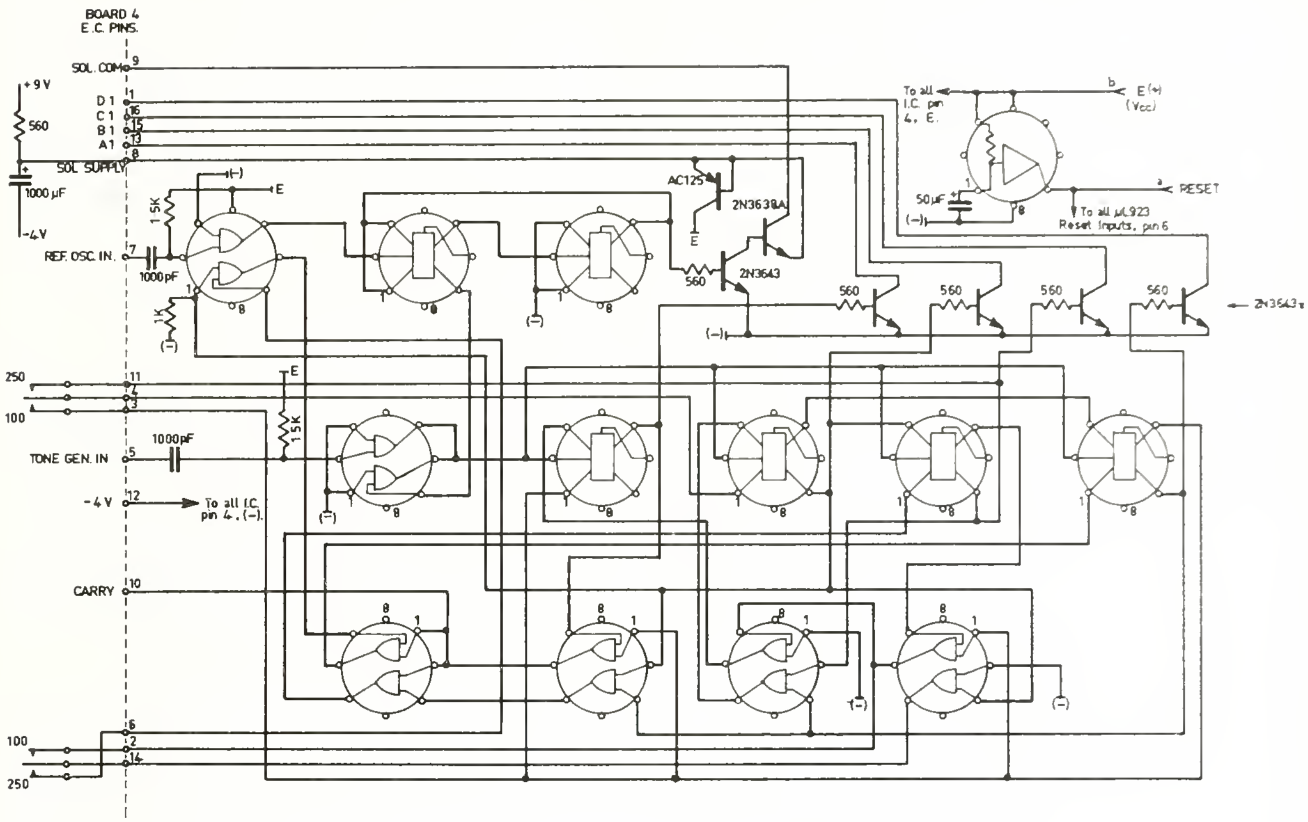


Figure 21. Braille Counter: Tens & Hundreds Digits, Board No. 3



J-K F.F. : µL923
GATES : µL914
BUFFERS : µL900

Figure 22. Gated Braille Bi-Modal Counter: Units Digits, Board No. 4

PART 2

An Auditory "Oscilloscope"*

Abstract

The cathode ray oscilloscope (CRO) is an instrument which is invaluable to the electrical engineer. The blind engineer is, however, deprived of its use and is placed at considerable disadvantage. It is, therefore, desirable to consider equivalents or substitutes for this instrument and the auditory approach used in this attempt met with some degree of success. The instrument makes use of a multidimensional auditory display in which frequency, amplitude, and timbre are all utilized. This technique has been shown to be more efficient than schemes using one dimension only.

Since an oscilloscope must be capable of displaying waveforms widely ranging in frequency, and since signals must be no higher in frequency than a few Hz. to be suitable for auditory modulation, the instrument incorporates a signal-sampling time-scaling device. Sampling is controlled by a slow-sweep generator or may be performed at a fixed point on the observed waveform, the sampling position then being controlled by an external linear-slider potentiometer marked in braille. Measurement of the waveform amplitude at the point can be made via an external braille voltmeter. As far as possible, the circuitry of a commercial oscilloscope has been used, the instrument described here consisting of an attachment which can be strapped to the side of an essentially conventional CRO.

*Designed by P. M. Seligman, supervised by J. A. Phillips, for a Master of Engineering Science (1970) in the Electrical Engineering Department, Monash University.

INTRODUCTION

Following the design of a Braille-reading Digital Multimeter for use by a blind student, the logical continuation of the work was an attempt to provide a substitute for the cathode ray oscilloscope. The instrument to be described here was also designed and built in the Department of Electrical Engineering and was used by the blind student in the final year of the Electrical Engineering course at Monash.

It is clear that in the design of an "oscilloscope" for the blind there are for all practical purposes only two basic approaches available; the auditory and the tactile. Of these the former was selected. Although a device of this type may not have as high potential performance as a tactile equivalent, it has the advantage of being easier and considerably cheaper to implement.

Auditory Displays

In view of the considerable acuity of human pitch perception, an obvious method of encoding low-frequency (of the order of 1 Hz) analogue information is by frequency modulation of an audible carrier tone. This technique, together with binaural location has been investigated by Black[1] for the transmission of handwritten characters. It was found that motion with a bandwidth up to about 3 Hz could be followed, and, further, that if only the vertical component (represented by frequency) was transmitted that the error rate did not increase much. In these experiments low-frequency pulse trains were used as the modulated carrier and an exponential frequency-to-input law was used to give a linear pitch-to-input sensation.

It was decided to perform similar experiments to those described above with the kinds of waveforms that are experienced in oscillographic displays and with a sinusoidal carrier centered about 1 kHz--a region of high pitch acuity. During the course of these experiments, frequency deviations of ±1, 2, and 3 octaves were used and this was found to have little bearing on the ability to differentiate between waveforms. Investigations also showed that although the general excursions of a function were easily detected, features involving the change of slope of an increasing function or even the comparatively gross difference between the peak of a triangular wave and the peak of a sinusoid were difficult to detect. This indicated that additional auditory information on the derivative of the function would improve matters. Psychophysical tests were performed, and using an elementary model[2] of the subject/system it was found that the estimated channel capacity could be increased from 4.9 bits/sec to 7.1 bits/sec, by the use of a multidimensional display which included the function derivative. It was thus decided to implement this feature in the practical auditory oscilloscope.

It remained to decide what type of modulation should be used in the practical auditory oscilloscope. The original tests in which the improvement was demonstrated, used chordal modulation in which dissonant and consonant gliding chords were used to display the positive and negative parts of the derivative. The amplitudes of the secondary tones in the chords indicated derivative magnitude. Although this multidimensional display was satisfactory, it required rather too much hardware for a practical implementation. "Timbre" modulation was found to be easier to implement and was just as effective in conveying derivative information. In this modulation, a pure sinusoidal tone is heard with a constant input. As before, with an increasing input the sinusoid increases exponentially in frequency (f) to give a sensation of linearly increasing pitch, but in addition to this, a secondary tone, a square wave of frequency 2f and amplitude proportional to the derivative is added to the pure tone. This has the effect of adding even harmonics of f to the sinusoid, turning the pure tone into a harsh nasal sound which becomes harsher with increasing slope. By the timbre of the tone it is easy to detect any change in function slope. With a negative going input, a different timbre is used, this being produced by the addition of a square wave of frequency f. This effectively means the addition of odd harmonics and results in a shrill squeaky sound which becomes a whine at higher frequencies. The amplitude of this square wave is also controlled by input function magnitude.

It may be asked why it is necessary to use two different timbres to indicate positive and negative slopes when the difference between these must be perfectly obvious from the rising or falling pitch of the tone. The reason for this can be seen if the case of the display of an equilateral triangular function is considered. If the upward slope of the wave is of the same magnitude as the downward slope and different timbre modulations are used for positive and negative slopes, an abrupt change in timbre will be heard at the transition. This would not be the case if both polarities of derivative used the same modulation. Complete continuity would be observed at the transition and the user would be left to deduce that because of the lack of an abrupt change in timbre, an abrupt transition at the peak of the observed function had occurred. A smooth-peaked wave would also show continuity, that is, the tone would become gradually purer as the slope reduced to zero and then gradually harsher again. The two functions while being distinguishable would therefore not be as obviously different as they would be with a two-timbre scheme. The auditory display is thus a three dimensional one, in that pitch, timbre strength, and timbre type are used, although the third dimension is only partially exploited. It could perhaps be called a 2-1/2 D display.

Time Scaling

It is clear that it is insufficient simply to devise auditory schemes to present analogue information if the information is not suitably time scaled for presentation. In the case of a substitute for an oscilloscope, signals of any frequency up to several MHz should be observable and these must be reduced to the order of 1 Hz while preserving the waveshape. With nonrepetitive signals this cannot be done without elaborate storage devices, but for repetitive signals, time scaling can be performed by sampling. A simple 5-inch oscilloscope of a type used by second year engineering students in the laboratories of the Electrical Engineering Department was used as a basis for the time scaling equipment. Slight modifications were made to the CRO to make the timebase and vertical signal outputs available externally via buffer amplifiers through a socket at the rear of the instrument. By taking the timebase output and comparing it with the output of a slow-sweep generator, the sampling instants are derived. Samples of the vertical output taken at these instants are held in a hold circuit enabling the waveform on the CRO screen to be reconstructed at the speed of the slow-sweep generator. The time-scaling circuit also provides the derivative output, the formation of which will be described further in sec. 2.

Description of Operation

We are now in a position to describe the operation of the complete instrument. Fig. 23 is a block diagram indicating the interconnection of the various sections.

The CRO timebase (TB) and "y" outputs are fed to the sample and hold unit. Starting the slow-sweep generator or applying an externally generated signal to the "x" input of the S.&H. unit produces a time-scaled output. This is fed to an exponential function generator which doubles its output for a 1-cm upward deflection and halves it for a 1-cm downward deflection on the CRO. The frequency of the linear voltage-controlled oscillator which follows, thus varies one octave-per-cm of vertical deflection. The sinusoidal output of this VCO is the fundamental auditory signal of the "oscilloscope" and is fed via an audio amplifier to the headphones.

It will be noticed, that in addition to the sinusoidal output of

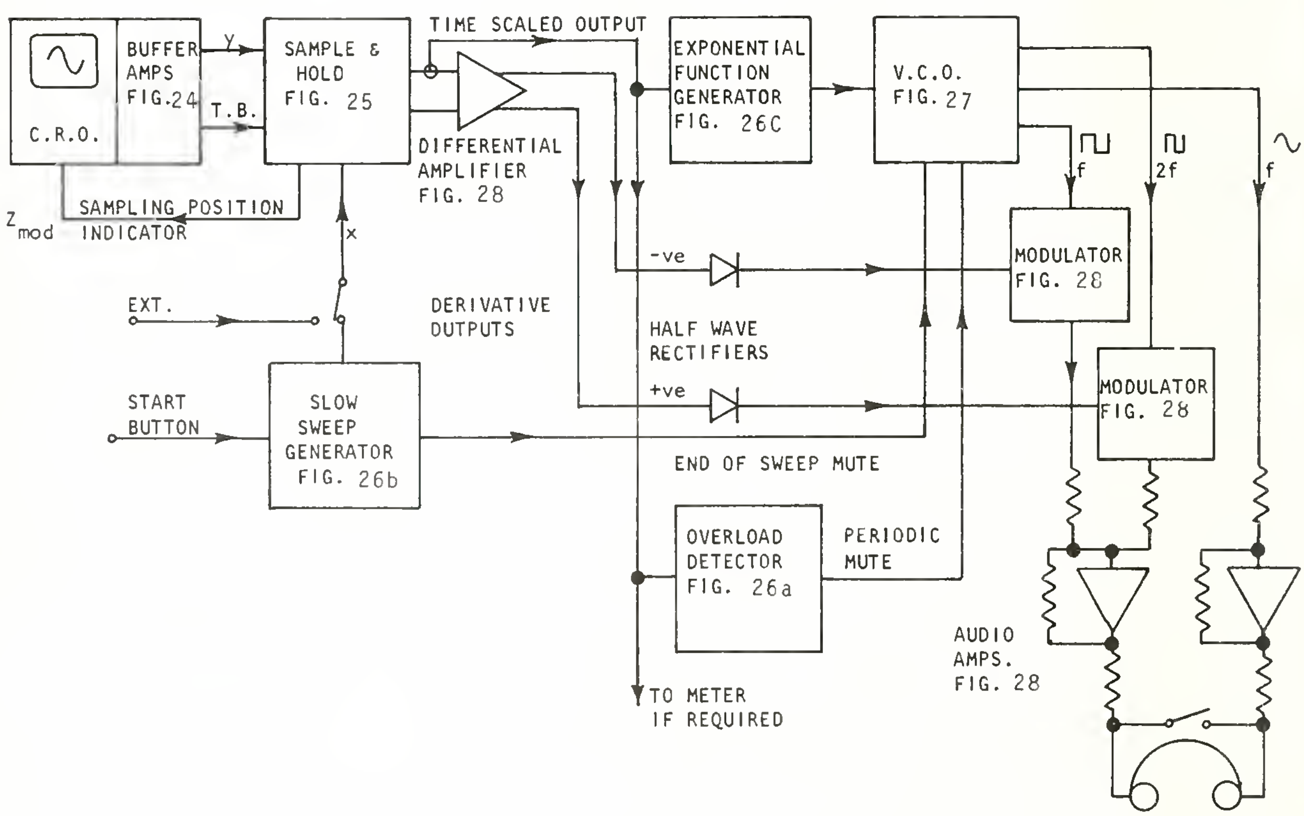


Figure 23. Complete Auditory Oscilloscope

the VCO, there are two square-wave outputs, one of the same frequency and the other of double frequency. These are used to give the tone its timbre. They pass through modulators and then also to the headphones and form the derivative auditory-signal path. The inputs to the modulators are controlled by a complementary (push-pull) output of a differential amplifier in conjunction with the S.&H. unit. Although both derivative outputs can swing in either the positive or negative direction, only the positive parts are used. In the negative going sections, half-wave rectifiers cut off the input to the corresponding modulator. Thus it can be seen that only one modulator can pass audio-frequency square-wave signals at any one time, and that the frequency is 2f with a positive derivative, and f with a negative one. The amplitude of the signal passed is equal to the magnitude of the derivative, the modulator gain being unity.

Further details included in Fig. 23 are:

1. The muting of the VCO by the sweep generator when its sweep has been completed.

2. The periodic muting of the VCO by the overload detector if the waveform on the CRO goes off screen.

3. Provision, for a sighted assistant, of a sampling marker via the Z mod (intensity) input of the CRO.

Controls Provided

The number of controls necessary to operate the instrument has been reduced to a minimum to avoid, as much as possible, sources of confusion to the blind operator. All rotary controls are of the stepped type to facilitate convenient resetting to any position frequently used. The controls provided are listed below:

Sweep speed. S_1, variable in 8 steps; 22, 16, 11, 8, 5.6, 4.0, 2.8, and 2.0 seconds total-sweep time.

Derivative gain. S_2, variable in 5 steps: 2.0, 1.0, 0.5, 0.2, and 0.1. Derivative signal level is -6 dB with respect to fundamental signal level for trace slope of 1 cm/cm when derivative gain is set to unity.

Volume Control.

S_3, variable in 5 steps giving fundamental signal levels of 74, 77, 80, 83, and 86 dB above 2×10^{-4} μbar with both Beyer DT48 and Sennheiser HD414 headphones.

Switches.

S_4, sweep start.

S_5, bandwidth; high/low--5-Hz sampling noise filter which is used when sampling rate is low.

S_6, derivative, on/off.

S_7, mono/stereo; derivative display, combined with or separated from fundamental. In the separated display, total power for both earphones for fundamental signal is transferred to one earphone and total power for derivative output is transferred to the other.

S_8, sweep selector; selects either internal linear sweep or external slider-controlled sweep. Center position of this switch mutes all displays.

Sockets.

Headphones; stereo phone socket.

External sweep; 5-pin socket providing also positive supply voltage for external linear slider, potentiometer.

External voltmeter; 3/4-in. by 4 mm sockets to enable external measurements of trace distance above screen base to be made. Output, 1V/cm.

DESIGN

Circuit description and design details of interest are given. Although some use has been made of integrated circuits, it is likely that if design were repeated, further use of integrated circuits would be made.

Buffer Amplifiers (Fig. 24)

The circuit is straightforward, taking a differential input from the CRO vertical amplifier and converting this to a single-ended output by means of a long-tail pair, one side of which drives a complementary emitter-follower. A low-impedance source is required to drive the sample and hold circuit. The trimming potentiometer P_1 is used to cancel residual fluctuations in tail current due to the finite dynamic resistance of the zener. The output voltage of the circuit is eight ±4 volts for a full screen display. The time base buffer consists simply of a potential dividing emitter-follower. This gives an output which ramps from 0 to 10 V. With 0-volt output, a standing current is drawn in T_6 by a 150-K resistance to the negative supply.

Sample and Hold (Fig. 25)

Fundamental output. This circuit is in fact a dual circuit which samples and holds the CRO vertical signal at two instants separated by a time, equivalent to that represented by 0.2 cm on the horizontal axis of the CRO (the time itself is dependent on the timebase setting of the CRO). The dual samples are required for production of the signal derivative and will be discussed further in the next subsection.

Transistors T_1 and T_2 form a comparator which fires the two schmitt

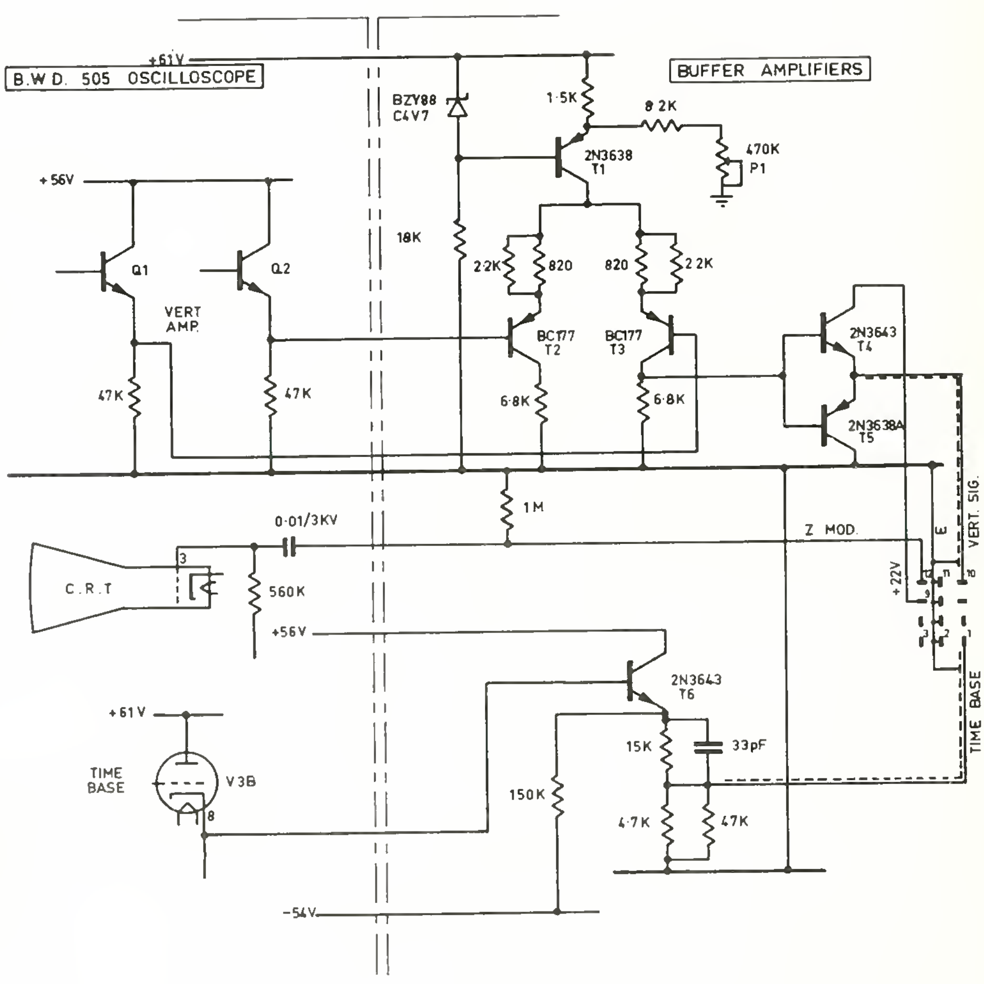


Figure 24. Buffer Amplifiers

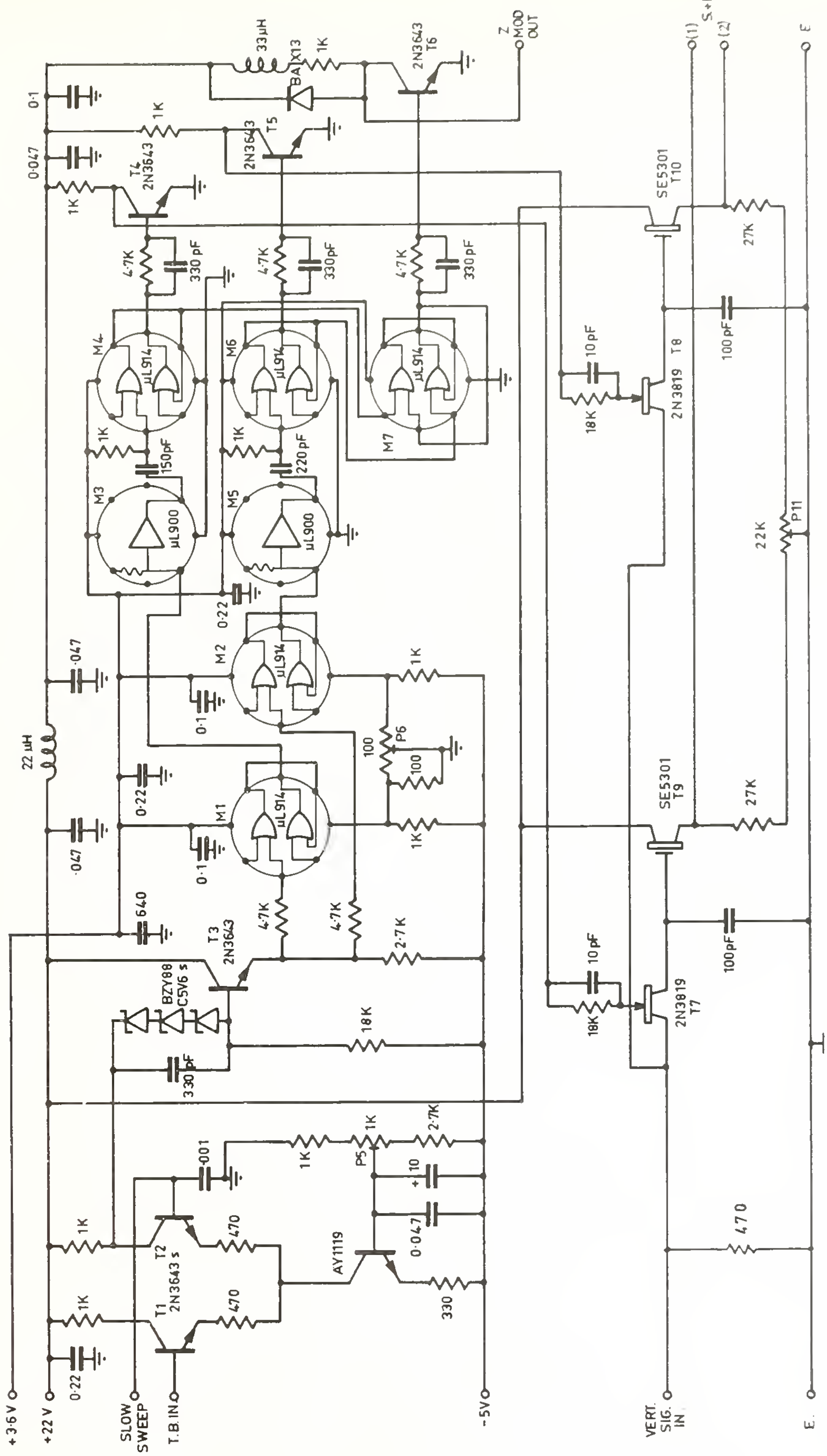


Figure 25. Sample and Hold

triggers consisting of the microcircuits M_1 and M_2. Triggering occurs when the timebase and slow-sweep voltage levels are almost equal. The schmitt outputs drive the two monostables comprising M_3, M_4, and M_5, M_6 respectively. These in turn drive the two saturating switches T_4 and T_5, producing the 100 nS, 22-volt sampling pulses required for the sampling operation.

The microcircuit M_7 is connected as a bistable flip-flop which is set at the beginning of the first sampling pulse and reset at the second. This drives the saturating switch T_6 producing a 22-volt pulse which when applied to the Z mod input of the CRO, produces an intensifying marker whose beginning and end indicate the sampling positions. In the sampling circuit, use is made of field effect devices in both sampling and holding operations. The junction FETs T_7 and T_8 are used as bipolar switches allowing 100-pF mica capacitors to charge to the vertical signal level present in the sampling period. Insulated gate FETs T_9 and T_{10} connected as source followers serve to detect the voltage on the holding capacitors. The circuit is capable of holding a signal with a time constant of approximately 60 seconds. The output marked S.&H. (1) which is the result of the earlier sample of the two, provides the time-scaled signal for the fundamental FM display. The trimming potentiometer P_{11} balances the two S.&H. outputs.

<u>Derivative output</u>. The problems of obtaining a time derivative from a time-scaled, sampled signal are two-fold:

1. Because of the stepped nature of the sampled signal, the derivative will be a series of impulses rather than a continuous function. Elimination of this effect requires the use of elaborate filters.

2. Since the degree of time scaling of the functions to be differentiated is variable, the functions can be encountered at different speeds. This makes the scaling of a time-derivative circuit difficult.

In order to overcome these problems, a dual sampling technique has been used. The method eliminates the scaling problem by obtaining the space derivative $^{dy}/dx$ instead of the time derivative $^{dy}/dt$ and does not require the use of elaborate filters. One sampling circuit is adjusted to sample Δx (equivalent to 0.2 cm of the CRT) ahead of the other. The difference, Δy, between the two samples if detected by a differential amplifier (Fig. 28) whose output is then $^{\Delta y}/\Delta x$, a good approximation to the gradient of the function $y(x)$.

<u>Overload Detector</u> (Fig. 26a)

Through the use of zener diodes and the trimming potentiometers P14 and P_{15}, the OR circuit M_1 detects sample and hold output voltages which are equivalent to trace displacements which exceed the CRT dimensions. The output of this circuit raises the supply voltage to one of the capacitor discharging resistors of the astable multivibrator based on the microcircuit M_3. This operates when overload occurs and produces the periodic muting output required.

<u>Slow Sweep Generator</u> (Fig. 26b)

In this circuit, T_2 acts as a constant current source which charges the 2-μF capacitor to produce a linear voltage ramp. The capacitor voltage is buffered by a source follower, T_3. By means of a level detector similar to those employed in the overload circuit, the voltage at the source of T_3 is monitored. Upon reaching 10 volts, it trips the bistable M_4. This produces a mute output and causes T_4 to discharge the capacitor, resetting the sweep. The sweep is started by depressing the pushbutton S_4, thereby setting the bistable M_4 and releasing the capacitor.

<u>Exponential Function Generator (Fig. 26c)</u>

This is achieved by use of the exponential volt-amp characteristic of a silicon semiconductor junction.

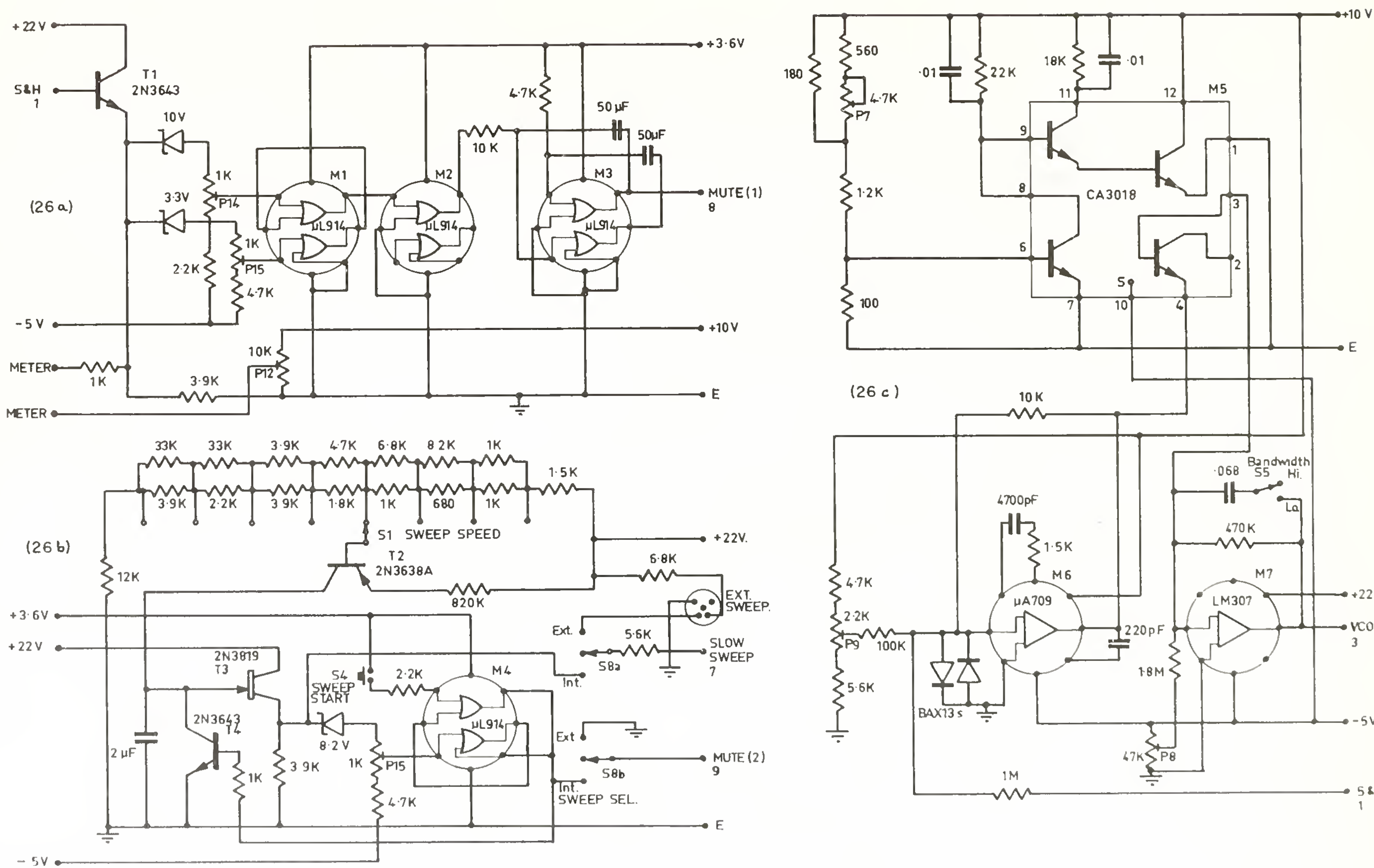


Figure 26a. Overload Detector; 26b Slow-Sweep Generator; 26c Exponential Function Generator

A monolithic circuit M_5 containing four transistors is utilized, one transistor, T_7, being used as a diode to provide the exponential characteristic and the other three to keep the chip heated to a constant temperature. The operation is as follows: the base emitter junction of T_8 is used as a temperature sensor. A fall in temperature of the chip results in decreased base current in T_8, raising its collector voltage and thereby increasing the dissipation in T_5 and T_6. The temperature of the chip is thus regulated, keeping the volt-amp characteristics of T_7 independent of ambient conditions. The chip temperature can be set by means of T_7. Two operational amplifiers M_6 and M_7 are used to provide the voltage drive and current measurement for T_7. P_9 sets the junction bias voltage while P_8 adjusts the output offset of the circuit.

Voltage Controlled Oscillator (Fig. 27)

This consists of an integrator comprising transistors T_1 and T_2, a schmitt trigger, T_3 and T_4 which detects when the integrator output voltage ramps below a predetermined level and a saturating switch, T_5 which, by shorting its output to the supply rail, resets the integrator. The rate of reset is linearly proportional to input voltage. The BAX13 diode and 6.8-K resistor at the input of the integrator protect T_1 during resetting. Resetting of the integrator produces a heavy pulse of current in the 220Ω resistor in the collector of T_2. This drives the two cascaded JK flip-flops M_1 and M_2 which produce the 2f and f square-wave outputs for the derivative display. Muting, or inhibition of the VCO operation is achieved by raising either the J or K input of M_1 to a small positive voltage.

Production of the sine wave of frequency f for the fundamental FM display is of some interest. The transistors T_8 and T_9 form a second integrator to which the square wave from M_1 is applied through T_7. T_7, via the emitter follower T_6, uses the oscillator input-control voltage to modulate the square-wave input to the integrator, thereby producing a triangular wave whose amplitude is independent of frequency. A close approximation to a sine wave is achieved by the use of two back-to-back silicon diodes which reshape

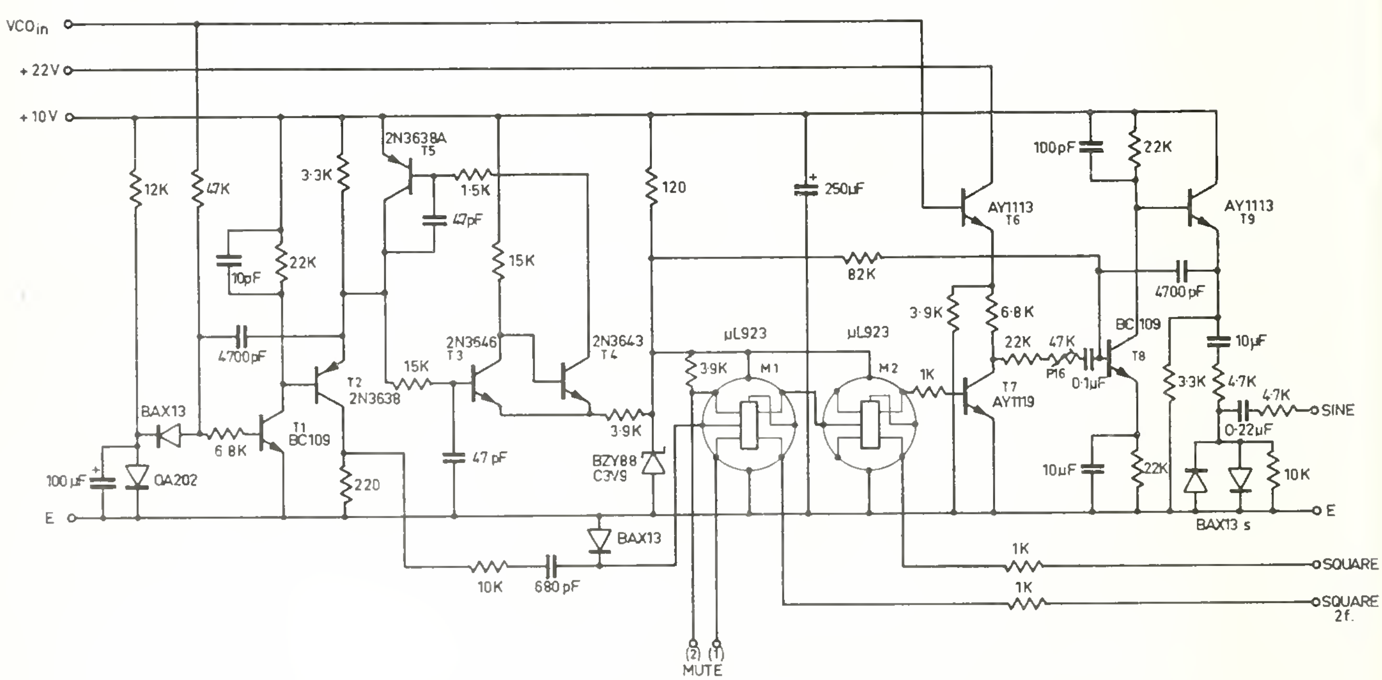


Figure 27. Voltage Controlled Oscillator

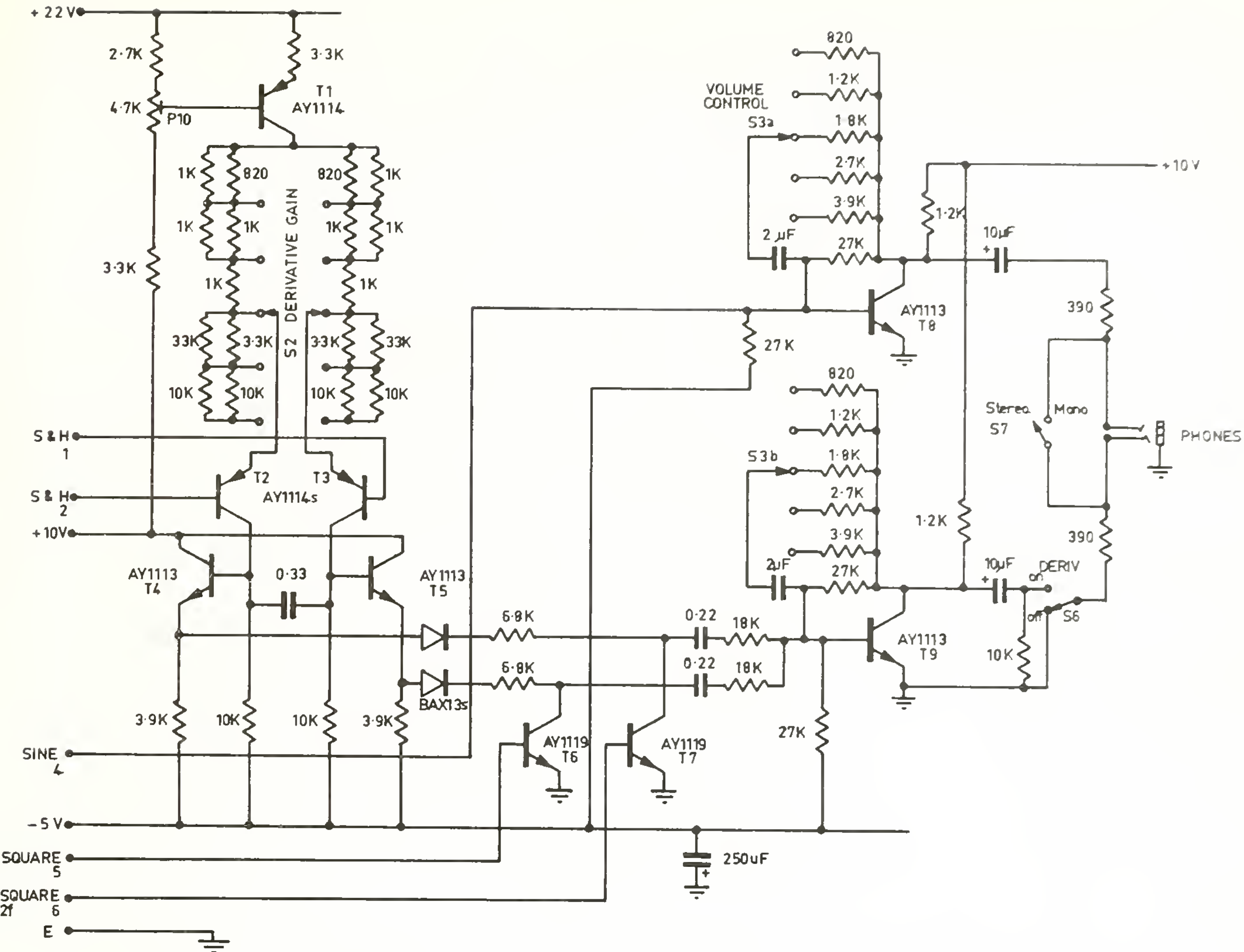


Figure 28. Differential Amplifier, Modulators, Audio Amplifiers

the triangular wave. This sine wave is adjusted for minimum distortion by the trimming resistor P_{16} which varies the triangular wave amplitude. Distortion at 1 kHz can be adjusted to below 2.5 percent, a suitably low level.

Differential Amplifier, Modulators, Audio Amplifiers (Fig. 28)

The differential amplifier here is that used to measure the difference between the two sample and hold outputs. Its gain is varied by switching of the emitter resistors of the transistors T_2 and T_3. The capacitor between the collectors of T_2 and T_3 limits the frequency response of the circuit to 25 Hz. Positive outputs only are taken, these being used to modulate, by means of T_6 and T_7, the two signals of frequency f and 2f which comprise the square wave outputs of the VCO. T_8 and T_9 are two shunt feedback audio amplifiers whose gains are controlled by variation of their feedback resistors. Series resistance is included in their outputs to allow fundamental and derivative signal mixing in monoaural operation.

Power Supply (Fig. 29)

The power supply makes use of two integrated circuit regulators using external series regulator transistors and is fairly self-explanatory. For simplicity all positive supplies are derived from one transformer winding and bridge rectifier. Series dropping resistors are used to reduce dissipation in the transistors T_2 and T_3.

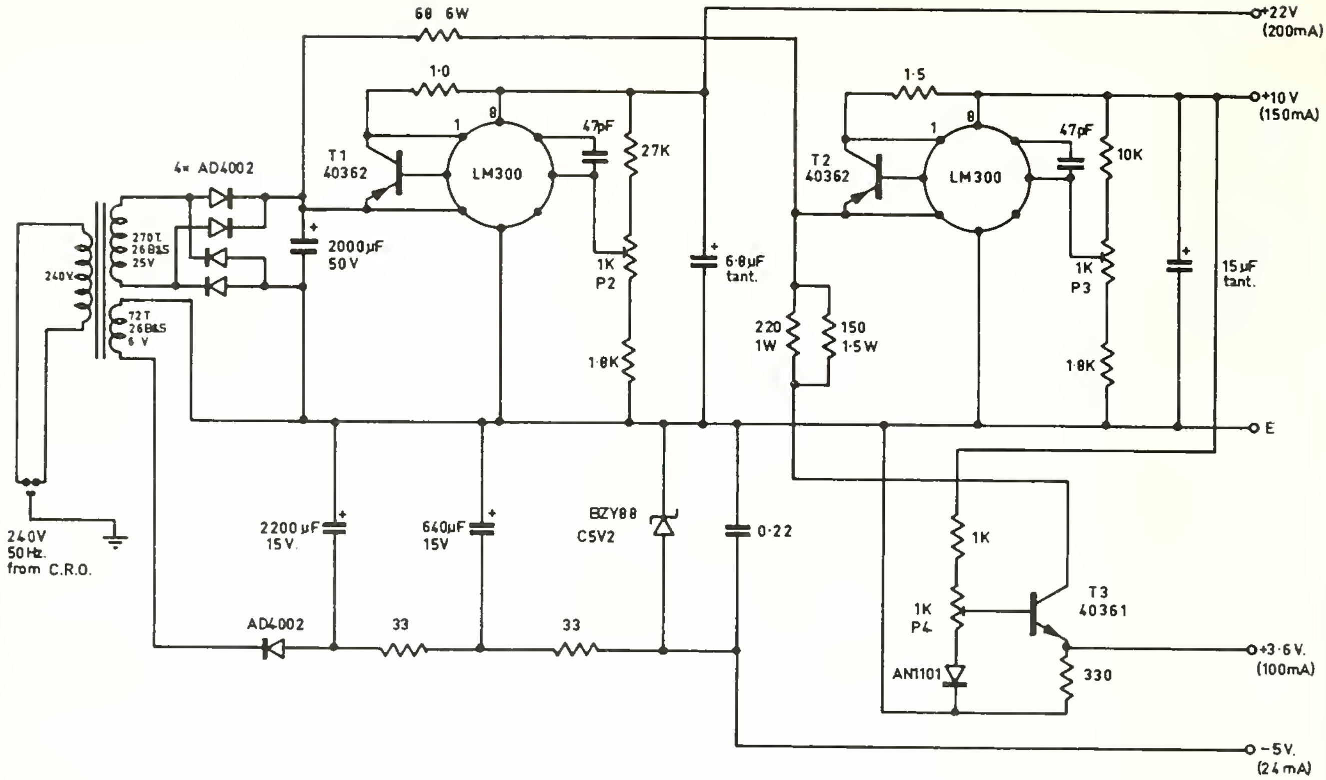


Figure 29. Power Supply

CONSTRUCTION

The instrument was constructed on a module consisting of four aluminum bars mounted between the front and back panel. The overall dimensions are: 3" wide, 8-1/2" high and 15" deep, the depth and height being arranged to be the same as those of the CRO enabling the unit to be attached to its side. The combination is shown in Fig. 30.

The circuits were constructed using a number of different techniques. The sample and hold unit which operates at fairly high speeds was constructed on a double-sided printed circuit board. One side of this board was left unetched and served as a ground plane. Small areas of copper were removed to clear component leads. The VCO circuit used a printed board without ground plane. This board had been designed for the experimental apparatus and required little modification to be adapted for this equipment. The remaining circuitry was constructed on "veroboard," a perforated board with copper strips running lengthwise along each row of holes.

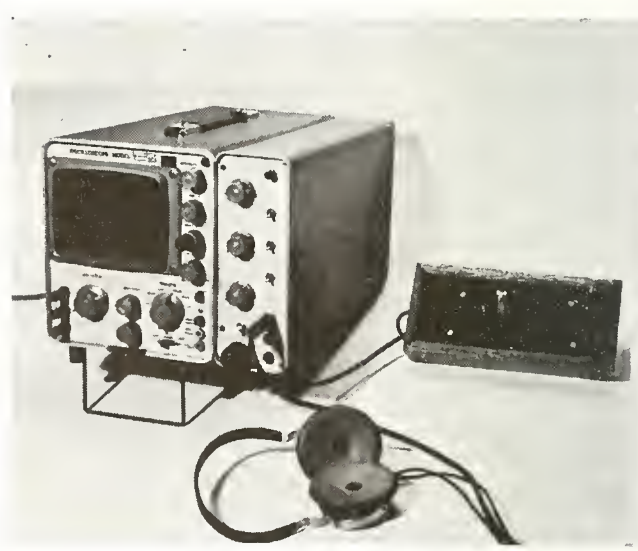


Figure 30. Auditory Oscilloscope attached to CRO

All circuit boards for the main part of the equipment were mounted vertically between the two outermost aluminum bars of the module. The power supply circuit board, however, was mounted on the bars nearest the CRO and the power transformer on the back panel. Mains supply to the unit was taken via a mains connector from the CRO switched and fused supply. Signal leads were brought via coaxial cables through a 12-pin connector on the back panel of the CRO.

Adjustment

Table 1 lists the trimming potentiometers used to align the equipment. These are given in the suggested order in which they should be adjusted. The derivative display should be switched on and derivative gain set to maximum in these adjustments. The sweep selector should be switched to "internal." In adjustments which require use of the earphones the display may be unmuted by

TABLE 1

Adjustment of Auditory Oscilloscope

Pot.	Fig.	Adjustment
P_1	2	Minimum ripple on vertical signal buffer amplifier output.
P_2	7	Relevant supply to +22 V.
P_3	7	Relevant supply to +10 V.
P_4	7	Relevant supply to +3.6 V.
P_5	3	Sampling marker to beginning of trace and fully on screen.
P_6	3	Sampling marker length to 0.2 cm.
P_7	4c	With equipment ambient temperature raised to 45°C; voltage at pin 11, M_5, to just 10 V.
P_8	4c	With P_9 set to lowest position and CRO vertical shift to lowest position; until VCO just begins to oscillate.
P_9	4c	With trace set to screen center; for VCO output frequency f = 1 kHz.
P_{10}	6	As above; until derivative signal (for 2f square wave) is just heard in earphones.
P_{11}	3	As above; until both derivative signals are heard equally or become inaudible--then adjust P_{10} until derivative signals are *just* audible.
P_{12}	4c	As above; and with external voltmeter connected at panel; for reading of 4.0 V.
P_{13}	4a	With trace set to screen top; for overload detector just operating.
P_{14}	4a	With trace set to screen base; for overload detector just operating.
P_{15}	4b	With repeated slow sweeps until marker moves just to end of trace before resetting.
P_{16}	5	For lowest distortion sinewave at earphones.

starting the sweep on a low speed or setting the sweep selector to internal and connecting the external, linear slider, potentiometer. All other controls may be set as is found convenient. The adjustments should be carried out with the CRO externally triggered and no signal on the y input.

CONCLUSION

Operation

Although considerable practice is required to learn to interpret the displays produced quickly and efficiently, the equipment is relatively simple to use. The sweep speed and display volume can simply be adjusted to convenient levels and for each particular pattern, the derivative gain set to give reasonably similar derivative and fundamental signal volumes. In cases where the derivative is of little importance, such as with the display of square waves, this facility may be switched off. When there is doubt as to the fundamental and derivative composition of the display, these may be separated by means of the mono/stereo switch. In cases where absolute measurements must be made on a waveform these are made using the external linear slider potentiometer and a braille voltmeter.

User's Comments

Two main points were made by a user of the equipment.

In situations where no information was given on the waveforms to be measured, some difficulty was encountered in determining whether the CRO ranges had been appropriately set and the triggering satisfactorily adjusted. Although with experience it is possible that performance in this direction could be improved, there is a case here for the use of a selfranging oscilloscope as an input device. The automatic triggering of the oscilloscope used was on the whole good, but on occasions when it did fail to trigger correctly an indicator of some type would have been useful.

The device was fairly tiring to use. It is likely that with frequent use this would be less the case, but with the experience to date, it has been found that after one hour, performance is considerably reduced. Short breaks, even of one minute duration, however, improve this situation significantly.

ACKNOWLEDGEMENTS

We would like to thank the staff of the Monash University Electrical Engineering Department for their assistance in the construction of these instruments and for their help in the preparation of this report.

We would also like to thank Tony Brown for his many useful comments and suggestions and his patience during the testing of the instruments.

REFERENCES

Black, W. L. An acoustic pattern presentation. American Foundation for the Blind, *Research Bulletin*, No. 16, May, 1968.

Seligman, P. M. A communication system model of auditory pattern recognition in the temporal mode. Proceedings of the Third International Conference on Systems Sciences, Hawaii, 1970.

A COMPARISON OF THREE READING MEDIA FOR THE BLIND:* BRAILLE, NORMAL RECORDING, AND COMPRESSED SPEECH

Dean W. Tuttle

Abstract

Purpose. This study attempted to compare reading by braille (B), reading by listening to normal recording (N), and reading by listening to compressed speech (C) with respect to an index of learning efficiency (comprehension score per unit of time).

Sample. Braille readers, 14 through 21 years of age who were attending schools in California were included in the sample. Students with additional handicaps were not excluded.

Research, Design, and Methodology. After an introduction to reading by listening to compressed speech, each subject took three equivalent forms of the Reading Versatility Test, Intermediate Level; one in braille, another in normal recording and a third in compressed speech. Care was taken to distribute the effects of form and order. Each test included four prose reading selections and 24 multiple-choice questions. Students were permitted to skip or reread any of the reading selections whether B, N, or C. An index of learning efficiency was computed for each test by dividing the number of minutes spent reading the selections.

One hundred and four subjects satisfactorily completed the testing procedures. Utilizing the medians of both braille comprehension scores and normal recording comprehension scores, four levels were identified: high braille readers, high listeners (39 subjects); high braille readers, low listeners (13 subjects); low braille readers, high listeners (13 subjects); and low braille readers, low listeners (39 subjects).

An analysis of variance procedure was used to analyze each of the contrasts B - N, N - C, and B - C, across the four levels and overall.

Conclusions.

1. For the total sample, there was no difference in comprehension among the three reading media.
2. For the total sample, reading by braille took almost twice as long as reading by listening to normal recording and almost three times as long as reading by listening to compressed speech.
3. For each of the four levels, reading by listening to compressed speech was more efficient than either reading by braille or reading by listening to normal recording.

---

*Editor's Note:

The Abstract, Background and Review of Literature, and the Bibliography printed here were extracted from the author's doctoral dissertation, *A Comparison of Three Reading Media for the Blind: Braille, Normal Recording, and Compressed Speech*, submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Special Education to San Francisco State College, Graduate Division, of the University of California, Berkeley, California.

4. For the total sample, reading by listening to compressed speech was more efficient than reading by listening to normal recording which, in turn was more efficient than reading by braille.

Implications. This study focused on but two aspects of reading behavior: comprehension and time. The reading of graphs, maps, and other technical materials was not represented in the tests. The effects of reading by listening on the acquisition of allied skills such as spelling and punctuation were not examined.

However, this study has demonstrated that blind students do not all respond in the same way to reading by braille and reading by listening. There are some students who comprehend much more through one medium than the other. This implies that, for any given individual, textbooks and recreational materials must be made available in the medium which is most effective for him.

Since compressed speech is the most efficient of the three reading media under study, local, state, and national agencies must not hesitate to provide visually-handicapped students with materials in compressed speech in order to help them meet ever-increasing reading demands. Furthermore, since reading by listening is an effective reading medium for the blind, it may very well be an effective reading medium for the sighted who encounter difficulty reading print.

This study does not imply that braille is outmoded. Braille is still the most exact medium for reading and writing for the blind.

BACKGROUND AND REVIEW OF LITERATURE

SUPPORT FOR UNDERLYING ASSUMPTION OF THIS STUDY

The underlying assumption is that reading by listening is a valid form of reading. Emerson Foulke (1969-1970) wrote a series of articles entitled, "Reading by Listening." He briefly compared the processes and skills involved in three forms of reading: print, braille, and listening. Reading, including reading by listening, is viewed as an active processing of symbols, be they visual, tactual, or auditory, for the intelligibility and comprehension of message units. Several studies have compared reading by braille with reading by listening (Lowenfeld, 1945; Nolan, 1967; Steel, 1969). Having identified 11 different skills, Hackett (1968) studied the hierarchy of skills in listening comprehension and reading comprehension, and found them to be similar.

NEED FOR COMPRESSION

Part of the problem of word rate can be stated very simply. Foulke (1964) found that the average braille reader can process braille at the rate of 104 words-per-minute. For a group of eighth grade blind subjects without additional handicaps, their braille reading rate was found to be 150 words-per-minute (Lowenfeld, Abel, Hatlen, 1969). Word rate can be improved through the use of recorded materials which have been read aloud. Reports of oral reading rate have ranged from 150 to 175 words-per-minute (Bocca and Calearo, 1963; Goldstein, 1940; Johnson et al., 1963; Nichols and Stevens, 1957). However, neither of these methods approximates the average word rate of the silent visual reader of 250 to 300 words-per-minute (Harris, 1947; Taylor, 1937).

METHODS OF SPEECH COMPRESSION

Foulke (1969) analyzed six methods of speech compression. The simplest method requiring no special device is to pace the oral reader at a faster rate. However, one cannot maintain this pace for long without an increase in articulation errors and loss of inflection (Kozhevnikov and Chistovich, 1965). Another simple method of attaining speech compression is to play back a tape or record at a faster speed than the speed at which it was recorded. Within certain limits, this has been found to be satisfactory, but it does introduce pitch distortion and a loss of voice quality (Fletcher, 1929; Foulke, 1966; Garvey, 1953a,b; Gore, 1968; Klumpp and Webster, 1961; Kurtzrock, 1957; McLain, 1962; Nixon, et al., 1968; Nixon and Sommer, 1968).

Compression by the sampling technique, whereby instantaneous segments of the speech sound are alternately retained and discarded, and the retained samples joined to form continuous speech, can be achieved by means of a computer (Cramer, 1967; Scott, 1963). Gerber and Scott (1971) describe dichotic speech, another form of compressed speech using the computer. Speech segments which would normally have been discarded are now joined to form continuous speech and are fed through earphones to the other ear simultaneously. Though highly satisfactory, both of these methods are currently impractical because of the high cost of computer time. The American Foundation for the Blind jointly with Bell Telephone Laboratories undertook the development of a harmonic compressor. The experimental prototype was completed in 1968 (Breuel and Levens, 1971). Its main disadvantage is that it is limited to compressions of 50 percent.

The sixth method of compression is an electromechanical device developed by Fairbanks, Everitt, and Jaeger and announced in 1954. It was later modified by Graham (1971). This sampling device has the capacity for discarding samples 20 to 40 milliseconds long while retaining samples 20 to 80 milliseconds in duration. The retained samples are then joined to form a continuous pattern. Because the discard sample is so short, no speech sound critical to the intelligibility of the word is ever fully discarded. Amounts of compression can be controlled and varied without a distortion in voice pitch or quality. For purposes of this study, the electro-mechanical sampling technique for compression is most appropriate. Thus, when compressed materials are referred to later, it should be understood that the materials have been compressed by this method.

HISTORICAL DEVELOPMENT OF THE ELECTRO-MECHANICAL COMPRESSOR

Miller and Licklider (1950) were interested in the intelligibility of interrupted speech. They found that the spoken word could be understood when it was turned on and off as slowly as ten times a second. Garvey (1953b) reasoned that if the "off" portions of the interrupted speech could be discarded, and the "on" portions abutted in time, the result would be intelligible compressed speech, free of pitch distortion. Using a recorded tape, he painstakingly cut and spliced to remove the "off" portions, and demonstrated that the resulting compressed speech was indeed intelligible. His method, however, was too cumbersome for anything but research purposes. Then Fairbanks et al. (1954), announced the development of their electro-mechanical apparatus for the compression and expansion of speech. This development stimulated many to consider the possibility that blind readers could more nearly approximate the reading rate of the silent visual reader.

INTELLIGIBILITY AND COMPREHENSION AS A FUNCTION OF WORD RATE

Compression and Intelligibility

With his splicing technique, Garvey (1953b) found that when a list of words was compressed to 40 percent of its original time, there was only a 10 percent loss in intelligibility. Kurtzrock (1957), using the electromechanical compression device, found a 50 percent loss in intelligibility when a list of words was compressed to 15 percent of its original time. Fairbanks and Kodman (1957) compressed a similar list of words to 13 percent of the original time and found 57 percent intelligibility. The latter investigators also discovered a substantial loss in intelligibility when the duration of the discard sample exceeded 80 milliseconds.

Relation of Intelligibility and Comprehension of Compressed Speech

Foulke and Sticht (1967) presented materials to subjects at five different compressions. Though both intelligibility and comprehension declined as the compression increased, comprehension declined more rapidly than intelligibility. This study suggested that there are other factors in addition to intelligibility which affect the degree of comprehension. They hypothesized that the perceptual and cognitive processes required for comprehension depend on a time factor needed for the registration and assimilation of input data (compare Overmann, 1971).

Compression and Comprehension

Diehl et al. (1959) found that, for word rates bounded by 126 and 272 words-per-minute, listening comprehension was unaffected by changes in compression. Fairbanks et al. (1957a) found little difference in listening comprehension when materials were presented to college students at 141, 201, and 282 words-per-minute. However, comprehension dropped rapidly with compressions beyond 282 words-per-minute. Foulke et al. (1962) used both literary and scientific selections with blind subjects and found comprehension through reading by listening to be only slightly affected by increasing word rates between 175 and 272 words-per-minute. They also found an accelerating loss in comprehension above 275 words-per-minute. Foulke and Sticht (1967) found a 6 percent loss in comprehension between 225 and 215 words-per-minute and a 14 percent loss between 325 and 425 words-per-minute. Other studies report similar findings (Foulke, 1968a; Harwood, 1955; Langford, 1968; Nelson, 1947; Woodcock, 1971).

Index of Learning Efficiency

Simple scores in comprehension and word rate do not take into account the time saved in reading by listening. An index of learning efficiency was defined as the comprehension score divided by the time required for the listening task. Fairbanks et al. (1957a), Enc and Stolurow (1960), Foulke et al. (1962) found, in their respective studies, that this index of learning efficiency increased with compression until a word rate of approximately 280 words-per-minute was reached.

On another dimension of learning efficiency, Enc and Stolurow (1960), Friedman et al. (1966), and Foulke (1966) were concerned with the relationship between word rate and retention. They concluded that word rate had no special effect on the rate at which forgetting occurred.

COMPREHENSION OF COMPRESSED SPEECH AS A FUNCTION OF LISTENER VARIABLES

Age of Listener

Fergen (1954), Wood (1965), and Foulke (1969) found a positive relationship between the age or grade of a child and his ability to comprehend accelerated speech. However, primary age children were able to respond successfully to short imperative statements which had been compressed.

Intelligence

Wood (1965) found no relationship between the IQ of primary age children and their ability to respond to instructions which had been compressed. Fergen (1954) found no relationship between the IQ of grade school children and their ability to comprehend accelerated speech. deHoop (1967) and Engman (1970) found that moderately compressed materials could be used with mentally retarded students without a significant loss in comprehension. (Compare Napier, 1971.) Woodcock (1971) reported that the IQ, when mental age is held constant, does not seem to be an important variable. On the other hand, when working with adults, Fairbanks, et al. (1957a, b), Goldstein (1940), and Nelson (1947) did find a positive relationship between IQ and ability to comprehend compressed speech. These studies offer no conclusive evidence about the relationship between IQ and reading by listening to compressed speech.

Print Reading Rate

Jesters and Travers (1965) had subjects read print or read by listening to normal recordings at similar word rates. For both reading print and reading by listening, comprehension declined as word rate increased. However, up to a rate of 200 words-per-minute, reading by listening yielded better comprehension scores than did reading print. Also Goldstein (1940), Orr, Friedman and Williams (1965) found a positive correlation between the subject's print reading rate and his ability to comprehend compressed speech.

Visual Status

Hartlage (1963) found that blind and sighted subjects did not differ significantly with respect to listening comprehension at a normal word rate. However, Foulke (1964a) found that blind subjects could comprehend compressed speech better than sighted subjects. This is probably due to the fact that the blind subjects were accustomed to reading by listening.

COMPREHENSION AS A FUNCTION OF THE LEVEL OF DIFFICULTY OF THE COMPRESSED MATERIAL

Formulae for the absolute difficulty of a reading selection have been developed by Dale and Chall (1948) and Flesch (1948). However, these formulae were developed for print reading. For lack of anything better, Foulke, et al. (1962) used one of these formulae to equalize the literary and scientific materials used. However, the subjects found the scientific selections more difficult to listen to than the literary material. Fairbanks, et al. (1957a), using five categories of difficulty, and George (1969) found listening comprehension not to be a function of the difficulty level of the material.

COMPREHENSION OF COMPRESSED SPEECH AS A FUNCTION OF TRAINING

Vorr and Miller (1965) exposed subjects to five listening selections compressed to 380 words-per-minute. Listening comprehension improved from the first to the third selection, but not thereafter. Woodcock (1971) reported a similar finding. Perhaps this demonstrates a simple adjustment to accelerated speech. Orr, Friedman and Williams (1965) found a 29.3 percent improvement in comprehension of material compressed to 475 words-per-minute following several weeks of training. Kleinman (1963), Napier (1971), and Rawls (1971) also found an improvement in listening to compressed speech after training had occurred. Foulke (1964) used materials compressed to 350 words-per-minute with blind subjects. He found no significant difference in tests of comprehension given before and after training. Other studies include Fairbanks, et al. (1957b), Friedman, et al. (1966). It is apparent that thus far no adequate, effective training program has been developed for improving comprehension of compressed speech.

THE RELATIONSHIP BETWEEN PRINT OR BRAILLE READING AND READING BY LISTENING

> "Do we learn more efficiently by listening or by reading? The answer, were it known, would be of prime importance to the educator as well as all others who seek to instruct, influence or convince others. Psychologists have sought this answer for over 70 years and are still pursuing it. A vast literature has grown up, but any definite answer has failed to appear." (Duker, 1966, p. 399.)

Intelligence

Print reading was found to be more effective than listening for subjects with higher IQ and better reading ability. Green (1934) after using both modalities to present psychological material to college students, found that reading print was superior for students who ranked in the upper quartile in reading ability and listening was superior for students in the lowest quartile. Davy (1971) found that high school students with reading problems had a significantly higher level of comprehension from listening to tape-recorded speech at normal speed than from reading equivalent printed material for an equal length of time.

Retention

For immediate recall, visual mode is favored. For delayed recall, auditory mode is favored. Corey (1934) using audio materials of 100 words-per-minute, with college freshmen, reported that the visual mode was better for immediate recall. However, after a few weeks, Corey found no significant difference.

Grade Level

For students below the seventh grade, listening is consistently reported as superior to reading due to the fact that reading skills have not yet been fully developed (Day and Beech, 1950; Haberland, 1956; Lumley, 1933). Young (1930) studied 2,000 children in the fourth, fifth, and sixth grades. The auditory mode was significantly superior at the fourth grade, but only slightly superior at the sixth. Reading print was found to be superior above the seventh grade (Cody, 1962; Haugh, 1950; Russell, 1928). Caughran (1953) suggested that mental age is more reliable than chronological age or grade level to determine the relative superiority of reading print to reading by listening. He reported reading print superior above a mental age of 13.5.

Difficulty of Reading Material

With respect to level of difficulty of the material, Larsen and Feder (1940) found that for 150 university freshmen, reading print was increasingly superior to reading by listening as the level of difficulty increased. Carver (1934) tested 91 college students and adults. Listening was superior for the easier material.

"Meaningful familiar material is more efficiently presented aurally whereas meaningless and unfamiliar material is more efficiently presented visually." (Day and Beech, 1950, p. 402.)

Braille Reading and Listening

It is uncertain if the relationship between print reading and listening is maintained for braille reading and listening. Nolan (1967) presented scientific, literary, and social studies materials to blind students in grades seven to ten. When the same amount of time was utilized, learning by listening to normal recordings was found to be more efficient than learning by braille. When comparing braille with talking books, Lowenfeld (1945) found that though braille was better for most students, talking books yielded relatively high comprehension scores for low IQ blind children in grades three through seven.

Correlations Between Reading and Listening

> "In respect to the relationship between listening ability and reading ability, correlations ranging from low to relatively high now make a positive relationship doubtful." (Keller, 1960, p. 149.)

Goldstein (1940) reported a correlation of 0.78. Similar high correlations were found by Bonner (1960), Evertts (1961), Holmes and Singer (1961), and Toussaint (1961). Using a procedure for testing listening comprehension which did not involve reading, Blewett (1949) found the correlation between print reading and listening to be 0.35. Other studies have likewise found low correlations between reading print and listening (Baldauf, 1960; Brown and Carlsen, 1955; Stromer, 1952). Correlations between braille reading and listening for third to seventh graders ranged between 0.56 and 0.76 (Lowenfeld, 1945).

SUMMARY

Of the three reading media, braille, normal recording, and compressed speech, braille is the slowest and compressed speech is the fastest. Some studies have compared reading by braille with reading by listening to normal recording, suggesting that, though more is comprehended through the former, the latter is more efficient. Other studies have compared reading by listening to normal recording with reading by listening to compressed speech. As the word rate of compressed speech is increased, comprehension declines more rapidly than intelligibility. An optimum rate for students of average or above average ability appears to be 275 words-per-minute. However, the optimum rate for below average students seems to be 250 words-per-minute. There was no conclusive evidence regarding the effectiveness of a training program in the use of compressed speech.

The relative superiority of reading print to reading by listening is undetermined. With respect to comprehension, half of the research studies favor the visual mode while the other half favor the auditory mode (Day and Beech, 1966). When controlling for amount and difficulty of material and age of subject, there is a moderate-to-low correlation between the two media. This suggests that some students read either print or braille better than they read by listening, while for others the reverse would be true.

BIBLIOGRAPHY

Allen, M. P. Two chests of treasure. *Great stories for young readers.* Pleasantville, N.Y.: Reader's Digest Association, 1969.

Baldauf, R. J. *A study of a measure of listening comprehension and its relation to the school achievement of fifth grade pupils.* Unpublished doctoral dissertation, University of Colorado, 1960.

Biggins, M. E. *A comparison of listening comprehension and reading comprehension in second and third grades.* Advanced Thesis, Indiana State College, 1961.

Blewett, T. T. *An Experiment in the Measurement of Listening at the College Level.* Unpublished doctoral dissertation, University of Missouri, 1949.

Bocca, E. & Calearo, C. Central hearing processes. In J. Jerger (ed.), *Modern developments in audiology*. New York: Academic Press, 1963, 337-70.

Bonner, M. C. S. *A critical analysis of the relationship of reading ability to listening ability.* Unpublished doctoral dissertation, Auburn University, 1960.

Bower, E. Learning and mental health in the school. *Association for Supervision and Curriculum Development Yearbook*, 1966, 23-47.

Breuel, J. W. & Levens, L. M. The American Foundation for the Blind harmonic compressor. In *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 185-92.

Brown, J. I. A comparison of listening and reading ability. *College English*, 1948, 10, 105-7.

Brown, J. I. & Carlsen, G. R. *Brown-Carlsen listening comprehension test.* Yonkers, N.Y.: World Book Co., 1955.

Carver, M. E. *A study of conditions influencing the relative effectiveness of visual and auditory presentation.* Unpublished doctoral dissertation, Harvard University, 1934.

Caughey, J. W., Franklin, J. H., & May, E. R. *Land of the free, a history of the United States.* Pasadena, California: Franklin Publications, 1967.

Caughran, A. M. *The effect on language comprehension of three methods of presentation.* Unpublished doctoral dissertation, University of Missouri, 1953.

Cody, M. I. *An investigation of the relative effectiveness of four modes of presenting meaningful material to twelfth-grade students.* Unpublished doctoral dissertation, Fordham University, 1962.

Corey, S. M. Learning from lectures versus learning from readings. *Journal of Educational Psychology*, 1934, 25, 459-70.

Cox, M. M. The relationship of speech and reading in an elementary school program. *Speech Teacher*, 1959, 8, 211-18.

Cramer, H. L. The intelligibility of time-compressed speech. *Proceedings of the Louisville conference on time-compressed speech.* Louisville: University of Louisville, 1967, 126-48.

Dale, E. & Chall, J. S. A formula for predicting readability. *Educational Research Bulletin*, 1948, 27, 11-20, 28.

Dawson, M. A. & Zollinger, M. The role of reading in relation to other areas of communication. *New Frontiers in Reading*. International Reading Association Conference Proceeding, 1960, 5.

Davy, J. L. *The efficacy of compressed speech as a means of increasing comprehension of children having reading problems.* Master's thesis, Keene State College, New Hampshire, 1971.

Day. W. F. & Beach, B. R. *A survey of the research literature comparing the visual and auditory presentation of information.* A. F. Technical Report 5921, November 1950.

Dayton, C. M. *Design of educational experiments.* New York: McGraw-Hill, 1970.

de Hoope, W. Effects and interaction effects of speaking role, visual limitation and intelligence level on aural acquisition and retention of sentences. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 115-25.

Devine, T. G. *The development and evaluation of a series of recordings for teaching certain critical listening abilities.* Unpublished doctoral dissertation, Boston University, 1961.

Diamond, R. & Kinney, R. The place of speech compression in academic study. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 36-54.

Diehl, C. F., White, R. C. & Burk, K. Rate and communication. *Speech Monographs*, 1959, 26, 229-32.

Dixon, W. J. (Ed.) *BMD Biomedical computer programs.* Berkeley: University of California Press, 1970.

Dixon, W. J. & Massey, F. J. *Introduction to statistical analysis.* (3rd ed.) New York: McGraw-Hill, 1969.

Duker, S. Listening and reading. *Elementary School Journal*, March 1965, 65, 321-29.

Duker, S. (Ed.) *Listening: Readings.* Metuchen, N.J.: Scarecrow Press, 1966.

Duker, S. *Listening Bibliography.* (2nd ed.) Metuchen, N.J.: Scarecrow Press, 1968.

Emslie, E. A., Kelleher, M. E. & Leonard, J. D. *A comparison of achievement in silent reading and listening in grade four.* Master's thesis, Boston University, 1954.

Enc, M. E. & Stolurow, L. M. Comparison of the effects of two recording speeds on learning and retention. *The New Outlook for the Blind*, 1960, 54, 39-48.

England, D. W. *A comparison of certain skills in reading and listening in two fifth grade groups.* Master's thesis, Ohio State University, 1953.

Engman, L. E. Ability of educable mentally retarded subjects to comprehend compressed speech. Master's thesis abstract. Center for Rate Controlled Recordings *Newsletter*, 1970, 4(12).

Evertts, E. L. *An investigation of the structure of children's oral language compared with silent reading, oral reading and listening comprehension.* Unpublished doctoral dissertation, Indiana University, 1961.

Fairbanks, G., Everitt, W. I. & Jaeger, R. P. Method for time or frequency compression-expansion of speech. *Transactions of the Institute of Radio Engineers Profession Group on Audio*, 1954, 27(2), 7-12.

Fairbanks, G., Guttman, N. & Miron, M. S. Auditory comprehension in relation to listening rate and selective verbal redundancy. *Journal of Speech and Hearing Disorders*, 1957, 22, 23-32. (a)

Fairbanks, G., Guttman, N. & Miron, M. S. Auditory comprehension of repeated high speed messages. *Journal of Speech and Hearing Disorders*, 1957, 22, 20-22. (b)

Fairbanks, G., Guttman, N. & Miron, M. S. Effects of time compression upon the comprehension of connected speech. *Journal of Speech and Hearing Disorders*, 1957, 22, 10-12. (c)

Fairbanks, G. & Kodman, F., Jr. Word intelligibility as a function of time compression. *Journal of the Acoustical Society of America*, 1957, 29, 636-41.

Feller, W. *An introduction to probability theory and its applications.* New York: John Wiley & Sons, 1966.

Fergen, G. K. *Listening comprehension at controlled rates for children in grades IV, V, VI.* Unpublished doctoral dissertation, University of Missouri, 1954.

Ferris, M. E. *A study of the relationship between reading comprehension and listening comprehension.* Master's thesis, University of Tennessee, 1964.

Finn, J. D. *NYBMUL, univariate and multivariate analysis of variance and covariance.* Buffalo: Computer Center Press, State University of New York, 1970.

Flesch, R. A new readability yardstick. *Journal of Applied Psychology.* 1948, 32, 231-3.

Fletcher, H. *Speech and hearing.* New York: D. Van Nostrand, 1929.

Foulke, E. *The comprehension of rapid speech by the blind, Part II.* Cooperative Research Project #1370. Washington, D.C.: U.S. Department of Health, Education, and Welfare, 1964. (a)

Foulke, E. Transfer of a complex perceptual skill. *Perceptual and Motor Skills*, 1964, 18, 733-40. (b)

Foulke, E. The retention of information presented at an accelerated word rate. *International Journal for the Education of the Blind*, 1966, 14(1), 11-15.

Foulke, E. (Ed.) *Proceedings of the Louisville conference on time compressed speech.* Louisville: University of Louisville, Center for Rate Controlled Recordings, 1967.

Foulke, E. Listening comprehension as a function of word rate. *The Journal of Communication*, 1968, 18(3), 198-206. (a)

Foulke, E. Non-visual communication. *International Journal for the Education of the Blind*, 1968, 18(3), 77; 1968, 18(4), 122. (b)

Foulke, E. *The comprehension of rapid speech by the blind: Part III.* Final Progress Report, Cooperative Research Project #2430. Louisville: University of Louisville, Non-visual Perceptual Systems Laboratory, 1969.

Foulke, E. Non-visual communication, Parts III-VI. *Education of the Visually Handicapped*, 1969, 1, 25-6; 3, 79-81; 4, 120-21; 1970, 1, 23-5.

Foulke, E. (Ed.) *Proceedings of the second Louisville conference on rate and/or frequency-controlled speech.* Louisville: University of Louisville, Center for Rate-Controlled Recordings, 1971.

Foulke, E., Amster, C. H., Nolan, C. Y., & Bixler, R. H. The comprehension of rapid speech by the blind. *Exceptional Children*, 1962, 29, 134-41.

Foulke, E., & Robertson, J. *The development of accelerated speech as a useful communication tool in the education of blind and other handicapped children.* Louisville: University of Louisville, Perceptual Alternatives Laboratory, 1970.

Foulke, E. & Sticht, T. G. The intelligibility and comprehension of time compressed speech. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 21-28.

Friedman, H. L. & Orr, D. H. Recent research in the training of compressed speech comprehension. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 69-76.

Friedman, H. L., Orr, D. B., Freedle, R. O., & Norris, C. M. Further research on speeded speech as an educational medium. *Progress Report #2, Grant No. 7-48-7670-267.* Washington, D.C.: U.S. Department of Health, Education, and Welfare, Office of Education, 1966.

Gardner, Earl J. *The case of the beautiful beggar.* New York: Morrow, 1965.

Garvey, W. D. The intelligibility of abbreviated speech patterns. *Quarterly Journal of Speech*, 1953, 39, 296-306. (a)

Garvey, W. D. The intelligibility of speeded speech. *Journal of Experimental Psychology*, 1953, 45, 102-8. (b)

George, R. G. *Difficulty of material and retention of compressed speech.* Unpublished doctoral dissertation, Indiana State University, 1969.

Gerber, S. E. & Scott, R. J. Dichotic speech-time compression. In *Proceedings of the Second Louisville Conference on Rate and/or Frequency Controlled Speech.* Louisville: University of Louisville, Perceptual Alternatives Laboratory, 1971.

Goldstein, H. *Reading and listening comprehension at various controlled rates.* Teachers College, Contributions to Education No. 821. New York: Bureau of Publications, Columbia University, Teachers College, 1940.

Gore, G. V. *A comparison of two methods of speeded speech presented to blind senior high school students.* Doctoral dissertation, Columbia University, New York, 1968.

Graham, W. The Graham compressor, a technical development of the Fairbanks method. In *Proceedings of the Second Louisville Conference on Rate and/or Frequency Controlled Speech.* Louisville: University of Louisville, Perceptual Alternatives Laboratory, 1971.

Green, E. B. Certain aspects of lecture, reading and guided reading. *School and Society*, May 1934, 39, 619-24.

Hackett, M. G. *A hierarchy of skills in listening comprehension and reading comprehension.* Doctoral dissertation, University of California, Berkeley, 1968.

Hampleman, R. S. *Comparison of listening and reading comprehension ability of fourth and sixth grade pupils.* Unpublished doctoral dissertation, Indiana University, 1955.

Hano, A. *Sandy Koufax: Strikeout king.* New York: Putnam, 1964.

Harley, R. An experimental program in compressed speech at the Tennessee School for the Blind. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 63-6.

Harris, A. J. *How to increase reading ability.* New York: Longman Green, 1947.

Hartlage, I. Differences in listening comprehension between blind and sighted subjects. *International Journal for the Education of the Blind*, 1963, 13, 1-6.

Harwood, K. A. Listenability and rate of presentation. *Speech Monographs*, 1955, 22, 57-9.

Hatfield, W. W. Parallels in teaching students to listen and read. *English Journal*, 1946, 35, 553-8.

Haugh, O. M. *The comparative value of reading and listening in the acquisition of information and the changing of attitudes of elementary grade students.* Unpublished doctoral dissertation, University of Minnesota, 1950.

Hays, W. L. *Statistics.* New York: Holt, Rinehart & Winston, 1963.

Helms, A. *Tape recording books for the blind.* New York: American Foundation for the Blind, 1962.

Hodgman, C. D. (Ed.). *Mathematical tables from handbook of chemistry and physics.* Cleveland: Chemical Rubber Publishing Co., 1954.

Holmes, J. A. & Singer, H. *The substrata-factor theory, substrata-factor differences underlying reading ability in known groups.* Berkeley: University of California, 1961. (Mimeograph)

Jester, R. & Travers, R. M. *Comprehension as a function of rate and modality of presentation.* Paper presented to American Psychological Association, Division 15, Chicago, September 1965.

Johnson, W., Darley, F., & Spriestersbach, D. C. *Diagnostic methods in speech pathology.* New York: Harper & Row, 1963, 202-3.

Joney, O. L. *A comparison of reading and listening in teaching factual material in grade four.* Master's thesis, Boston University, 1956.

Keller, P. W. Major findings in listening in the past ten years. *Journal of Communication*, 1960, 10, 29-38.

Kelley, E. V. and others. *A comparison of silent reading and listening through written recall and multiple choice tests, grades 6 & 7.* Master's thesis, Boston University, 1952.

Kirk, R. E. *Experimental design: Procedures for the behavioral sciences.* Belmont, California: Brooks Cole Publishing Co., 1969.

Kleinman, J. *Effects of training sessions on the ability to comprehend compressed speech.* Master's thesis, University of Pittsburgh, 1963.

Klumpp, R. G. & Webster, J. C. Intelligibility of time-compressed speech. *Journal of the Acoustical Society of America*, 1961, 31, 265-7.

Kozhevnikov, V. A. & Chistovich, L. A. *Speech: Articulation and perception* (Moscow-Leningrad). Washington, D.C.: JPRS, 1965, 30, 543. (Translation)

Kurtzrock, G. H. The effects of time and frequency distortion upon word intelligibility. *Speech Monographs*, 1957, 24, 94.

Langford, R. P. *The effect of time compressed speech on listening comprehension.* Unpublished doctoral dissertation, New York University, 1968.

Larsen, R. P. & Feder, D. D. Common and differential factors in reading and hearing comprehension. *Journal of Educational Psychology*, 1940, 31, 241-52.

Lazarsfeld, P. F. *Radio and the printed page.* New York: Duell, Sloan & Pearce, 1940.

Lindsey, C. A. *A comparison of silent reading and listening as instructional media in the teaching of certain aspects of language.* Doctoral field study, Colorado State College of Education, 1951.

Lowenfeld, B. *Braille and talking book reading, a comparative study.* New York: American Foundation for the Blind, 1945.

Lowenfeld, B., Abel, G. L. & Hatlen, P. H. *Blind children learn to read.* Springfield, Illinois: Charles C. Thomas, 1969.

Lumley, F. H. Research in radio education at Ohio State University. *Fourth Yearbook of the Institute for Education by Radio.* Columbus: Ohio State University, 1933.

Many, W. A. *The comprehension of identical materials presented under reading and listening conditions.* Master's thesis, State University of Iowa, 1953.

Maxwell, M. *A comparison of three standardized college reading tests.* Unpublished study, University of California at Berkeley, 1971.

McDonald, A. S. et al. *Reading versatility tests, and manual of directions.* Huntington, N.Y.: Educational Development Laboratories, 1968.

McLain, J. A comparison of two methods of producing rapid speech. *International Journal for the Education of the Blind*, 1962, 12, 40-3.

Miller, G. A. & Licklider, J. C. R. The intelligibility of interrupted speech. *Journal of the Acoustical Society of America*, 1950, 22, 167-73.

Mills, D. M. Interrelating reading and listening in grades four through eight. *Reading and the Language Arts.* Proceedings of Chicago Press, 1963, 59-62.

Morrison, D. F. *Multivariate statistical methods.* New York: McGraw-Hill, 1967.

Napier, G. D. An investigation into extended use of time compressed speech with intermediate-grade subjects. *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 282-8.

Nelson, H. E. *The effect of variations of rate on the recall by radio listeners of "straight" newscasts.* Unpublished doctoral dissertation, State University of Iowa, 1947.

Nichols, P. G. & Stevens, L. A. *Are you listening?* New York: McGraw-Hill, 1957.

Nixon, C. W., Mabson, W. E., Trimboll, F., Endicott, J. E. & Welch, B. E. Observations on man in an oxygen-helium environment at 380 mm. Hg total pressure: IV communications. *Aerospace Medicine*, 1968, 38(1), 1-9.

Nixon, C. W. & Sommer, H. C. Subjective analysis of speech in helium environments. *Aerospace Medicine*, 1968, 39(2), 139-44.

Nolan, C. Y. Reading and listening in learning by the blind. *Exceptional Children*, 1963, 29, 313-16.

Nolan, C. Y. Listening and reading in learning. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 67-8.

Nolan, C. Y. & Kederis, C. J. *Perceptual factors in braille word recognition.* Research Series No. 20. New York: American Foundation for the Blind, 1969.

Orr, D. B. The measurement of listening comprehension. *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 219-23.

Orr, D. B., Friedman, H. L. & Williams, J. C. C. Trainability of listening comprehension of speeded discourse. *Journal of Educational Psychology*, 1965, 56(3), 148-56.

Overmann, R. A. Processing time as a variable in the comprehension of time compressed speech. *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 103-18.

Parker, C. C. Effect of rate of compression and mode of presentation on the comprehension of a recorded communication to junior college students of varying aptitudes. *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 21-28.

Plessas, G. P. *Reading abilities and intelligence factors of children having high and low auding abilities.* Unpublished doctoral dissertation, University of California at Berkeley, 1957.

Postman, N. & Weingariner, C. *Teaching as a subversive activity.* New York: Delacorte Press, 1969.

Rawls, R. Program of training for listening-reading for visually impaired students using compressed speech recordings. *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 289-312.

Rose, E. *A comparative study of the Brown-Carlsen listening comprehension test and three tests of reading comprehension.* Unpublished doctoral dissertation, New York University, 1958.

Russel, R. D. A comparison of two methods of learning. *Journal of Educational Research*, 1928, 18, 235-8.

Scott, R. Interrelating reading and listening in grades nine through fourteen. *Reading and the Language Arts.* Proceedings of the Annual Conference on Reading. Chicago: University of Chicago Press, 1963, 63-7.

Scott, R. J. *Temporal effects in speech analysis and synthesis.* Unpublished doctoral dissertation, University of Michigan, 1965.

Scott, R. J. Computers for speech time compression. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 29-35.

Steele, N. W. *Learning by blind children of low ability: The relative efficiency of reading and listening.* Unpublished doctoral dissertation, George Peabody College for Teachers, 1969.

Sticht, T. G. Studies on the efficiency of learning by listening to time-compressed speech. *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 80-9.

Stromer, W. F. *An investigation into some of the relations between reading, listening and intelligence.* Unpublished dissertation, University of Denver, 1952.

Taylor, E. A. *Controlled reading.* Chicago: University of Chicago Press, 1937.

Taylor, J. L. Use of compressed speech, tapes and discs and of variable frequency power supply with selected children and adults. *Proceedings of the Louisville Conference on Time Compressed Speech.* Louisville: University of Louisville, 1967, 55-60.

Toussaint, I. H. *Interrelationships of reading, listening, arithmetic and intelligence and their implications.* Unpublished doctoral dissertation, University of Pittsburgh, 1961.

Verne, J. *From the earth to the moon.* New York: Scribner, 1918.

Vorr, J. B. & Miller, J. M. The effect of practice on the comprehension of speeded speech. *Speech Monographs*, 1965, 32, 452-5.

Warren, R. P. Poetry in a time of crack-up. *Intellectual Digest*, March-April, 1970.

Witty, P. A. & Sizemore, R. A. Studies in listening. *Elementary English*, 1958, 35, 538-52; 1959, 36, 59-70; 36, 130-40; 36, 297-301.

Wood, C. D. *Comprehension of compressed speech by elementary school children.* Washington, D.C.: U.S. Department of Health, Education, and Welfare, Office of Education, 1965.

Woodcock, R. W. The application of rate-controlled recordings in the classroom. *Proceedings of the Second Louisville Conference on Rate and/or Frequency-Controlled Speech.* Louisville: University of Louisville, 1971, 90-102.

Young, W. E. *The relation of reading comprehension and retention to hearing comprehension and retention.* Unpublished doctoral dissertation, State University of Iowa, 1930.

THE USE OF MYOELECTRIC FEEDBACK IN TEACHING FACIAL EXPRESSION TO THE BLIND*

Nancy Colleen Webb

PART 1

Background

Facial expression is perhaps the most important of all non-verbal communication. It has been used by actors and artists through the ages to describe the finest nuances of affect. In 1877 Charles Bell put forth a lengthy theoretical treatise on the significance of facial expression, and Darwin (1896) discussed the development of facial expression within the evolutionary scheme. While much facial expression is spontaneous, it is often employed purposefully in social interchanges. This ability is virtually nonexistent in the blind (Thompson, 1941; Fulcher, 1942; Dumas, 1932; Eikenberry, unpublished paper; Foulke, personal communication), and it would be useful for them to develop it. It should increase their social effectiveness to be able to control and manipulate their facial musculature. The purpose of this study was to attempt to teach facial expression to blind subjects using biofeedback obtained by transducing the myoelectric activity of the facial muscles.

The many different facial expressions are the result of various combinations of muscular contractions. Most of the major muscles may be defined in terms of expressive function(s) (Gray, 1959; Quiring, 1960). Patterns of muscular and feature involvement have been analyzed in detail by such investigators as Thompson (1941) and Fulcher (1942), and have been used as criteria for identifying expressions (Landis, 1924b; Frois-Wittman, 1930). It must be noted, however, that most expressions involve several of the muscles in one way or another, and many muscles can be divided into parts which may move independently. The descriptions which follow, then, concentrate upon the primary, rather than the only muscles involved in various expressions.

Expressions of pleasure, happiness, or joy result primarily from the contraction of the *zygomaticus*, which draws the corners of the mouth back and up. The expression is even more pronounced if the *orbicularis oculi* (sphincter muscle of the eye) becomes involved. Contraction of this circular muscle causes narrowing of the eyes often seen in expressions of happiness. Expressions of anger, on the other hand, employ quite a different set of muscles. The *corrugator*, a small muscle originating at the arch of the eyebrow and extending just to the bridge of the

---

*A thesis submitted to the Faculty of the Graduate School of the University of Louisville in partial fulfillment of the requirements for the degree of Master of Arts.

nose, is the primary muscle used. It causes the forehead to wrinkle vertically between the eyebrows. Other muscles which may be involved in an angry expression are the *dilator naris*, which widens the nostrils, and the *orbicularis oris* (sphincter of the mouth), which, either alone or in combination with the *mentalis* or the *risorius*, gives the mouth various tightly-drawn appearances typical of displeasure. An intensified state such as rage will include the *masseter*, which may be used to clench the teeth or to protrude the lower jaw. Puzzlement, a much more mild emotion, may use the same *corrugator* movement used in anger, but none of the other muscles involved in expressing that emotion. Fear usually involves the *frontalis*, which wrinkles the forehead transversely, the *levator palpebrae superioris*, which widens the eyes, and the *masseter*, this time to open the mouth by dropping the jaw. Surprise results from a lesser degree of the same *frontalis* and *masseter* movement. Other expressions and the primary muscles effecting them are: scorn or contempt--*levator anguli oris*; sadness or grief--*triangularis*; sulkiness--*mentalis*; irony--*depressor labii inferioris*; grinning--*risorius* (Gray, 1959; Quiring, 1960; Chusid, 1970; Landis, 1924b; Thompson, 1941).

Movement of the facial muscles comes under the control of the many branches of the seventh cranial nerve (except for the *levator palpebrae superioris*, which is innervated by the third cranial nerve). Except for the bilateral innervation of the *frontalis* (forehead) muscle, facial muscles receive contralateral cortical innervation (Chusid, 1970). A theory of dual neural control of facial movement was postulated by S. A. K. Wilson in 1929 (Fulcher, 1942). He puts forth the following as evidence pointing to separate innervating pathways: the fact that certain automatic movements of the facial musculature due to respiratory processes can be interrupted temporarily by voluntary action or through emotional excitement; and cases of partial facial paralysis and pathological laughing and crying. More recent writers tend to agree with Wilson's findings. In their textbook on neuroanatomy, Crosby, Humphrey, and Lauer (1962) note, in their discussion of cortical motor control of the face, that supplementary motor pathways may become involved in the expression of emotion. They, too, base their conclusion on clinical pathology, observing that destruction of the facial component of the cortico-bulbar system may prevent voluntary movements, but not natural expression. Fulcher (1942) extends this line of thought with the idea that each neuromuscular branch has its own patterning development, the emotional developing patterns for expressing the self, the volitional developing its own patterns for social communication.

Obviously, spontaneous expression, or that occurring reflexively as part of a total emotional response, is observed first in the infant. Sherman (1927) found that the facial patterns twelve-day-old infants produced in response to various kinds of stimulation could not be differentiated from one another. At around 21 days of life, the smile appears, and many observational studies have focused on this expression. Goldstein (1957) feels that the infant smile is different from all other facial movements, and that it occurs long before any kind of imitation is possible. Goodenough (1931) states that there is a "core of native reaction-patterns" which appears too early to be learned. Spitz (1946) studied 251 white, black, and Indian infants from widely diverse environments and concluded that the smile is universal. She stated that the motor patterning of the smile is present at, or soon after, birth, but sometime after the second month, the smile takes on a "semantic" function. Washburn (1929) performed an intensive study of infant smiling and laughing, assuming that these responses were different degrees of the same affective state. She found all smiling to be responsive, requiring specific stimulation. Other investigators, however, claim to have observed a spontaneous dropping-off-to-sleep smile (Spitz, 1946; Freedman, 1964). Washburn (1929) noted that smiling increased in frequency of occurrence over the first year of life, whereas the frequency of laughing remained fairly stable. She concluded that smiling is "more" learned and laughing "more" innate, and that developmental differences are more important than individual differences.

As the child learns to control the production of various expressions, he begins to learn to perceive these in others. A developmental lag between the receptive and expressive phases of this learning process was documented by Odom and Lemond (1972). Much as the child's receptive vocabulary develops prior to his ability to use the same concepts expressively, children of two different age groups were found to be able to discriminate among more expressions than they could accurately produce. The discrimination skill seems to improve at a faster rate than the production skill, so that by age 10, the lag is even greater than it is at age 5. These skills have not been compared in older individuals, so their relative positions are unknown for adolescence and adulthood.

It would appear, then, that while the basic "machinery" of naturally occurring expression is innate, the influence of learning is evident in the abilities of people both to simulate various expressions at will, and to interpret the expressions of others with some degree of accuracy. To document the existence of either of these abilities is to assume the existence of the other, due to the communicative nature of the phenomenon. Evidence that people can expressively communicate through facial gestures is inseparable from the evidence that people can interpret those gestures.

Many studies have shown that this communication, indeed, occurs. Feleky (1914) was the first to use judges to view a number of photographs, guess the feelings of the person by the expression on his face, and attach appropriate labels. Using a linear scale where all errors were not of equal magnitude, she found enough agreement among 100 judges to warrant further research in the area. Buzby (1924) reported that while judges were successful on expressions signifying disdain, disgust, horror, and bewilderment, they judged anger and dismay poorly. Boucher (1969) determined that judges could differentiate fear, sadness, and pain on the basis of facial expression. Thompson and Melzer (1964) found love, happiness, fear, and determination easiest to identify, and disgust, contempt, and suffering most difficult. Frois-Wittman (1930) found a high degree of concurrence on expressions of pain, laughter, and pleasure, and moderate agreement on disdain, horror, and attention, although judges did not agree on disappointment, anxiety, cynicism, or aversion. Landis (1924a) reported highest agreement on contemplation, pleasure, sex-feeling, and disgust, while pain was lowest. Enjoyment and shame had the highest correlation coefficients between intended expression and judged expression in a study by Tomkins and McCarter (1964), with surprise and distress lowest.

In most studies, accuracy means that the judge has labeled an expression with the same term the expressor had in mind when producing it. In some cases, a judge would be accurate if he used the same label that the experimenter had in mind while trying to evoke a particular emotion. On the other hand, consensus might be considered to be a valid criterion for identifying expressions. If a number of judges agree on a particular label, there is face validity in this even though it may not reflect the expressor's intentions. Since an interpreter is necessary for an expression to have meaning, its meaning must depend in part on the opinion of the interpreter. Generally, consensus and accuracy rise and fall together, and although Tomkins and McCarter (1964) found that consensus did not always predict accuracy, they discovered that confusion on the part of the judges tended to be systematic. Osgood (1966), discovering that certain dimensions of expression tended to be confused with others in a systematic way, noted the congruity between his findings and those of Tomkins and McCarter (1964). In Tomkins and McCarter's study, judges did not confuse enjoyment with anything, while Osgood reported confusion of the dimensions quiet pleasure and glee only with each other. Tomkins and McCarter's surprise was confused with both interest and fear, whereas Osgood found surprise confused with interest (though not vice versa), and fear confused with surprise (though not vice versa).

An examination of the literature reveals several factors which influence accuracy and consensus among judges. Several of these pertain primarily to the judge, and these will be examined first.

The nature of the judging task is one important factor. Asking the judge to identify expressions with labels resulted in semantic problems both within studies and in relating one study to another. Allowing judges to choose their own labels resulted in too much individual difference in preference of terms, while limiting the judges to certain labels forced the experimenter to select descriptors somewhat arbitrarily. This and other problems in early qualitative studies were dealt with by quantifying the study of facial expression. Woodworth constructed a linear scale with six categories:

1. Love, Mirth, Happiness;
2. Surprise;
3. Suffering, Fear;
4. Determination, Anger;
5. Disgust;
6. Contempt

(Woodworth and Schlosberg, 1956). When judgments were obtained on a series of photographed expressions, inaccuracies were found to be somewhat systematic. In most cases, the correct category was the modal selection, while those closest to it on either side had the next highest number of responses. For example, if a photograph portrayed surprise, most judges selected category 2 (surprise), while most judgment errors went into categories 1 (love) and 3 (suffering), and very few, if any, were as far away as category 5 (disgust). This scale was determined to be circular since the responses to category 6 photographs spilled over into category 1 and vice versa.

Arranging these categories in a circle, Schlosberg constructed two axes through the circular surface, one representing basically a pleasure dimension (pleasantness-unpleasantness), the other a quality-of-attention dimension (attention-rejection) (Woodworth and Schlosberg, 1956). The scale positions of photographs plotted according to these axes correlated 0.94, 0.92, and 0.96 in three separate experiments with data from judgments. The validity of this scale in predicting judge behavior has held up since the time of these early studies in 1941. However, in 1954, Schlosberg added a third dimension (sleep-tension) and found it could be reliably incorporated into the surface (Osgood, 1966).

Several factor analytic studies have confirmed these basic dimensions. Engen, Levy, and Schlosberg (1958) found consistency of judgments highest for the pleasantness-unpleasantness (P-U) dimension, next for the sleep-tension (S-T) dimension, and lowest for attention-rejection (A-R). Gladstones (1962) found three dimensions, two resembling Schlosberg's P-U and S-T; the third he labeled expressionless-mobile. His findings concerning strength of prediction corresponded exactly to those of Engen et al. (1958). Four dimensions were reported by Frijda and Philipszoon (1963):

1. Pleasantness-unpleasantness;
2. Naturalness and submission-artificiality and condescension;
3. Intensity of expression-control of expression;
4. Attentional activity-disinterest.

Osgood (1966) concludes that there are at least three dimensions to communication through facial expression.

Part of the disagreement as to number and quality of dimensions is due to the number and diversity of the scales of measurement, and part due to the various methods employed in treatment of the data. Varimax solution, bipolar scales method, and multidimensional method of complete triad have all been used. The literature does reveal complete agreement on a pleasantness dimension, and almost complete agreement on an activation dimension. The third and any additional dimensions are those most debated.

Sherman (1927) found that situational cues seemed to be the factor which made the difference in accuracy of judging reactive expressions. His judges' accuracy improved considerably when they saw the context in which each photo was taken. In a further investigation of this hypothesis, Frijda (1961) gave a control group only the situational cues and found their judgments far less accurate than those who judged on the basis of facial expressions alone. These conflicting results are most likely due to the fact that Sherman's subjects were 12-day-old infants whose faces contained very little information. It appears that, although situational cues do play a role, facial expressions of adults are specified to a considerable degree by the face alone. Landis (1924b) proposed that rather than a stimulus evoking an emotional state which is documented in the face, a situation-reaction complex produces a particular feeling. These situation-reaction complexes are what we have attempted to describe with labels.

Besides being partly situation-dependent, judgments were found to be affected by training (Woodworth and Schlosberg, 1956), and by suggestion (Jarden and Fernberger, 1926; Landis, 1924b), even if it was purposefully misleading (Fernberger, 1928). Langfeld (1918), documenting individual differences in suggestibility, demonstrated the independence of suggestibility from accuracy of judgment.

As previously noted in the developmental lag study by Odom and Lemond (1972), the age of the judge has a definite bearing on accuracy of judgment. Gates (1923) studied the behavior of judges along a developmental continuum. Asking for labels to six relatively unambiguous photographs, she recorded responses from judges ranging from three years of age to adulthood. Her findings were as follows: over 50 percent of the judges labeled laughter correctly at 3 years, pain from 6 to 7 years, anger at 7 years, fear at 10 years, surprise at 11 years, and scorn (only 43 percent) at 11 years. All adults labeled scorn correctly. For a test constructed after this study, Gates (1925) found the scores correlated highly with measures of social or emotional maturity, but not with physical or mental maturity. This indicates the social significance of facial expression.

Other specific variables pertaining to judges have been evaluated for their contribution to accuracy of judgment. The sex and sophistication of judges have been tested for experimental effect. Buzby (1924) found women and the unsophisticated to be more accurate, while Jarden and Fernberger (1926) and Sherman (1927) found no effect for either variable, nor did Gates (1925) find a sex difference in children. Engen, Levy, and Schlosberg (1957) reported that the judgments of newspaper readers were as accurate as those obtained in the laboratory, and Levy, Orr, and Rosenzweig (1960) found judges drawn from two clinical populations to be as accurate as normals. In a series of studies on crosscultural comparisons of judges, Ekman and his associates have determined that there are no significant differences in judge accuracy from country to country or between literate and preliterate cultures (Ekman, 1970; Ekman and Friesen, 1971; Ekman, Sorenson, and Friesen, 1969). Tomkins and McCarter (1964) suggest that the judge may be operating under certain perceptual taboos which influence his usage of labels (their judges tended not to use the label "shame"). How judges perceive expressions concerned Haslam and Pedersen (1966). They had judges rate 20 pictures of facial expressions on 20 semantic differential scales. They collected information on the judges' age, sex, class and major in college, and various personality measures, and found that certain dimensions of perspective (factor analyzed from the responses to the pictures) were associated with certain of these variables. They state that there are "different idealized types of people which represent distinct modes of perception of facial expression of emotions, and these types can be identified by some of their personality characteristics [p. 646]."

Communication via facial expression is affected by other variables which primarily concern the expressor. What the critical facial stimuli are has concerned several investigators. In an attempt to evaluate the part-whole relationship, Boring and Titchener (1923) used a series of feature drawings by Piderit to construct a plaster model with 20 movable pieces. Using this model to produce a variety of facial patterns, they found that particular meanings may be represented by particular simple expressions, while more complex meanings may require more complicated expressions. Dunlap (1927) did a study which showed the mouth to be more important than the eyes in the communication of different expressions. Buzby (1924) found the eyes and upper part of the face to contain more information. It must be noted that Dunlap's label "mouth" actually included everything below the midpoint of the nose. Frois-Wittman (1930) and Coleman (1949) found no consistent dominance of either part.

Landis (1924b) performed a detailed observational analysis of muscular involvement in several spontaneous expressions and concluded that a smile was the only expression which could be called typical of any situation in his experiment. While he did not find that unique muscular patterns characterized the various situations, both the situations and the analysis of the muscular involvement were subjectively determined. Also, he reported certain very unusual reactions of his subjects such as smiling while watching the decapitation of a rat; smiling at the tactile discovery of frogs in a pail, which casts some doubt on the validity of his laboratory situations relative to real world situations. The range of emotions aroused was probably quite limited (Woodworth and Schlosberg, 1956). He reported, but could not account for, an individual-patterning phenomenon, i.e., there tended to be a predominance of certain muscle groups in each individual. Tomkins and McCarter (1964) felt that each face had a predominant expression which could contaminate its portrayal of other affects. Frois-Wittman (1930), in an attempt to clarify this issue, used judges to label expressions and then analyzed muscle involvement both according to the judged expressions and according to the intended expressions. He found that muscular patterns predicted modal judge behavior in every case, though they did not characterize the intent of the expressor except in laughing, crying, and horror. Still, judges were accurate beyond chance. Frois-Wittman felt that an explanation for the part-whole differences was that movement per se is an inadequate criterion since the qualities of type and degree of movement are not delineated. Besides, the significance of a given muscular movement is relative to the entire pattern.

The cognitive nature of the expressor's task may affect judge accuracy. The subject may be instructed to produce various expressions or he may be stimulated in various ways and his "natural" facial responses used as the material to be judged. If he is asked to produce an expression, he may attempt to reproduce it from memory, or he may imagine a situation that would evoke the requested expression, and attempt to react to that imagined situation. If he reproduced an expression from memory, it might be a kinesthetic memory of his own face, a visual memory of his own face, or a memory of someone else's face. Fulcher (1942) presents a lengthy discussion of the difficulty the experimenter has in controlling this cognitive variable. Even though he took pains to instruct his subjects merely to "look as if," not to "feel," say, angry, he felt it necessary to offer examples of situations in which one might appear, say, angry. A very vivid imagination might provoke the actual emotion, and the accompanying facial behavior. On the other hand, expressions of "real" emotions being filmed in a laboratory may not be quite the same as expressions occurring spontaneously in the natural world (Woodworth and Schlosberg, 1956).

Landis (1924a) performed a seminal study of the facial expression of "real" emotions. He created various situations in the laboratory intended to elicit certain feelings. The facial responses to these situations (or feelings) were preserved in both moving and still pictures and subjected to the judgment procedure. Next he had each subject recall each situation, remember his feelings, and re-enact the facial expressions. Pictures of these expressions were then judged. Results showed greater accuracy with the "acted" expressions than with those taken in the real situation. The actual responses to the stimuli were more varied and thus more difficult to judge; when subjects attempted to reproduce the responses, they produced more conventional expressions. This distinction between natural and voluntary expressions becomes even more critical in the expressive behavior of the blind, to be discussed in Part 2.

Another factor is that some expressions may be easier to produce than others. Expressions of pleasure (laughing, smiling, etc.) are the earliest to appear and are, by all accounts, the easiest to produce (e.g., Frois-Wittman, 1930; Fulcher, 1942). Not much material has been provided on this subject except that in middle childhood, anger, interest, and surprise follow laughter in ease of production, while distress and fear are most difficult (Odom and Lemond, 1972). For the adult, difficulty for any particular expression should vary from individual to individual according to Landis (1924b) and Tomkins and McCarter (1964).

The expressor may be affected by a semantic factor. He may not be able expressively to distinguish between two similar terms, or may have difficulty relating a particular term to a particular feeling. Subjects may differ in their evaluation of such relative terms as discontent--anger--rage. Tomkins and McCarter (1964) found that semantic confusion, degree of emotion portrayed, and the overshadowing of facial affect by formal language were factors in the communication of various affects.

As previously mentioned, the age of the person producing the expression is critical. Within the first few weeks of life, reactive expressions are non-differentiable (Sherman, 1927). By age 5, there is some ability to effect differential facial patterning voluntarily, and by age 10, this ability has improved significantly (Odom and Lemond, 1972). Hanada, Inoue, Hazeki, and Takano (1960) electrographically demonstrated that the ability to contract facial muscles develops gradually with age. Whether the ability improves still further has not really been validated, but adult expressors are fairly effective.

In summary, it has been shown that people do involve the face in their expression of emotion, using certain patterns of muscular contractions in conjunction with certain feelings. While the basic expressive equipment of naturally occurring expression is innate, the influence of learning is evident in the ability of people to produce voluntarily expressions which simulate the spontaneous ones. People can, to some extent, perceive the emotions of others by their facial patterning. The extent to which this communication is successful depends on several factors. Some expressions are easier to communicate than others, and classifying expressions into dimensions is easier than exact labeling. Expressions tend to be more varied and thus more difficult to interpret if they are spontaneous than if the expressor is consciously trying to communicate. In interpreting reactive expression, knowledge of the situation in which the expression is occurring helps considerably. Cultural factors do not seem to have much effect on success of communication, but suggestion and training are both effective. Age makes a difference both in the ability to produce, and in the ability to discriminate among, expressions, receptive skills exceeding expressive skills.

PART 2

Facial Expression of the Blind

The question of voluntary versus "natural" or reflexive expression is an important one in the study of sighted persons, but it becomes critical in the study of the blind. Goodenough (1932) observed the facial reactions of a congenitally blind-deaf girl of 10 years of age. In response to a small doll being dropped down her back, she produced normal facial expressions of surprise, attention, determination, anger, rejection, and happiness in her finally successful effort to retrieve it. Fear was also observed in other situations.

Freedman (1964) cites several observational reports documenting the smile of blind children at normal ages. Thus vision, per se, is not a prerequisite for the occurrence of either spontaneous or responsive smiling. Auditory, tactile, and internal stimuli are known to evoke smiles (e.g., Spitz, 1946; Washburn, 1929). Vision, however, does play a part in the later development of all facial expression.

Thompson (1941) set out to compare in detail the spontaneous facial behavior of blind and seeing children. She observed and filmed 26 blind (including 4 deaf-blind) and 29 seeing children in various real life situations. These children ranged from seven weeks to 13.5 years of age, affording a developmental continuum for isolation of maturational factors. Thompson concentrated on the expressions of laughing, smiling, and crying, and observed other expressions to a lesser degree. She had judges to determine the amount of involvement of eight facial features in each expression and found that expressions of laughing and smiling occurred at all age levels, and crying at younger levels, in both blind and seeing children. Two sets of judges were asked to evaluate total expressions. These were judges familiar with the blind and judges not familiar with the blind. Expressions of anger, sulkiness, annoyance, and sadness were observed in the blind and were more accurately judged by those who had worked with blind children. Fear was not observed, but Thompson notes that none of the situations was frightening. Thus, while laughing, smiling, and crying may be assumed to be innate (agreeing with Darwin, 1896; Washburn, 1929; and Landis, 1924b), the other expressions mentioned above may be affected by learning.

As to the maturational question, important findings were:

1. For laughing, the effect of maturation was to decrease amount of facial activity in both blind and sighted children;

2. For smiling, this effect was the same *only in blind children*--the amount of facial activity in smiling did not decrease in the sighted;

3. For crying, activity increased for both groups as far as it was observed (none seen after the third year).

Thompson noted that in laughing and smiling, random muscular movement was limited in the older seeing children, and that expressions of the sighted were more uniform than those of the blind. She accounted for both of these in terms of visual mimicry. Her study, Thompson felt, supported Wilson's theory (Fulcher, 1942) that the facial musculature is under a dual neural control, and while "emotional" expression is affected by maturation, some amount of imitation is involved in "voluntary" expression.

The theory also finds support in those studies dealing with voluntary expression rather than that occurring spontaneously. To be more accurate, one might rephrase it "expression occurring in response to a request rather than in response to naturally occurring internal or situational stimuli." The widely cited findings of Mistschenka (e.g., Woodworth and Schlosberg, 1956;

Thompson, 1941) are in agreement with Thompson's (1941). Mistschenka noted that blind children are inferior in their ability to move facial muscles at request, and that this inability is even more pronounced in regard to their voluntary production of facial expressions. He found a gradual retardation of voluntary facial patterning of the blind between the ages of 4 and 18.

Dumas (1932) was the only investigator to study voluntary facial expression in adult subjects. He found that 33 congenitally blind adults were grossly inadequate in their ability to produce facial expressions at request. He was convinced from the observations of those who lived or worked with them, however, that their expressions of real emotion were not remarkable.

Probably the most illuminating investigation into the development of voluntary facial expression was that of Fulcher (1942). He compared blind and seeing children in a three-way analysis of the expressions happy, sad, angry, and afraid: first with respect to amount of facial activity; second with respect to movement of specific parts of the face; and third, with respect to adequacy. His results indicated that the blind show less facial activity in their expressions of every emotion, though the relative amounts of activity for the various emotions is similar to the sighted. As Thompson (1941) found, there was an increase with age in the facial activity of the sighted, while activity in the blind children decreased with age. Though the differentiation of the expressions of the blind is not as sharp as that of the seeing, the blind do tend to show the same trends of differential activity. This suggests that though vision is probably the most meaningful factor in the development of expression, it is not solely responsible for it. Fulcher admits that it is difficult in a study of this type to insure that the expression is truly "posed" and not the result of the subject's feelings, e.g., he may imagine something which scares him rather than merely trying to look afraid.

To summarize these studies, it would appear that in infancy, both blind and seeing exhibit a certain amount of facial activity which is largely innate. As they grow older, the sighted are stimulated through social interaction to imitate expressions they see on the faces of others. This tends to stylize their expressions and eliminate unnecessary movement. Thus, through visual facilitation, they build a repertoire of learned motor patterns from their natural expressive rudiments. The blind, however, lacking the visual stimulation and feedback, tend to use their facial musculature less and less until at maturity, spontaneous expression is underdeveloped and voluntary expression is totally inadequate. As the older blind child begins to realize that his expressions may be inappropriate, he will probably prefer to make slighter movements or none at all. As part of an emotional outflow, a blind person's facial patterns will be "normal" as judged by those around him. The fact that judges not familiar with the blind will not be as accurate in judging their expressions supports the idea that vision tends to stereotype expressions, where the blind maintain patterns which are more individualized (and thus more easily detected by those who know them). In his attempt to respond to a request to produce a particular expression, the blind person is at a loss since he has no reference point and no practice at voluntary control of the facial muscles. There may be an entire neuromuscular network which fails to develop.

RATIONALE FOR THE PRESENT STUDY

Several studies indicate that it could be an important social gain for the blind to be able to exercise more control over facial expression. Shears and Jensema (1969) found that a sample from the normal population, in ranking desirability of various afflictions (in friend or in self), used "interference in the communication process" as one criterion for judgment. Himes (1960), in studying culturally-defined stereotypes of blind people, found that sighted students were very accepting of the idea of having a blind student on campus (at an impersonal distance), but did not, on the whole, accept the idea of a blind student as a steady date.

Thus as intimacy of hypothetical social relationships increases, the sighted tend to be less willing to become involved with the blind. The blind would do well to change the stereotype which creates this situation, particularly since they tend to evaluate themselves in terms of the sighted (Strauss, 1967). Zunich and Ledwith (1965) reported that blind children felt they were less popular than their sighted peers, due perhaps to an abnormal body image. Many of these social problems of the blind might be mitigated somewhat through development of facial control. Dumas expressed the same opinion in 1932, "It would obviously be a great service to the blind to teach them mimicry which would make them seem more like ourselves, [sic] it would draw us nearer them and at the same time contribute to adapt them to this community life from which their blindness isolates them [p. 31]."

Osgood (1966), noting that facial behavior plays a significant role in the "gestural code," developed a linguistic analogy of facial expression wherein each element has a counterpart: temporal sequences of facial movements $\approx$ sentences; momentary patternings (e.g., as might be captured in a still photo) $\approx$ phrases; configurations of significant parts (e.g., mouth) $\approx$ words; and muscular patterning of these parts (e.g., curled lip) $\approx$ phonemes. Since the blind have poor control over these elements, they are unable to effectively "converse" in this nonverbal language.

Tomkins and McCarter (1964) propose a theory of affect in which the face assumes a vital role. They feel that the primary human motive is affective response, and affects are primarily facial behaviors. The face is the "organ of maximal transmission of information to self and others [p. 120]," and its evolution is to increasing expressiveness through greater visibility of the facial musculature and through increasing differentiation of muscular innervation. According to this theory, the blind will become more and more visibly different, and learning facial control will become more and more essential.

A technique called biofeedback has been utilized by many researchers (and some clinicians) to train subjects in the control of various physiological systems not normally under "voluntary" control. It is hypothesized that the lack of perceptible feedback from a given "involuntary" system is the reason for the lack of control. When the activity of that system is made perceptible through bioelectric transduction, control becomes feasible. Biofeedback is a relatively recent development in operant methodology. Specifically, it refers to the establishment and operation of a closed electrophysiological circuit in which selected biopotentials generated by a person are transduced into auditory, visual, or tactual signals which are fed back to the person.

Many studies have been done with externalized feedback of the various physiological systems. The best known work has dealt with the enhancement of the alpha frequency of the electroencephalogram (e.g., Kamiya, 1968; Hart, 1968; Brown, 1970; Peper and Mulholland, 1971). Control of heart rate and variability has been demonstrated by Engel and Hansen (1966); Levene, Engel, and Pearson (1968); Brener, Kleinman, and Goesling (1969); Shapiro, Tursky, and Schwartz (1970); and Lang (1971). Blood pressure and skin temperature have been externalized and fed back (Brener and Kleinman, 1970; DiCara and Miller, 1968; Green, Green, and Walters, 1970). Most work with myoelectric feedback has been an effort to decrease muscle tension through representing its level by a signal which the subject attempts to manipulate. Budzynski and Stoyva (1969; 1972), Green et al. (1970), and Hardyck, Petrinovich, and Ellsworth (1966) are among those successfully utilizing muscle feedback to lower tension.

A blind person attempting to control facial movement may be analogous to a "normal" person attempting to control brain rhythms or heart rate. Dumas (1932) reports that one blind subject stated that while he knew perfectly well what the experimenter was asking him to do (simulate various expressions), ". . . I do not know how joy, sorrow or anger are expressed on my face [p. 32]." His subjects appeared to have no memory or knowledge of the facial components of their emotional expression. He noted that some subjects felt their face (manually) while laughing, and tried to reproduce the lifting of the cheeks. Thus, it would appear that feedback of the specific movements involved in the various expressions is what is needed.

Since blind people do exhibit an inadequacy in voluntary facial expression, and are thus unable to participate in an important communication network, they should profit from gaining control over the facial musculature. Due to the feasibility of gaining this type of control through biofeedback, it was decided to perform an experiment in which the myoelectric signals from contracting facial muscles would be transduced into auditory signals which the subject could perceive and attempt to manipulate.

PART 3

Method

SELECTION OF EXPRESSIONS AND JUDGES

Before training blind subjects to produce expressions to be judged, it was necessary to select the best expressions and judges for this purpose. These two selection processes were carried out simultaneously in a pilot study.

First, five expressions were preselected according to two criteria--recognizability according to past literature and uniqueness of muscular involvement (i.e., each expression should emphasize a different muscle for ease of distinction). Accordingly, the following expressions were chosen: happiness, disgust, fear, anger, and sadness.

Motion picture film was taken of seven sighted subjects (four men and three women) voluntarily producing each of the five expressions in counterbalanced order (see Appendix 1, Instructions to Sighted Subjects). This film was edited to randomize subjects and expressions, and was presented to a group of 15 people, each of whom independently matched the five labels to the expressions (see Appendix 2, Instructions to Judges, 1). Analysis of these data disclosed the following:

1. The distribution of judge errors indicated that three of the judges were clearly superior, ten average, and two poor. The three highest-scoring judges were selected to continue in the experiment.

2. Subject errors also distributed themselves normally over a range extending from 17 errors for the best subject to 42 errors for the worst subject (Fig. 2).

3. Of the five expressions, only happiness was recognized in almost every case. In terms of judge errors, the expressions were recognizable in the following order from easiest to most difficult: happiness (11), fear (40), disgust (41), sadness (50), and anger (56). These results are consistent with those reported most often in the literature.

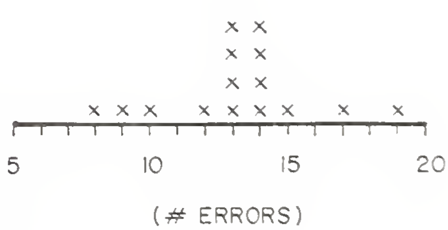


Figure 1. Distribution of Judge Errors (First Judging).

4. The chi-square statistic was used to evaluate contingency between judged expressions and intended expressions and a significant chi-square value ($p < 0.001$) was obtained (Table 1). The degree of this association is indicated by a phi coefficient of 0.41.

As a result of these data, it was decided to have the best three judges plus five additional (new) judges view a second series of expressions produced by the best five subjects plus two new subjects. The expressions sadness and disgust were removed from the second series for the following reasons: sadness

TABLE 1

Contingencies for First Judging

Expression Judged	Expression Intended: Afraid	Angry	Disgusted	Happy	Sad
Afraid	75 (0.71)*	17 (0.04)	13 (0.01)	4 (0)	6 (0)
Angry	21 (0.04)	58 (0.55)	17 (0.11)	0 (0)	18 (0.01)
Disgusted	5 (0.01)	22 (0.11)	29 (0.27)	1 (0)	13 (0.01)
Happy	3 (0)	1 (0)	7 (0)	97 (0.92)	0 (0)
Sad	1 (0)	7 (0.01)	39 (0.12)	3 (0)	68 (0.64)

*parenthetical numbers indicate ratio-scale values

$\chi^2 = 353.39$, $p < 0.001$

$\phi' = 0.41$

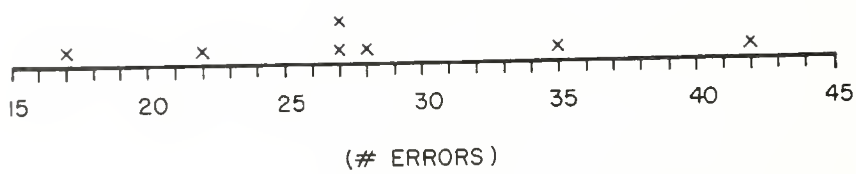


Figure 2. Distribution of Subject Errors (First Judging).

produced no consistent pattern of muscular contractions, and little muscular contraction of any sort. Consequently, there would be no myoelectric feedback to guide responses during training. Disgust was dropped partly because it also lacked a characteristic pattern of muscular contractions, and partly because it had high confusability with both anger and sadness. Many subjects complained about attempting to differentiate between disgust and anger. Anger, though more poorly judged, was felt to be easier to condition with muscle feedback since its muscular signature was more universal than that of disgust and also more distinct from happiness and fear than was that of disgust.

The second set of data, then result from eight judges viewing seven subjects each producing three expressions: happiness, fear, and anger. The instructions and procedures of this judging were the same as before. Results indicated that one of the three originally chosen judges was tied for first place, though the other two did not do as well. There were very few judge errors this time, the greatest number being three (Fig. 3). It was decided to use the top four judges for the final task, that of judging the blind expressors. The subject charged with most errors also had three (Fig. 4).* The chi-square statistic was significant beyond 0.001 and the phi coefficient was 0.73, showing a high degree of concurrence (Table 2). Happiness was again the easiest expression to judge (zero errors), while anger moved into second place (four errors), leaving fear last (seven errors).

*One subject was dropped from consideration since she made a total of 10 errors, eight of which were the result of *every* judge labeling her fear expression "anger."

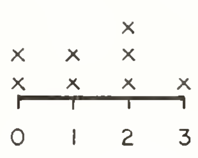


Figure 3. Distribution of Judge Errors (Second Judging).

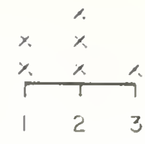


Figure 4. Distribution of Subject Errors (Second Judging).

The muscular contractions responsible for the expressions on the second film were observed and recorded in order to establish criteria for use during the training of blind subjects. The results of this analysis are shown in Table 3. Replacement of one of the expressions was indicated by this analysis, although the expression of fear was identified quite accurately by judges, five different patterns of muscular contraction were employed in the production of this expression. It was expected that *frontalis* movement would be observed in the fear expression (Thompson, 1941), but only two subjects actually employed this muscle to any appreciable degree. Quiring (1960) states that the function of the *frontalis* is to move the scalp backward and forward and to raise the eyebrows as in surprise. Through informal observation it was noted that the *frontalis* was consistently used in the expression of surprise, and it was felt that if judges could discriminate surprise as well as fear, surprise would be preferable to fear for training purposes.

Consequently, expressions of surprise produced by the six best subjects were recorded on film, and these expressions, together with their expressions of happiness and anger recorded on the second film, were used in assembling the third film. Three judges identified all 18 expressions on this film correctly (6 subjects x 3 expressions), and the remaining judge made only one error. Further statistical analysis was clearly not required. Inspection of the muscular contractions responsible for the expression of surprise indicated that five of the six subjects used the *frontalis* to express that emotion.

TABLE 2

Contingencies for Second Judging

Expression Judged	Expression Intended: Afraid	Angry	Happy
Afraid	11 (0.61)*	4 (0.06)	0 (0)
Angry	5 (0.06)	14 (0.77)	0 (0)
Happy	2 (0)	0 (0)	18 (1.0)

*parenthetical numbers indicate ratio-scale values

$\chi^2 = 57.86$, $p < 0.001$ $\Phi' = 0.73$

TABLE 3

Muscles Used by Sighted Subjects

Subject	Expressions: Happy	Angry	Afraid	Surprised
1	zygomaticus, orbicularis oculi	levator palpebrae, orbicularis oris	frontalis, masseter	zygomaticus, frontalis
2	zygomaticus	corrugator	masseter	frontalis, masseter
3	zygomaticus, orbicularis oculi	corrugator, orbicularis oris	frontalis, masseter, levator palpebrae	zygomaticus, frontalis, levator palpebrae, masseter
4	zygomaticus	corrugator, orbicularis oris	(none)	masseter, orbicularis oris
5	zygomaticus	corrugator, masseter	levator palpebrae	zygomaticus, levator palpebrae, frontalis, corrugator
6	zygomaticus	corrugator, orbicularis oris	corrugator	frontalis, masseter

SUBJECTS

The five subjects who participated had the following characteristics:

	Sex	Age	Onset of Blindness age	cause	Degree of Vision
1.	F	45	10 years	tumor	light perception
2.	F	19	post-natal	RLF*	light perception
3.	F	18	post-natal	RLF*	none
4.	M	43	peri-natal	unknown	none
5.	M	20	11 years	detached retina	none

*Retrolental fibroplasia

APPARATUS

Myoelectric response was obtained from three facial loci. At each locus, the myoelectric response was picked up by gold-plated surface electrodes (Grass type E5G) connected in a bipolar configuration, and applied to the input of a bioamplifier (Medical Associates model 110), the dc gain of which is approximately 1,000. The output of this amplifier was rectified, averaged, and applied to the input of a voltage-controlled oscillator whose output frequency was a positive function of input voltage. The oscillator output was further amplified by an audio amplifier and applied to a loudspeaker. Two of the loudspeakers were situated on either side of the subject, the third directly behind him. Thus, the location of the tone informed the subject which muscle he was contracting, and the frequency of that tone gave him information concerning the strength of contraction.

PROCEDURE

Each subject was paid $6.00 for participating in the experiment. The procedure consisted of three phases: pretraining, training, and post-training.

Pretraining

Each subject was requested to express happiness, anger, and surprise (see Appendix 3, Instructions to Blind Subjects). These expressions were recorded on Super-8 film, type TXR 464, with a motion picture camera (Cannon Super 8 Auto Zoom, model 518).

Training

The purpose of the experiment was explained to the subjects. Each was prepared for training by first scrubbing the entire face with a facial scrub (a honey-almond-mint mixture) shown in pilot studies to be superior to an alcohol-rubbing preparation in terms of its effect on skin resistance. (Resistance with the scrub is about one-half what it is with alcohol.) Each site was wiped with alcohol, and electrode jelly* rubbed in. Each electrode cup was filled with jelly and taped onto the skin with a small gummed sponge disc with a hole in the middle (Dr. Scholls' Corn Pads, Small). This was held securely in place with a piece of 3-M Blenderm surgical tape. The electrode pairs were placed in the following configuration (Fig. 5a):

---

*This was a highly saturated electrolytic jelly, homemade according to a formula used by Lawwill (in press):

42 gm boric acid
720 ml H_2O
300 gm sodium chloride
210 ml glycerin
15 ml concentrated hydrochloric acid
40 gm tragacanth gum

In order to increase viscosity for use with cup electrodes, about 50 gm tragacanth was added to the original solution.

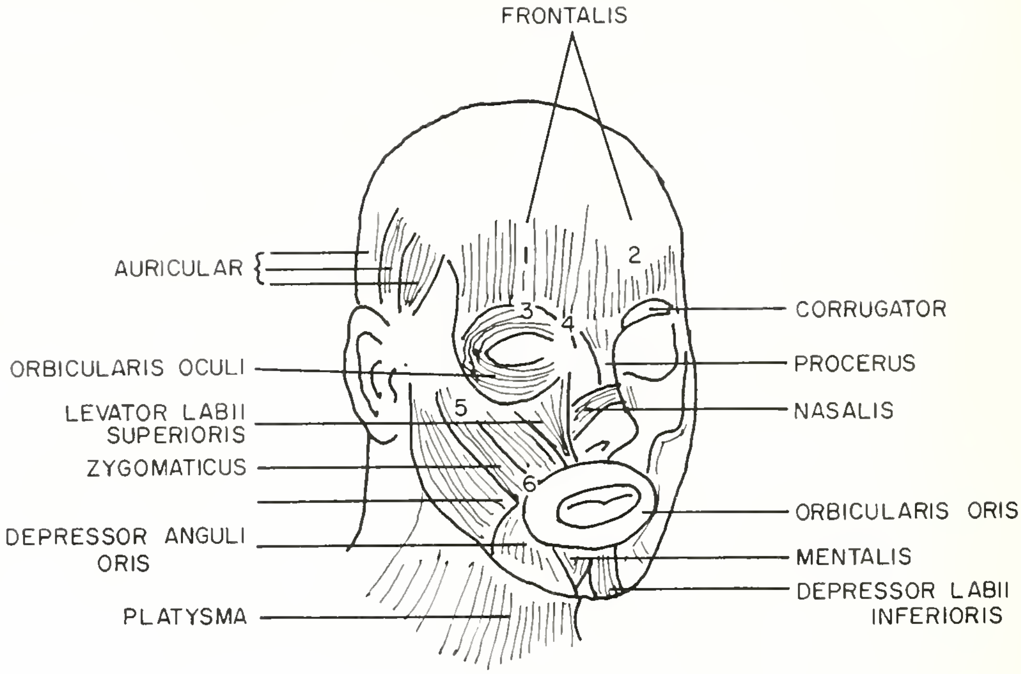


Figure 5a. Standard Electrode Placement

Figure 5b. Modified Electrode Placement

1. right frontalis
2. left frontalis
3. origin of corrugator
4. insertion of corrugator
5. origin of zygomaticus
6. insertion of zygomaticus

A common ground electrode was placed on the back of the neck. Resistances ranged from 7,000 ohms to 25,000 ohms between electrode pairs, and from 10,000 ohms to 30,000 ohms electrode-to-ground.

The following guidelines, as established in the pilot study with sighted subjects, were employed in judging criterion behavior:

Expression	Muscular Involvement	
	essential	secondary
happy	zygomaticus	orbicularis oculi
angry	corrugator	orbicularis oculi
surprised	frontalis	masseter

Procedure during this phase varied from subject to subject, according to the needs and abilities of the individual. It was preestablished that training would continue until all criteria were reached or three hours time was spent. Subjects 1 and 5 were trained for approximately one-half hour, Subject 4 was trained for two hours, and Subjects 2 and 3 for three hours.

No subject had trouble producing a happy expression, and none was given more than 10 trials. Subjects 1 and 5 had very little trouble with the anger and surprise expressions, learning quickly to differentiate between these movements of the forehead on the basis of the feedback.

An important change in procedure was indicated by a common difficulty found in the three subjects who needed longer training (Ss 2, 3, and 4). These subjects had a very difficult time with the movements involved in the anger expression. At first they could not get the *corrugators* to move at all; each finally succeeded by a contortion of the face involving several muscles, notably the *levator labii superioris* (infraorbital head) and the *orbicularis oculi*. The result of this was a tightly wrinkled nose with the upper lip drawn upward and the eyes tightly shut. It was therefore decided to move electrode 5 from the origin of the *zygomaticus* to the midpoint of the infraorbital head of the *levator labii superioris* (Fig. 5b). The subjects then had to learn to operate the *corrugator* relatively independently of the *levator labii superioris*, keeping one speaker on and the other off.

Posttraining

With the electrodes removed, each subject was again requested to express happiness, anger, and surprise, and these expressions were recorded on film. From these films, and the films made during phase one (pretraining), a final film was constructed in which all of the pre- and post-training expressions produced by all subjects were arranged in random order. This film was shown to the panel of judges twice. During the first showing, following the procedure employed in selecting judges and expressions each judge labeled each expression with one of the three descriptors with which he was provided (see Appendix 4, Instructions to Judges, 2). During the second showing, each expression was identified by the experimenter and classified by each judge as appropriate or inappropriate. Expressions judged inappropriate were relabeled by the judges with descriptors they regarded as more appropriate. Expressions judged appropriate were further classified as adequate or inadequate, and rated for degree of adequacy or inadequacy.

PART 4

Results

The four judges made a total of 22 errors in the identification of the 30 expressions. Distribution of judge errors and subject errors may be found in Figs. 6 and 7. Table 4 shows the judge errors for each subject on each expression before training and after training. The effectiveness of training was determined by a *t* test comparing judge errors on pretreatment expressions with errors on posttreatment expressions. This produced *t* values of 2.66, significant beyond the 0.05 level (4 d.f.) for subjects, and 4.37, significant at the 0.025 level (2 d.f.) for expressions. The computational formula used was that for matched pairs, since independence could not be assumed (Hays, 1963, p. 335).

TABLE 4

Location of Judge Errors

	Expressions							
	Pre-training				Post-training			
Subjects	H	A	S		H	A	S	
1	3	1	2	6	0	0	0	0
2	4	1	1	6	0	0	0	0
3	0	0	4	4	2	0	0	2
4	0	1	2	3	0	0	1	1
5	0	0	0	0	0	0	0	0
	Total errors 19				Total errors 3			

H - Happy
A - Angry
S - Surprised

$t = 2.66$, $p < 0.05$

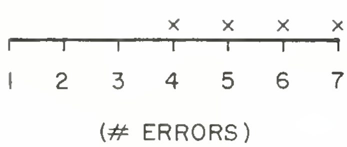


Figure 6. Distribution of Judge Errors (Final Judging)

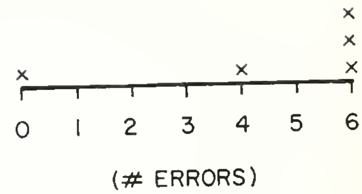


Figure 7. Distribution of Subject Errors (Final Judging).

The intersection of judged and intended expressions was arranged into two contingency tables, one for pretraining expressions and one for posttraining expressions. In Table 5, both the actual numbers and the ratio-scale values may be seen. Both chi-square values were significant beyond the 0.001 level, the value for pretraining contingency being 36.093, the posttraining value being 103.427. The strength of association in each table is shown by the phi coefficient (Hays, 1963, p. 606). For the pretraining data, a phi of 0.55 was found, while for the posttraining data, this value rose to 0.93. Thus the coincidence of judged and intended expressions was much stronger after, than before, training.

Cochran's Test (Hays, 1963, p. 629) was performed on judge errors to determine inter-rater reliability. The *Q* value of 51.574, significant beyond the 0.01 level (29 d.f.) allows one to reject the hypothesis that there were no differences among the 30 expressions in terms of difficulty of the judging task. The judges tended to concur in the errors they made.

Judgments regarding appropriateness and adequacy of expressions support the contention that training was effective. Table 6 summarizes these judgments for all judges, all subjects, and all expressions. The number of times pretraining expressions were classified appropriate was 42, of a possible 60 (4 judges x 15 expressions), while the number rose to 53 for expressions filmed after training.

TABLE 5

Contingencies for Final Judging

Expression Judged	Expression Intended: Pretraining Happy	Angry	Surprised	Posttraining Happy	Angry	Surprised
Happy	13 (0.65)*	2 (0.001)	5 (0.002)	18 (0.90	0 (0)	0 (0)
Angry	6 (0.002)	17 (0.85)	4 (0.001)	0 (0)	20 (0.95)	1 (0)
Surprised	1 (0.001)	1 (0.001)	11 (0.55)	2 (0)	0 (0)	19 (0.95)
	$\chi^2 = 36.093$, $p < 0.001$			$\chi^2 = 103.427$, $p < 0.001$		
	$\phi' = 0.55$			$\phi' = 0.93$		

*Parenthetical numbers indicate ratio scale values.

The number of expressions judged adequate also rose from 28 (of a possible 42) before training, to 44 (of a possible 53) after training. The judges concurred more often than not in classifying expressions as to appropriateness and adequacy. On only three of the 30 expressions did the judges split 2-2 on appropriateness judgments. Some concurrence was seen even in the relabeling of expressions regarded as inappropriate, for example, all three judges who felt that expression 10 (surprise) was inappropriate stated that it looked more like an expression of happiness.

TABLE 6

Appropriateness and Adequacy Ratings

Ratings	Expressions: Pretraining	Posttraining
Appropriate	42	53
Adequate	28	44

Significant pretraining to posttraining differences were found between:

1. Appropriateness judgments for subjects ($t = 2.99$, $p < 0.025$;
2. Appropriateness judgments for expressions ($t = 2.04$, $p < 0.05$);
3. Adequacy judgments for subjects ($t = 2.76$, $p < 0.025$);
4. Adequacy judgments for expressions ($t = 3.05$, $p < 0.005$).

No pre- post-differences in appropriateness or adequacy appeared for happy expressions or for angry expressions alone. Surprise expressions, however, were found to be more appropriate after training ($p < 0.025$). Surprise also tended toward a difference in adequacy judgments, although significance was not reached ($p < 0.1$). For inappropriate expressions of surprise, the judges most often felt "angry" would more accurately describe the expression. Other surprise poses they felt inappropriate elicited labels of "happy" (used four times), "frightened," "hurt," "concerned," and "curious."

The muscles used by each subject for each expression on the final film were observed and recorded. Table 7 shows a comparison of muscular

TABLE 7

Muscles Used by Blind Subjects

	Expressions					
	Pretraining			Posttraining		
Subject	Happy	Angry	Surprised	Happy	Angry	Surprised
1	zygomaticus	(none)	masseter	zygomaticus	corrugator, orbicularis oris	frontalis, masseter
2	zygomaticus, orbicularis oris, triangularis, levator labii sup., mentalis	orbicularis oris, frontalis	masseter, (frontalis)*	zygomaticus, orbicularis oris, masseter	corrugator, orbicularis oris, levator labii superioris	frontalis masseter, (levator labii sup.)
3	(none)	orbicularis oris	(none)	zygomaticus	corrugator, orbicularis oculi	frontalis masseter
4	(none)	(zygomaticus)	(masseter)	zygomaticus, levator labii superioris, (mentalis)	corrugator, orbicularis oris, orbicularis oculi	frontalis masseter
5	zygomaticus	orbicularis oris	masseter	zygomaticus	orbicularis oris, orbicularis oculi (corrugator)	frontalis masseter

*parenthetical muscle names indicate very slight movement

involvement for pretraining and posttraining expressions. It strikes one immediately how many more muscles were involved in the posttraining expressions overall. In the pretraining expressions, the number of muscles most often moved was one or none, with only Subject 2 involving several muscles in one of the three expressions. After training, two to three muscles were employed for each expression. In the expressions of happiness, the only improvement in terms of muscle involvement was that two subjects who had moved no muscles before training moved the *zygomaticus* after training. For anger and surprise, however, improvement was more substantial. In general, the pretraining poses showed contractions of muscles which were considered to be of secondary importance in portraying anger and surprise (see criteria, p. 247). After training, while subjects retained those secondary-muscle movements, they also demonstrated primary-muscle involvement. In two cases, inappropriate movement (*frontalis* and *zygomaticus* in anger) was eliminated through training, and in two cases primary- and secondary-muscle movement was observed where no movement at all was seen in the corresponding pretreatment expressions.

PART 5

Discussion

It appears from the data presented that the facial expressions of the blind subjects improved considerably as a result of myoelectric feedback training. The results cannot be explained by judge, subject, or expression variables. Concurrence was fairly high among judges and the distribution of judge errors showed small variability. Of five subjects, four shared fairly equally in the error pool. Errors were divided fairly evenly over expressions also. The only factor which could account for the improved quality of expressions was changes in patterning of muscular contractions.

The most important observations on muscle movement were related to the anger expression. Three of the subjects displayed very similar patterns of difficulty in effecting *corrugator* contraction. First they could get no sound from the speaker connected to the electrodes on their *corrugators*. Eventually each discovered a way to activate that speaker--by contracting a number of muscles, among which were the *corrugators*. The expression resulting from this looked much more like pain or revulsion than anger. The main offenders were the *levator labii superioris* and the *orbicularis oculi*, without which the subjects appeared to be unable to get *corrugator* movement. Sumitsuji, Matsumoto, Tanaka, and Kaneko (1967) have employed electromyographic techniques in the study of the facial muscles, and have documented synergistic relations among all of the muscles except two (*frontalis* and *orbicularis oculi* are antagonistic). They note particularly strong synergistic relations between the *orbicularis oculi*, the *levator labii superioris*, and the *corrugator*. The muscles are related in the following manner: when the *levator* is contracted, the *corrugator* is automatically pulled downward. Thus the two are inseparable if *levator* contraction is the desired action. *Corrugator* contraction, however, can be effected independently of *visible levator* movement. Strong *orbicularis oculi* contraction can cause some visible movement in both the *corrugator* and the *levator*, but *corrugator* contraction, again, can be accomplished without visible movement of the *orbicularis oculi*.

After relocating one electrode so that *levator labii superioris* movement could be monitored, the subjects attempted to isolate *corrugator* contraction with the help of the feedback. As training progressed, movement of the *levator* became more and more diminished, but the involvement of the *orbicularis oculi* remained intense. It seemed that the subjects needed the help of another muscle to pull the *corrugator*, so that the feedback they got was at least partly from the synergistic movement of the *corrugator* in sympathy with other muscles. In the final anger expressions of these subjects, *orbicularis oculi* movement is evident, and some *levator labii superioris* movement can still be seen in one subject. It is almost certain that with more training, these subjects could learn to completely isolate *corrugator* movement, in view of the change from use of both the *levator* and the *orbicularis oculi* to use of the *orbicularis oculi* only to "help" the *corrugator*. It is probable that this change was a result of the fact that the subject had feedback from *levator* movement, but none from *orbicularis oculi* movement. Another electrode relocation was not feasible within the structure of the present study.

Two tentative conclusions to be drawn from this are that the *corrugator* is used much less by the blind than by the sighted, and that it functions primarily to make adjustments that facilitate visual perception. Although Fulcher (1942) also observed little voluntary use of the *corrugator* by his blind subjects, sighted people often employ the *corrugator* to enhance visual acuity or to shield the eyes from bright light. Also pointing to the visual aid role of the *corrugator* is the fact that it was only the congenitally (or postnatally) blind in this study who had no voluntary control of this muscle at the beginning of training. The two adventitiously blinded subjects, while not actually using the *corrugator* in the pretraining expressions, had little trouble gaining mastery over it once training began. The feedback was, therefore, much more necessary in the case of the congenitally blind who had never experienced the voluntary control over this muscle which develops with vision.

The muscular patterning required for surprise was much easier for all subjects to produce. However, since no subject had used the primary surprise muscle (*frontalis*) in the pretraining surprise expressions, there was unlimited room for improvement. Since every subject did, in fact, gain control over *frontalis* contraction, improvement in the appropriateness of this expression was significant.

The expression of happiness needed least training since most blind people are fairly adequate in voluntarily expressing this type of emotion (Dumas, 1932; Fulcher, 1942). Three of the five subjects in this study used the primary muscle for showing happiness (*zygomaticus*) before training, so attempting to train this pattern was not really necessary. All subjects learned in a very few trials and probably relied little on the myoelectric feedback. The most beneficial aspect of having an "easy" expression like happiness was that it provided the subject with reinforcement early in the process, and with a model after which to pattern the more difficult tasks.

There appear to be two components to gaining voluntary control over the facial musculature to effect the various patterns. In the normal development of the sighted, these components develop more or less concurrently, although in general, knowledge lags behind control (Odom and Lemond, 1972). In training blind subjects in the present study, these components were artificially divided into stages, so that the subject was first given information concerning desired patterning, and was then trained to control effectively that patterning with the "mirror" provided by auditory feedback. In some instances the first stage was sufficient, although feedback was still helpful in the rapid differentiation of the expressions as the subject changed from one to another. The feedback stage became critical in cases where the subject was unable to effect the desired movements. Thus in the present study, feedback was probably unnecessary for the effective production of the happy expression (although it may have expedited acquisition). Feedback was useful in acquiring the expression of surprise, especially in distinguishing between the forehead movement involved in surprise and that involved in anger, and it was essential to the learning of the expression of anger.

Feedback of the myoelectric activity of the facial muscles to aid the blind in improving voluntary facial expression seems to be a promising research area. The training procedure employed in this study can be considered not only effective, but rapid, simple, interesting, and useful to blind people. For future work in the area, several recommendations are in order.

As for choice of expressions, those should be used for which the most benefit can be derived from feedback. Anger would certainly be high on the list. Happiness is not recommended. Most other expressions, including surprise, would probably fall somewhere between these two extremes. The following expressions should be considered since each results primarily from the movement of a single muscle: grinning (*risorius*), puzzlement (*corrugator*), revulsion (*levator labii superioris*), contempt (*levator anguli oris*), sulkiness (*mentalis*), irony (*depressor labii inferioris*), and determination (*orbicularis oris*). These associations of expressions with contractions of particular muscles would, of course, have to be verified. Pain and fear are likely to involve too many different muscles from subject to subject, and sadness is likely to involve none, so these are not recommended. If systematic electromyographic analyses of each expression were performed on a large group of people, one would have an exact myographic definition of each expression with mean strength of contraction and variability values for each muscle. This would certainly be helpful in guiding the training of facial control.

It would be desirable to effect the following changes in apparatus:

1. Four or five feedback circuits would allow for the training of a larger number of expressions, and for more definitive patterning among these.

2. Use of a more sophisticated signal than the kind used in the present study would be necessary if the number of circuits was increased. Rather than having spatial and intensity cues, it would be desirable to have a frequency cue such that each muscle involved might be defined by a particular frequency of the feedback signal, while the amplitude of this signal would remain a function of intensity of contraction.

3. For more flexibility and convenience, each feedback generator should have external controls for the adjustment of threshold and gain.

Procedural improvements might include the following:

1. A tape-recorded criterion response produced by a sighted subject might be presented to the blind subject as a guide.

2. For congenitally blind subjects, a longer period of training would be beneficial. This would include a more formal and lengthy "weaning" procedure, wherein the subject would learn to produce the desired facial pattern without feedback.

3. A followup test at some later date would provide useful information on the longrange effectiveness of training.

SUMMARY

Blind people lack skill in producing facial expressions at will. The biofeedback technique was employed to facilitate their gaining this type of control over the facial musculature. Five blind subjects were provided with an auditory "mirror" of their facial activity by transducing myoelectric signals from facial muscles into sound. Expressions of happiness, surprise, and anger were defined primarily by involvement of the *zygomaticus*, the *frontalis*, and the *corrugator*, respectively. These muscles were connected through separate voltage-controlled oscillators to separate loudspeakers, such that each muscle activated a different speaker.

Motion pictures of each subject producing the three expressions before and after training were assembled in random order and were shown to preselected judges who attempted to identify the expressions. The judges were correct significantly more often on the posttraining expressions. Appropriateness and adequacy of expressions, as rated by the judges, also improved significantly as a result of training.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the invaluable assistance Dr. Emerson Foulke provided in directing this project. Appreciation is extended to committee members Dr. Paul Jones, especially for assistance with the filming apparatus, and Dr. Adam Matheny for his interest and valuable comments. Special thanks are due Stan Hertel, who designed the apparatus, and Fred Higbie, who built it. Thanks are also extended to Dr. Irwin Nahinsky for the use of his research space.

APPENDIX 1

Instructions to Sighted Subjects

This is a study of facial expression. We are concerned with the differences between the blind and the sighted in producing voluntary or posed expressions. We will film posed expressions of both blind and sighted subjects, and judges viewing these expressions will attempt to match each to its label. Your task will be merely to produce the expressions to be filmed.

We will ask you to produce five different expressions, each of which may be practiced until you feel you are ready to have it filmed. I will sit behind this screen and will not watch you at any time, so that you may feel free to manipulate your face in any way you wish. Remember, the important thing is to produce expressions which are both realistic and distinct from each other so the judges will be able to tell what you intended to express.

If there are no questions, we will begin by getting familiar with the specific expressions before positioning the camera for filming. Ready?

(use randomized list for order of expressions)

(position and focus camera)

We will do each expression in the same order this time. I will give you the expression, and when you feel you have it like you want it, press this switch and I will turn on the camera for five seconds. Try to maintain the expression for that period. Ready?

APPENDIX 2

Instructions to Judges, 1

This is a study of facial expression. There are two types of expression--that which is more or less reflexive, where facial movement is one part of a total emotional reaction, and that which is social in nature, its main purpose being to communicate information to others. We are concerned with the second type. If facial expressions do have communicative value, we should be able to "read" someone's face if he poses specifically for that purpose. On the filmstrip, you will see various people producing various expressions. Your task is to label each expression accurately.

On your judging sheet, note the five descriptors: afraid, angry, disgusted, happy, and sad. All the expressions you will see will represent one of these five. There is no limit to the number of times any descriptor may be used, and the poses are in random order. On the lines numbered 1-35, you will enter your judgment using the abbreviations provided. Each expression will be on the screen for approximately five seconds. I will stop the projector between expressions so you will have time to record your judgment. Be certain to make a judgment for every expression and be very careful not to mix up the numbers. You will have only once to view each exposure. Any questions?

This judging is a preliminary one, and from the results, we will select a few of the best judges to continue in the experiment. This entails more judgments at a later date and a fee of $2.00 payable upon completion of the judging task.

APPENDIX 3

Instructions to Blind Subjects

This is a study of facial expression. We are concerned with the differences between the blind and the sighted in producing voluntary or posed expressions. We will film posed expressions of both blind and sighted subjects, and judges viewing these expressions will attempt to match each to its label. Your first task will be merely to produce the expressions to be filmed.

We will ask you to produce three different expressions--happiness, anger, and surprise--each of which may be practiced until you feel you are ready to have it filmed. I will sit behind a screen and will not watch you at any time, so that you may feel free to manipulate your face in any way you wish.

(Let subject practice expressions.)

If there are no questions, we will begin by positioning the camera.

(Position and focus camera.)

I will give you each expression and when you feel you have it like you want it, press this switch, and I will turn on the camera for five seconds. Try to maintain the expression for that period. Ready?

APPENDIX 4

Instructions to Judges, 2

This is your final judging task. There are two stages, the first will follow the same procedure as before, and I will explain the second when we come to it. As before, each expression will be on the screen for five seconds. The descriptors you will use are listed at the top of your sheet (happy, angry, surprised). Please work independently. Two things are different this time:

1. All the people you will see are blind;

2. If you are not certain in making your judgment, circle the letter you choose.

(Complete first task)

We will now go back over each expression. I am going to tell you what each one is and you will rate it as to appropriateness and adequacy (explain rating procedure).

REFERENCES

Barber, T. X., DiCara, L. V., Kamiya, J., Miller, N. E., Shapiro, D., & Stoyva, J. *Biofeedback and self control: 1970.* Chicago: Aldine-Atherton, 1971.

Basmajian, J. V. Control and training of individual motor units. *Science*, 1963, 141, 440-1.

Basmajian, J. V. Electromyography comes of age. *Science*, 1973, 176, 603-9.

Bell, C. *The anatomy and philosophy of expression.* London: George Bell and Sons, 1877.

Booker, H. E., Rubow, R. T., & Coleman, P. J. Simplified feedback in neuromuscular training: An automated approach using EMG signals. *Archives of Physical Medicine*, 1969, 50, 621-5.

Boring, E. G., & Titchener, E. G. A model for the demonstration of facial expression. *American Journal of Psychology*, 1923, 34, 471-86.

Boucher, J. D. Facial displays of fear, sadness, and pain. *Perceptual and Motor Skills*, 1969, 28(1), 239-42.

Brener, J., & Kleinman, R. Learned control of decreases in systolic blood pressure. *Nature*, 1970, 226, 1963-1064.

Brener, J., Kleinman, R., & Goesling, W. The effects of different exposure to augmented sensory feedback on the control of heart rate. *Psychophysiology*, 1969, 5(5), 510-6.

Brown, B. B. Recognition of aspects of consciousness through association with EEG alpha activity represented by a light signal. *Psychophysiology*, 1970, 6, 442-52.

Budzynski, T. H. Some applications of biofeedback-produced twilight states. Paper presented at the meeting of the American Psychological Association, Washington, 1971.

Budzynski, T. H. & Stoyva, J. M. An instrument for producing deep muscle relaxation by means of analog information feedback. *Journal of Applied Behavior Analysis*, 1969, 2(4), 231-7.

Budzynski, T. H. & Stoyva, J. M. Biofeedback techniques in behavior therapy. In N. Birbaumer (Ed.), Die Bewaltigung von Angst. Beitrage der Neuropsychologie zur Angstforschung. (The mastery of anxiety. Contributions of neuropsychology to anxiety research.) *Reihe Fortschritte der Klinischen Psychologie*, Bd. 4. Munchen, Wein: Verlag Urban & Schwarzenberg, 1972. (In press) (English preprint)

Budzynski, T. H., Stoyva, J. M., & Adler, C. Feedback-induced muscle relaxation: Application to tension headache. *Journal of Behavior Therapy and Experimental Psychiatry*, 1970, 1(3), 205-11.

Buzby, D. E. The interpretation of facial expression. *American Journal of Psychology*, 1924, 35, 602-4.

Chusid, J. G. *Correlative neuroanatomy and functional neurology.* Los Altos: Lange Medical Publications, 1970.

Cleaves, C. M. The control of muscle tension through psychophysiological information feedback. *Dissertation Abstracts International*, January 1971, 31(7B), 4231.

Coleman, J. C. Facial expressions of emotion. *Psychological Monographs*, 1949, No. 296.

Crosby, E., Humphrey, T., & Lauer, E. *Correlative anatomy of the nervous system.* New York: The Macmillan Company, 1962.

Darwin, C. *Expression of the emotions in man and animals.* New York: D. Appleton & Company, 1896.

DiCara, L. V., & Miller, N. E. Instrumental learning of systolic blood pressure responses by curarized rats: Dissociation of cardiac and vascular changes. *Psychosomatic Medicine*, 1968, 30, 489-94.

Dumas, M. G. Mimicry of the blind. . . . *And there was light*, 1932, 2, No. 5.

Dunlap, K. The role of eye-muscles and mouth-muscles in the expression of the emotions. *Genetic Psychology Monographs*, 1927, 2, 197-233.

Ekman, P. Universal facial expressions of emotion. *California Mental Health Research Digest*, 1970, 8(4), 151-8. (*Psychological Abstracts*, 1972, 47, 6605.

Ekman, P., & Friesen, W. V. Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology*, 1971, 17(2), 124-9.

Ekman, P., Sorenson, E. R., & Friesen, W. V. Pan-cultural elements in facial displays of emotion. *Science*, 1969, 164(3875), 86-8.

Engel, B. T., & Chism, R. A. Operant conditioning of heart rate speeding. *Psychophysiology*, 1967, 3, 418-26.

Engel, B. T., & Hansen, S. P. Operant conditioning of heart rate slowing. *Psychophysiology*, 1966, 3, 176-87.

Engen, T., Levy, N., & Schlosberg, H. A new series of facial expressions. *American Psychologist*, 1957, 12, 264-6.

Engen, T., Levy, N., & Schlosberg, H. The dimensional analysis of a new series of facial expressions. *Journal of Experimental Psychology*, 1958, 55, 454-8.

Feleky, A. M. The expression of emotions. *Psychological Review*, 1914, 21, 33-41.

Fernberger, S. W. False suggestion and the Piderit Model. *American Journal of Psychology*, 1928, 40, 562-8.

Freedman, D. G. Smiling in blind infants and the issue of innate vs. acquired. *Journal of Child Psychology and Psychiatry*, 1964, 5, 171-84.

Frijda, N. H. Facial expression and situational cues: A control. *Acta Psychologia Amsterdam*, 1961, 18, 239-44. (*Psychological Abstracts*, 1962, 36, 3CC39F)

Frijda, N. H., & Philipszoon, E. Dimensions of recognition of expression. *Journal of Abnormal and Social Psychology*, 1963, 66, 45-51.

Frois-Wittman, J. The judgment of facial expression. *Journal of Experimental Psychology*, 1930, 13(2), 113-51.

Fulcher, J. S. "Voluntary" facial expression in blind and seeing children. *Archives of Psychology*, 1942, No. 272.

Gates, G. S. An experimental study of the growth of social perception. *Journal of Educational Psychology*, 1923, 14(8), 449-61.

Gates, G. S. A test for ability to interpret facial expressions. *Psychological Bulletin*, 1925, 22, 120.

Gladstones, W. H. A multidimensional study of facial expression of emotion. *Australian Journal of Psychology*, 1962, 14(2), 95-9.

Goldstein, K. The smiling of the infant and the problem of understanding the "other." *Journal of Psychology*, 1957, 44, 175-91.

Goodenough, F. L. The expression of the emotions in infancy. *Child Development*, 1931, 2, 96-101.

Goodenough, F. L. Expression of the emotions in a blind-deaf child. *Journal of Abnormal and Social Psychology*, 1932, 27, 328-33.

Gray, H. *Anatomy of the Human Body*. Philadelphia: Lea & Febiger, 1959.

Green, E. E., Green, A. M., & Walters, E. D. Self regulation of internal states. In J. Rose (Ed.), *Progress of Cybernetics: Proceedings of the International Congress of Cybernetics*, [illegible]. London: Gordon & Beach, 1970.

Hanada, M., Inoue, H., Hazeki, K., & Takano, H. Electromyographic studies of the expression first report on the expressive changes of facial muscles with the various ages and in the case of catatonia and Parkinsonism. *Brain Nerves*, 1960, 12, 427. Cited by N. Sumitsuji et al., Electromyographic investigation of the facial muscles. *Electromyography*, 1967, 7, 77-96.

Hardyck, C. D., Petrinovich, L. F., & Ellsworth, D. W. Feedback of speech muscle activity during silent reading: Rapid extinction. *Science*, 1966, 154(3755), 1467.

Hart, J. T. Autocontrol of EEG alpha. *Psychophysiology*, 1968, 4, 506. (Abstract)

Haslam, W. B., & Pedersen, D. M. Points of view in the perception of facial expressions of emotion. *Perceptual and Motor Skills*, 1966, 22(2), 645-6.

Hays, W. L. *Statistics*. New York: Holt, Rinehart & Winston, 1963.

Himes, J. S. The measurement of social distance in social relations with the blind. *New Outlook for the Blind*, 1960, 54, 54-8.

Jarden, E., & Fernberger, S. W. The effect of suggestion on the judgment of facial expression of emotion. *American Journal of Psychology*, 1926, 37, 565-70.

Jervis, F. M. A comparison of self-concepts of blind and sighted children. *Perkins School for the Blind Publication No. 20*. Watertown: Perkins School for the Blind, 1959.

Kamyia, J. Operant control of the EEG alpha rhythm and some of its reported effects on consciousness. In C. Tart (Ed.), *Altered States of Consciousness*. New York: Wiley, 1968.

Lacey, J. I., & Lacey, B. C. Verification and extension of the principle of autonomic response stereotypy. *American Journal of Psychology*, 1958, 71, 50-73.

Landis, C. Studies of emotional reactions: I. A preliminary study of facial expression. *Journal of Experimental Psychology*, 1924a, 7, 325-41.

Landis, C. Studies of emotional reactions: II. General behavior and facial expression. *Journal of Comparative Psychology*, 1924b, 4, 447-509.

Landis, C. The interpretation of facial expression in emotion. *Journal of General Psychology*, 1929, 2, 59-72.

Lang, P. J. Autonomic control or learning to play the internal organs. In T. Barber et al. (Eds.), *Biofeedback and Self-Control: 1970*. Chicago: Aldine-Atherton, 1971.

Langfeld, H. S. Judgments of facial expression and suggestion. *Psychological Review*, 1918, 25, 488-94.

Langley, L. L., Telford, I. B., & Christensen, J. B. *Dynamic Anatomy and Physiology*. New York: McGraw-Hill, 1969.

Lawwill, T. Lateral inhibition in amblyopia: VER and metacontrast. *Documenta Ophthalmologica*, 1973, in press.

Levene, H. I., Engel, B. T., & Pearson, J. A. Differential operant conditioning of heart rate. *Psychosomatic Medicine*, 1968, 30, 837-45.

Levy, L. H., Orr, T. B., & Rosenzweig, S. Judgments of emotion from facial expressions by college students, mental retardates, and mental hospital patients. *Journal of Personality*, 1960, 28, 342-9.

Lippold, O. C. J. Electromyography. In P. H. Venables & I. Martin (Eds.), *A Manual of Psychophysiological Methods*. Amsterdam: North-Holland Publishing Company, 1967.

Luce, R. D., Bush, R. R., & Galanter, E. (Eds.). *Handbook of Mathematical Psychology*. New York: Wiley & Sons, 1967.

Miller, N. E., DiCara, L. V., Soloman, H., Weiss, J. M., and

Dworkin, B. Learned modifications of autonomic functions: A review and some new data. In T. Barber et al. (Eds.), *Biofeedback and Self-Control: 1970*. Chicago: Aldine-Atherton, 1971.

Miller, R. E., Murphy, J. V., & Mirsky, I. A. Relevance of facial expression and posture as cues in communication of affect between monkeys. *AMA Archives of General Psychiatry*, 1959, 1, 480-8.

Mistschenka, M. N. Ueber die mimische Gesichtsmotorik der Blinden. *Folia Neuropathologica Estoniana*, 1933, 13, 24-43. Cited by J. S. Fulcher, "Voluntary" facial expression in blind and seeing children. *Archives of Psychology*, 1942, No. 272.

Morris, J. E., & Nolan, C. Y. (Eds.) *Bibliography of Research on the Visually Handicapped, 1953-1971.* Louisville: American Printing House for the Blind, 1972.

Odom, R. D., & Lemond, C. M. Developmental differences in the perception and production of facial expressions. *Child Development*, 1972, 43, 359-69.

Osgood, C. E. Dimensionality of the semantic space for communication via facial expressions. *Scandinavian Journal of Psychology*, 1966, 7, 1-30.

Paskewitz, D. A., Lynch, J. J., Orne, M. T., & Costello, J. The feedback control of alpha activity: Conditioning of disinhibition. *Psychophysiology*, 1970, 6, 637-8. (Abstract)

Peper, E., & Mulholland, T. Methodological and theoretical problems in the voluntary control of electroencephalographic occipital alpha by the subject. In T. Barber et al. (Eds.), *Biofeedback and Self-Control: 1970.* Chicago: Aldine-Atherton, 1971.

Quiring, D. P. *The Head, Neck, and Trunk: Muscles and Motor Points.* Philadelphia: Lea & Febiger, 1960.

Shapiro, D., Tursky, B., & Schwartz, G. Differentiation of heart rate and systolic blood pressure in man by operant conditioning. *Psychosomatic Medicine*, 1970, 32, 417-23.

Shapiro, J. G. Responsivity to facial and linguistic cues. *Journal of Communication*, 1968, 18, 11-17.

Shears, L. M., & Jensema, C. J. Social acceptability of anomalous persons. *Exceptional Children*, 1969, 36, 91-6.

Sherman, M. The differentiation of emotional responses in infants. *Journal of Comparative Psychology*, 1927, 36, 265-84.

Spitz, R. A. The smiling response: A contribution to the ontogenesis of social relations. *Genetic Psychology Monographs*, 1946, 34.

Strauss, H. M. A study of reference group and social comparison processes among the blind. *Dissertation Abstracts International*, May 1967, 27, 3939-A.

Sumitsuji, N., Matsumoto, K., Tanaka, M., Kashiwagi, T., & Kaneko, Z. Electromyographic investigation of the facial muscles. *Electromyography*, 1967, 7, 77-96.

Thompson, D. F., & Meltzer, L. Communications of emotional intent by facial expression. *Journal of Abnormal and Social Psychology*, 1964, 68, 129-35.

Thompson, J. Development of facial expression of emotion in blind and seeing children. *Archives of Psychology*, 1941, No. 264.

Thompson, R. F., Lindsley, D. B., & Eason, R. G. Physiological psychology. In J. B. Sidowski (Ed.), *Experimental methods and instrumentation in psychology.* New York: McGraw-Hill, 1966.

Tomkins, S. S., & McCarter, R. What and where are the primary affects? Some evidence for a theory. *Perceptual and Motor Skills*, 1964, 18, 119-58.

Toonen, B. L., & Wilson, J. P. Learning eye fixation without visual feedback. *American Foundation for the Blind Research Bulletin*, 1969, 19, 123-8.

Venables, P. H., & Martin, I. (Eds.). *A Manual of Psychophysiological Methods.* Amsterdam: North-Holland Publishing Company, 1967.

Washburn, R. W. A study of the smiling and laughing of infants in the first year of life. *Genetic Psychology Monographs*, 1929, 6, 397-535.

Wenger, M. A., Engel, B. T., & Clemens, T. L. Studies of autonomic response patterns: Rationale and methods. *Behavioral Science*, 1957, 2, 216-21.

Winer, B. J. *Statistical Principles in Experimental Design.* New York: McGraw-Hill Book Company, 1962.

Woodworth, R. S., & Schlosberg, H. *Experimental Psychology.* New York: Holt & Company, 1956.

Zunich, M., & Ledwith, B. E. Self-concepts of visually handicapped and sighted children. *Perceptual and Motor Skills*, 1965, 21, 771-4.

MODIFIED IBM SYSTEM 3

IBM has announced that David Schwartzkopf, a visually impaired programmer, has modified the IBM System 3 components to permit a braille print-out.

The period in the System 3 alphabet is used as a "flying period," and utilizes two print positions on three lines, to form the six possible embossing points for the braille cell. The System 3 printer ribbon is removed and a 14-inch elastic strip (20 cents) is placed over the printer hammers. In operation, the embossing head forms raised dots on the reverse side of the paper.

A modification in the RPG II compiler for the S-3/Model 10 card system was also required. The work was accomplished under the internal grant scheme of the company by Schwartzkopf, at the Rochester, Minnesota laboratories. Schwartzkops is now a senior associate programmer at the IBM Boca Raton, Florida facility. The compiler program and an instruction manual are available through local IBM branch offices.

MACHINE A ECRIRE PARLANTE ET TELESCRIPTEUR PARLANT POUR AVEUGLES*

(TALKING TYPEWRITER AND TALKING TELETYPEWRITER FOR THE BLIND)**

A la Faculté des Techniques de l'Université de Ljubljana, en Yougoslavie, un système de machine à écrire parlante et de télex parlant a été mis au point à l'usage des aveugles. L'ensemble se compose de trois éléments fondamentaux:

a) Machine à écrire parlante de construction courante, plus circuits électroniques.

b) Téléscripteur de modèle courant.

c) Groupe électronique assurant les commandes automatiques, les émissions sonores et les mémoires correspondants.

Les combinaisons ac, bc, abc sont possibles.

La machine à écrire parlante est de constion courante, perfectionnée de circuits électroniques qui codifient les frappes de telle sorte qu'en appuyant sur l'une quelconque de ses touches elle produit un son équivalent à la voie humaine. La lettre "a" correspond au son "a", la lettre "b" au son "b", le chiffre 3 correspond au mot "trois", le nombre 125 aux mots un, deux, cinq, etc. Pour la ponctuation, trois tonalités de hauteur différente sont utilisées: pour le point 400 Hz, la virgule 700 Hz, le trait d'union 1200 Hz. Tout autre signe de ponctuation est représenté par une combinaison de ces 3 fréquences.

La durée d'un son simple, nombre ou ponctuation est d'environ 220/1000 de seconde, soit 4, 5 sons par seconde ou environ 270 à la minute, dans le cas d'une écoute directe au fur et a mesure de la frappe. Autrement dit, lorsque la vitesse de frappe est d'environ 270 touches/minute l'écoute est simultanée. Ce modèle, destiné à l'éducation des opérateurs aveugles a été spécialement conçu en vue d'assurer une écoute très claire. Lorsque la frappe est plus rapide, la mémoire magnétique peut entrer dans le circuit pour adapter la vitesse d'audition; la vitesse de frappe n'est alors plus limitée.

La machine à écrire parlante est équipée d'un dispositif électronique qui, au moyen d'un signal sonore, avertit l'aveugle de la dernière ligne de la page.

En incluant le téléscripteur dans le système, de nouveaux postes peuvent etre envisagés pour standardistes aveugles ou autres emplois spécialisés. Le principe en est le suivant: le télégramme (adressé ou recu) peut etre lu par l'opérateur aveugle, chaque signe pouvant ainsi etre transformé en sons correspondants. Les impulsions reçues par le téléscripteur sont codées à quelque vitesse qu'elles arrivent, puis mises en mémoire d'où elles peuvent être ensuite soit reprises, soit décodées et transformées en signaux sonores correspondants. Le réglage de la vitesse de décodage est conçu de manière que l'opérateur aveugle puisse lire le message à la vitesse qui lui convient.

Toutes indications ou ordres sont donnés à l'opérateur par son ou contact. Les écouteurs stéréophoniques, grace à leur réglage, permettent l'écoute de ce qui va être transcrit, ce qui est transcrit et ce qui a déjà été transcrit.

---

*Nous avons le plaisir de reproduire cidessous le texte que nous a adressé M. Arsen Surlan de Ljubljana (Yougoslavie).

**This announcement appeared in *Le Louis Braille*, November/December 1972, No. 150, page 4. It is reprinted by permission of the Association Valentin Hauy pour le Bien des Aveugles.

Pour faciliter la commande des appareils, des pédales sont incorporées. La capacité d'enregistrement, en mémoire, de la machine à écrire ou du téléscripteur est d'environ une heure.

Une machine à écrire réalisée à la Faculté -- ROG-TOPS-S3 -- et un téléscripteur LOZENZ-SEL, ont été utilisés.

Pour tous renseignements, prière de s'adresser à M. Arsen Surlan, Faculté des Techniques électriques, 61000 Ljubljana, Trzaska 25, Yougoslavie.

THE PHILIPS TELEVISION ENLARGER

H. Bouma
Eindhoven, The Netherlands

The Institute for Perception Research is a joint venture of the Philips Company (in particular Philips Research Laboratories) and the Eindhoven University of Technology. Although primarily aimed at research in the field of human perception, the Institute has as a side activity a few projects on developing aids for people with perceptual or motor handicaps.

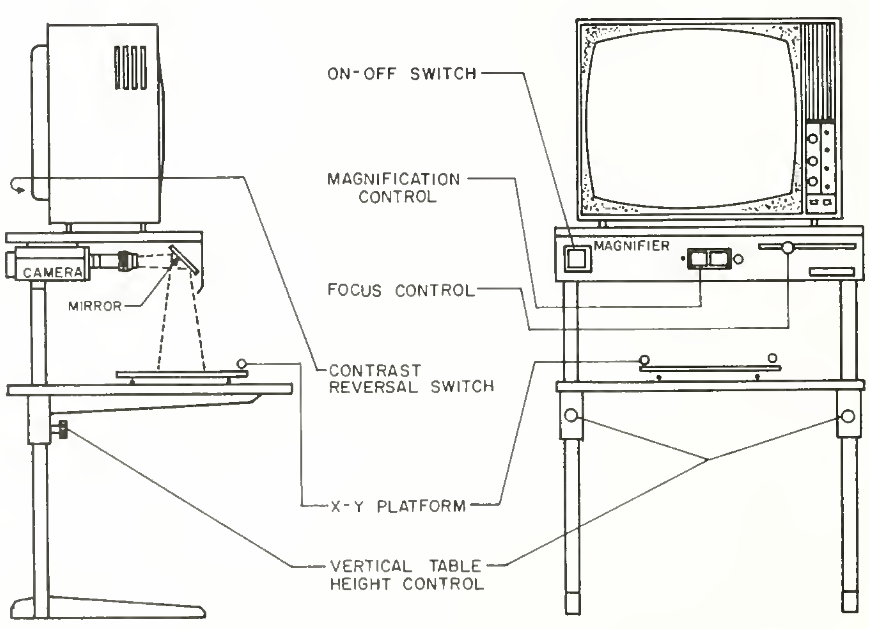
Stimulated by an article written by Dr. Genensky, in 1971 we adapted a CCTV system to the needs of an individual with a severe visual handicap to see if it would enable him to read again. In 1972 we tested new prototypes at three institutes for visually handicapped children and adults, for periods of a few weeks each. Also, we made contacts with production and distribution units within Philips, with the results that a TV magnifier built according to our specifications became commercially available in the Netherlands in December 1972.

As with most other CCTV systems for enlarging print, basic components of the system are an X-Y tablet, a TV camera and a large-screen TV set. We chose an electrically driven zoom objective, which in its present form provides a magnification range of between 5 and 25 times.

We decided to deviate somewhat from related apparatus to achieve a complete and stable setup which requires no separate table and which is not portable. The reason for this was that we wished to simplify controls as far as possible, and to provide the best TV magnifier to serve the need.

Approximately one hundred fifty people in the visual acuity range between 0.01 and 0.25 have been tested. Seventy-five percent preferred the TV magnifier over their own optical aids. Ten people could read with the TV-magnifier only, and, in fact, used braille in daily life. According to our experience, the upper acuity limit where more classical optical aids take over is lower for children (0.1) than for adults (0.25) probably because of stronger accommodation power in children. We agree with Dr. Genensky's findings that the functional disturbances (low acuity, visual-field restrictions) are of more importance than the type of disease. We have met a number of people who, to our surprise, could read with the TV magnifier, despite severe visual-field restrictions.

THE PHILIPS TELEVISION MAGNIFIER



A BRAILLE CODE FOR INTERACTIVE TERMINAL USE

J. Boyle, W. Jacobs and N. Loeber*

In order to support a wide variety of interactive computer terminal applications, a single-celled braille code is needed that consists of alphabetic characters, numbers, punctuation, and those special symbols that are most frequently encountered in secretarial, scientific, legal, educational, and some programming applications. This one-cell code could be used for such on-line activities as computerized text entry and editing, data-base inquiry and update, computer-assisted instruction, and programming in languages such as PL/1, COBOL, and 360/370 assembly language source code.

Existing braille codes have been examined for their possible adoption as a standard braille interface in a terminal environment. Each code reviewed had drawbacks which led us to the conclusion that a special code tailored to the needs of a diversified group of braille terminal users should be considered. Revision to existing standards and their impact on the experienced reader of braille is an area of major concern. However, existing literary codes which are simple and widespread in use, and more specialized codes with lesser usage were not designed for, and will not fill, the needs of the multiplicity of applications in which a terminal for the blind could be adopted.

The following chart is a first draft of a general-purpose interactive terminal braille code to meet the above-stated objectives. For purposes of comparison, the symbol assignments for literary braille grades 1 and 2, and programmer's code have been presented. Attempts have been made to minimize changes to existing literary codes. Readers comments and suggestions on establishing a common braille code for computer terminal use are encouraged.

*IBM Corporation
Monterey and Cottle Roads
San Jose, California 95193

CODE COMPARISON CHART

Symbol	Literary Grade 1	Literary Grade 2	Programmer's Code	Terminal Braille
● ○ ○ ○ ○ ○	A or 1	A or 1	A	A
● ○ ● ○ ○ ○	B or 2	B or 2	B	B
● ● ○ ○ ○ ○	C or 3	C or 3	C	C
● ● ○ ● ○ ○	D or 4	D or 4	D	D

CODE COMPARISON CHART (Continued)

Symbol	Literary Grade 1	Literary Grade 2	Programmer's Code	Terminal Braille
⠑	E or 5	E or 5	E	E
⠋	F or 6	F or 6	F	F
⠛	G or 7	G or 7	G	G
⠓	H or 8	H or 8	H	H
⠊	I or 9	I or 9	I	I
⠚	J or 0 (zero)	J or 0 (zero)	J	J
⠅	K	K	K	K
⠇	L	L	L	L
⠍	M	M	M	M
⠝	N	N	N	N
⠕	O	O	O	O
⠏	P	P	P	P
⠟	Q	Q	Q	Q
⠗	R	R	R	R
⠎	S	S	S	S

CODE COMPARISON CHART (Continued)

Symbol	Literary Grade 1	Literary Grade 2	Programmer's Code	Terminal Braille
○● ●● ●○	T	T	T	T
●○ ○○ ●●	U	U	U	U
●○ ●○ ●●	V	V	V	V
●● ○○ ●●	X	X	X	X
●● ○● ●●	Y	Y	Y	Y
●○ ○● ●●	Z	Z	Z	Z
●● ●○ ●●		AND	AMPERSAND	AMPERSAND
●● ●● ●●		FOR	GREATER THAN	EQUAL SIGN
●○ ●● ●●		OF	OPENING BRACKET OR PERCENT SIGN	LEFT PARENTHESIS
○● ●○ ●●		THE	NOT SYMBOL	NOT SYMBOL
○● ●● ●●		WITH	CLOSING BRACKET OR LESS THAN	RIGHT PARENTHESIS
●○ ○○ ○●		CH	ASTERISK	1
●○ ●○ ○●		GH	LEFT PARENTHESIS	2
●● ○○ ○●		SH	QUESTION MARK	3
●● ○● ○●		TH	LEFT BRACE	4

Symbol	Literary Grade 1	Literary Grade 2	Programmer's Code	Terminal Braille
⠱		WH	EQUAL SIGN	5
⠫		ED	DOLLAR SIGN	6
⠻		ER	OR SYMBOL	7
⠳		OU	UNDERSCORE	8
⠪		OW	AT SIGN	9
⠺	W	W	W	W
⠂	COMMA	COMMA	1	COMMA
⠆	SEMICOLON	SEMICOLON	2	SEMICOLON
⠒	COLON	COLON	3	COLON
⠲	PERIOD	PERIOD	4	PERIOD
⠢		EN	5	LESS THAN SYMBOL
⠖	EXCLAMATION POINT	EXCLAMATION POINT	6	EXCLAMATION POINT
⠶	PARENTHESIS LEFT & RIGHT	PARENTHESIS LEFT & RIGHT	7	ASTERISK

CODE COMPARISON CHART (Continued)

Symbol	Literary Grade 1	Literary Grade 2	Programmer's Code	Terminal Braille
o o ● o ● ●	OPEN QUOTES OR QUESTION MARK	OPEN QUOTES OR QUESTION MARK	8	QUESTION MARK
o o o ● ● o		IN	9	GREATER THAN SYMBOL
o o o ● ● ●	CLOSE QUOTES	CLOSE QUOTES	0	QUOTES
o ● o o ● o		ST	SLASH	SLASH
o ● o o ● ●		ING	PLUS SIGN	PLUS SIGN
o ● o ● ● ●	NUMBER SIGN	NUMBER SIGN	NUMBER SIGN OR RIGHT BRACE	POUND SIGN
o ● o ● ● o		AR	RIGHT PARENTHESIS	OR SYMBOL
o o o o ● o	SINGLE QUOTE	SINGLE QUOTE	SINGLE QUOTE	SINGLE QUOTE
o o o o ● ●	HYPHEN	HYPHEN	HYPHEN	HYPHEN OR MINUS
o ● o o o o	ACCENT SIGN	ACCENT SIGN	CENT SIGN	PERCENT SIGN OR TWO-CELL INDICATOR
o ● o ● o o		USED FOR TWO CELLED CONTRACTION	SEMICOLON	DOLLAR SIGN OR TWO-CELL INDICATOR
o ● o ● o ●		USED FOR TWO-CELLED CONTRACTIONS	EXCLAMATION POINT	0 ZERO
o o o ● o o		USED FOR TWO-CELLED CONTRACTIONS	COLON	AT SIGN OR TWO-CELL INDICATOR

Symbol	Literary Grade 1	Literary Grade 2	Programmer's Code	Terminal Braille
○ ● ○ ○ ○ ●		ITALIC SIGN OR DECIMAL POINT	PERIOD	ITALIC SIGN OR UNDERSCORE
○ ○ ○ ● ○ ●	LETTER SIGN	LETTER SIGN	QUOTES	LETTER SIGN
○ ○ ○ ○ ○ ●	CAPITAL SIGN	CAPITAL SIGN	COMMA	CAPITAL SIGN

ELECTROMECHANICAL PERFORATED TAPE READER FOR THE BLIND

Centrum Obliczeniowe PAN
Skrytka pocztowa Nr 22
00-901 Warszawa P K i N

The electromechanical perforated tape reader is the first device built in Poland with the intention of employing blind programmers in electronic computing centers. Using this device, a blind programmer can easily read by touch, information recorded on the perforated tape. The device consists of an ordinary reader of an eight-track perforated tape, and a braille countershaft in the form of a handy console (Fig. 1). The console is fitted with a system of eight movable pins controlled by signals from the reader, and two pushbuttons for continuous and intermittent work (Fig. 2).

TECHNICAL FUNCTIONING DATA

The device consists of two parts; a reader of eight-track perforated tape (basically any type), and a braille countershaft.

The perforated tape reader is adapted to coordinate with the braille countershaft. The countershaft is a miniature console of the following dimensions: 25 cm long, 10 cm wide, and 3.5 to 6.5 cm high. Its top slants slightly towards the person using the device.

There are two reader windows in the top of the console, consisting of eight appropriately arranged moving pins which successively reproduce the characters of the perforated tape according to the code in which those characters have been recorded. In view of the fact that the eighth track of the perforated tape is rarely used, the pins have been arranged in two rows, as follows:

	0 8
	0 7
0 3	0 6
0 2	0 5
0 1	0 4

This system corresponds to the arrangement of punctures on the perforated tape into those on the left

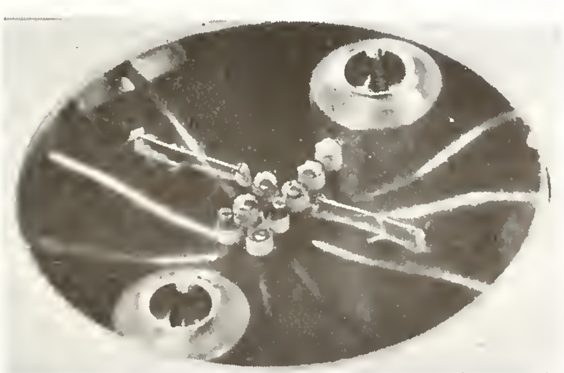


Figure 1.

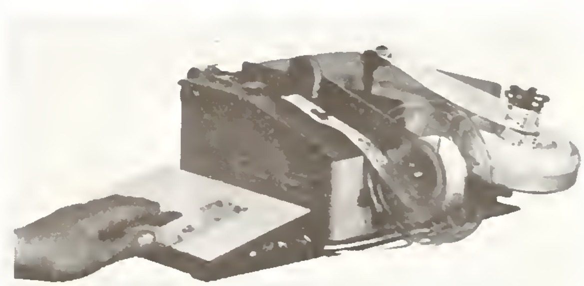


Figure 2.

and those on the right of the guiding perforated row. On the console, within the reach of the fingers of one hand, there are two pushbuttons: one for intermittent work and another for continuous work.

Every time the intermittent work button is pressed, there appears an arrangement of pins which corresponds, in a slightly modified manner, to the arrangement of punctures of the tape character which is being read. The arrangement of the pins does not change as long as the intermittent work button is not pressed again. After it is pressed, a new, consecutive arrangement of pins appears, representing the next character. The continuous work push button is used for continuous reading or for moving the tape at a regular speed of two to ten characters per second. The adaptation of the perforated tape reader to cooperation with the braille countershaft calls for only slight modifications which do not exclude the reader from further utilization. Either reserve readers available in electronic computing centers, or readers withdrawn from use because of their lower performance, can be used for this purpose.

PROTOTYPE

The prototype of the device has been built in the Computing Center of the Polish Academy of Sciences, PAN, Warsaw, Palac Kultury i Nauki, X pietro, according to a design by Jerzy Reszel and Ryszard Sawa. The price of the prototype device is relatively high (about 12,600 zł) because the perforated tape reader used was rather expensive (10,600 zł). The price of the braille countershaft is about 2,000 zł. Work was started recently on building a perforated tape reader (costing several thousand zł) which could be used with the braille countershaft. With a yearly production of perhaps a dozen sets, the price of one device will probably be about 5,000 zł.

USE IN ELECTRONIC DATA PROCESSING

The device may be used for examination or reading of short perforated tapes, and for checking dubious tape segments resulting from failure in punching devices. At present, in view of the lack of braille printing devices controlled by data carriers, it may also be used for reading all material coded on the perforated tape.

Together with tape punching devices, the electromechanical reader makes it possible for the blind to control the correctness of recording of data or programs. The device could also be used to read any kind of material coded on perforated tape in the braille code. Recording material on perforated tape is far less expensive than printing it in braille or recording on a magnetic tape.

ADVANTAGES AND LIMITATIONS

The small size and shape of the console adds to the usefulness of the device; however one has to know the code used on the perforated tape in order to use the device. The arrangement of the eight pins makes it possible to read the full stock of 256 characters which are used at present in perforated tape technology. In view of general use of perforated tape in Poland, the device should be part of the basic equipment of a blind programmer of electronic digital computers.

LANGUAGE MEANING (GENDER SHAPING) AMONG BLIND AND SIGHTED STUDENTS*

John G. Cull and Richard E. Hardy

Virginia Commonwealth University

Abstract

Blind students showed significant differences from their sighted counterparts in assigning gender to 17 commonly used words out of 50. Language seems to help condition perception, and persons who are deprived of vision seem to have different interpretations concerning the meaning of words in the language.

INTRODUCTION

Language plays an important part in our perception of the feeling of persons toward us and, in general, of the total environment around us (1, 2, 7). Problems relating to communication skills and sight loss have been described in the literature (3, 4, 6).

The purpose of this research was to evaluate the meaning of words within the language system for both blind and sighted students to determine whether substantially different meanings exist for the two groups.

METHOD

Twenty-two totally blind students at the Virginia School of the Blind in Staunton, Virginia, and 64 sighted subjects from the Wilson Memorial High School in Fishersville, Virginia, were randomly selected from classes of senior English. These two schools were selected because of the similarity. They are both located in a rural section of Virginia. The students in both schools have a high degree of similarity in educational, cultural, and social levels, and in level of general academic achievement.

The Gender Association Survey (5) which is based on semantic differential tests was administered in May of 1971. Subjects reacted to abstract and concrete English nouns on a five-point masculinity-femininity scale where number 1 was masculine, and number 5 was feminine.

No reason for the study was given to the subjects in order that preconceived ideas about the survey could vary uncontrolled. Biographical data included age, sex, and education. None of the students used a second language at home.

RESULTS

The mean scores on the Gender Association Survey for blind and sighted males and females were compared. (Tabular material available from the authors at the address shown at the end of this article.) A standard error of the mean differences for males and females showed that both groups scored as could be expected from chance factors alone.

For purposes of cross-validation, both the blind and sighted groups were then divided into random subgroups, and the same statistical procedure was applied. Results indicated that when comparisons were made between the two groups of blind subjects, only two words were interpreted significantly different at the 0.05 level. The comparison between the two groups of sighted subjects in interpreted response indicated that three words

*Received in the Editorial Office on January 26, 1973 and published immediately at Provincetown, Massachusetts.
Reprinted by permission of The Journal Press, 2 Commercial Street, Provincetown, Massachusetts. This paper appeared originally in The Journal of Psychology, 1973, 83, 333-4.

were interpreted significantly different at the 0.05 level.

The blind and sighted groups were compared on their responses to the masculinity and femininity connotations of the English nouns on the survey. Differences at the 0.05 level of significance were found for 17 words, as follows: love, progress, star, knot, chair, sun, thief, work, man, defeat, cloud, smoke, root, fear, belief, battle, life.

REFERENCES

1. Jacobovits, L. A. & Miron, M. S. (Eds.). *Readings in the psychology of languages.* Englewood Cliffs, N.J.: Prentice-Hall, 1967.

2. Korzybski, A. *Science and Sanity.* New York: Country Life Press, 1933.

3. Minor, L. E. A study of the incidence of speech deviations among visually handicapped children. *New Outlook for the Blind,* January 1963, 57(1), 10-14.

4. Moor, P. M. Blind children with development problems. *Children,* January-February 1961, 1, 9-13.

5. Osgood, C. E. *The Gender Association Survey.* Unpublished manuscript, Institution of Communicational Research, University of Illinois, Urbana, 1967.

6. Rogow, S. The nonverbal blind child: Two paths to speech. *New Outlook for the Blind*, January 1969, 63(1), 1-7.

7. Saporta, S., (Ed.). *Psycholinguistics.* New York: Holt, Rinehart & Winston, 1961.

Virginia Commonwealth University
Regional Counselor Training Program
Box 499 WWRC
Fishersville, Virginia 22939

REPORT OF THE PERCEPTUAL ALTERNATIVES LABORATORY FOR THE PERIOD JULY 1, 1972 - JUNE 30, 1973

Emerson Foulke*

The function of a perceptual system is to gather the information used by the individual in regulating his interactions with his environment. When, because of sensory or motor impairment, 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 an action 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. At its present stage of development, the research program of the Laboratory is concerned primarily with the investigation of perceptual alternatives for individuals with visual impairment. However, perceptual alternatives for visually unimpaired children with severe reading problems, and for children with profound motor disabilities have also received attention, and the long-range objective of the Laboratory is to investigate the entire spectrum of useful perceptual alternatives.

During the past year, a substantial commitment of time and effort was made to the search for funds with which to carry forward the Laboratory's program of research. In September 1972, Paul Ward, Director of the University Development Office, and I traveled to New York and explored the possibility of funding with the executive officers of several private foundations. As a result of this effort, grants were obtained from two foundations: $25,000.00 from the Robert Sterling Clark Foundation, and $75,000.00 from the Grant Foundation. The grant from the Robert Sterling Clark Foundation is currently providing general support for the Laboratory's program of research. This term of support will end September 31. The grant from the Grant Foundation makes provision for general support, and for the support of several specific projects to be discussed later. The support provided by the Grant Foundation will commence on October 1, and extend through June 30, 1975.

Maxwell A. Kerr, President and co-owner of ADA-MAX, an audio-visual engineering firm in Jackson, Michigan, and I co-authored a proposal for research on techniques for retrieving information from tape recorded texts. This proposal was submitted to the Seeing Eye Foundation, where it received favorable consideration, and the Seeing Eye Foundation has made a grant of $15,582.96 to the Perceptual Alternatives Laboratory to support the project described in the proposal, and discussed in a later section of this report. The initial and terminal dates for the period of support have not yet been established, but it will be approximately coincident with the 1973-74 fiscal year.

In May, Dr. James Driscoll, Chairman of the Department of Psychology, and I went to Washington,

*Director
Perceptual Alternatives Laboratory
University of Louisville
Louisville, Kentucky 40208

D.C. and held discussions with the administrators who supervise the extramural support programs in several federal agencies. These discussions were undertaken in an effort to become better informed about the types of research, and levels and terms of support regarded as feasible by the agencies we visited. The hypothesis is that the perspectives gained through these discussions will permit a more efficient quest for funds from federal sources, and this hypothesis will be tested shortly by the submission of proposals now in preparation.

ACQUIRING INFORMATION BY LISTENING

The information that is ordinarily acquired by reading the printed page may 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 better use of the time he spends in his car by listening to recorded oral reading as he drives. 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 or large print. The investigation of reading by listening is a major component of the Laboratory's program of research. 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 Comparative Evaluation of Simple Index Codes for the Identification of Locations in Tape Recorded Texts

A serious problem, experienced by those who read by listening to tape recorded texts, is the difficulty of finding specific locations, such as chapter headings, paragraph headings, or the locations at which new pages begin in the inkprint analogues of such texts. Because these locations cannot be found easily, the retrieval of desired information is an inefficient process, and as a consequence, tape recorded texts are less effective than their inkprint analogues.

The retrieval problem may be reduced by recording, at appropriate locations in the track on which text is recorded, tones so low in frequency that they are nearly inaudible. Because they are nearly inaudible, when the tape is reproduced at the normal playback speed, their presence does not interfere with the perception of speech that has been recorded on the same track. When the tape is played back in the fast-forward mode on a tape recorder that has been modified so that the tape remains in contact with the playback head during fast-forward operation, the tones are increased in frequency by an amount that is proportional to the increase in tape speed, and they are heard as clearly audible "beeps," displayed against the background of high-pitched chatter that results from reproducing speech at the fast-forward tape speed.

This system of indexing is currently employed by Recording for the Blind in its preparation of recorded textbooks. A rudimentary code with two characters is used. One character, a single "beep," signifies the beginning of a new page. The other character, two consecutive "beeps," signifies the beginning of a new chapter. An announcement at the beginning of each track indicates the pages covered on that track, and if a new chapter starts on the track, this fact is also announced. With this information, the reader can, by interpreting the code signals that are manifest during fast-forward operation, locate pages and chapters in which he is interested. An index code with a larger number of characters should permit a more detailed search of a tape recorded text, and the result should be more efficient retrieval.

A project has been initiated in collaboration with the American Printing House for the Blind, the objective of which is to develop one or more such codes. Tones produced by an oscillator will be used as code elements, because their electronic generation is a simple matter, because they can be recorded satisfactorily, and because they can be varied in several dimensions in which human observers are known to demonstrate good discrimination. The one or more codes to be tested will include tones of two durations, tones of two pitches and two portamento effects. Code characters will be composed of either one or two of these elements. By exploiting all possible combinations of these elements, 42 characters can be composed. The first task will be to evaluate these characters in terms of speed and accuracy of identification. The information gained by evaluation will guide the selection of code characters for further testing. One or more codes will be constructed, and used to index tape recorded texts. These texts will be examined by subjects who are given tasks requiring search and retrieval. The efficiency with which they perform these tasks will be compared with the efficiency that characterizes the performance of such tasks when conventionally recorded tapes are used.

THE TALKING DICTIONARY

The objective of this project is to record, on tape, the oral reading of a dictionary in a manner that will permit rapid search of the recorded format and efficient retrieval. The dictionary is presented on cassette. To prepare a cassette, two tape recordings are needed. One tape, referred to hereafter as the text tape, contains the full text of the dictionary. The other tape, referred to hereafter as the index tape, contains only the pronunciations of the words that are pronounced, spelled and defined on the text tape. The index tape is recorded at 15 inches-per-second (ips), which is an approximation of the fast-forward speed of the modified cassette recorded on which the recorded dictionary is reproduced. In order to prepare a dictionary cassette, the text tape is reproduced at the speed at which it was recorded, and the index tape is reproduced at 15/16 ips. The signals from these tapes are mixed and recorded on a cassette at 15/16 ips. To reproduce this cassette properly, two modifications of the conventional cassette recorded are required. Its motor speed must be continuously variable through a range that centers on a playback speed of 15/16 ips, and the playback head must not be retracted from the cassette when the recorder is placed in the fast-forward mode. This second modification permits the tape to be scanned by the playback head when the cassette recorder is running at the fast-forward speed. The cassette players now supplied to blind and physically handicapped readers by the Library of Congress, and the cassette recorders sold to blind and physically handicapped readers by the American Printing House for the Blind include all of the modifications required for the proper reproduction of the Talking Dictionary. When the dictionary cassette is played on the modified cassette recorder at 15/16 ips, the signal containing the full text of the dictionary is reproduced properly. The signal containing only the pronunciations of the words that are also spelled and defined in the full text is reproduced at a speed which is so much slower 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. When the cassette recorder is placed in the fast-forward mode of operation, the signal containing the pronunciations of words is intelligibly reproduced and displayed against the background of 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 unintelligible, it adds only noise to the signal that is being processed by the listener, and it does not offer serious interference. As the listener scans at the fast-forward speed, he must make slight adjustments in motor speed in order to maintain the index signal at the proper pitch. 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 definition to which the index word refers, occur at the same point on the tape. Each cassette contains a braille label and a large-print label indicating the first and last word recorded on each track. Using these labels, the listener selects the cassette and the track containing the word in which he is interested, and plays the cassette 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 the normal visual reader to consult a printed 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 the braille dictionary. Though a superior reader may consume less time 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. Furthermore, most of the blind people who read by listening do not read braille at all, and for them, the Talking Dictionary may provide the only alternative to dependence upon the assistance of a visual reader in consulting a dictionary.

This project was also reviewed in last year's report, and in that report, an automatic control device for handling the tape recorders used in preparing the master tapes needed for cassette duplication was described. Experience proved this device to be inadequate, and much of the effort expended on this project during the current year, was devoted to the development of an improved control device. The new control device has now been completed, and it appears to function satisfactorily. It operates in the following manner.

As the reader's voice is recorded on one track of a stereo tape, a tone from an audio frequency oscillator is recorded on the other track. After pronouncing each word on the index tape, and after completing each segment on the text tape, the reader presses a button which briefly interrupts the tone produced by the oscillator. When these tapes are reproduced the recorded tones are sensed by circuitry which operates relays that start and stop the transports on which the tapes are being reproduced. When both tones are present, or when neither tone is present, both transports run. If the tone on one tape is absent, the transport handling that tape is stopped, and remains stopped until the termination of the tone on the other tape is sensed. Then, the idle transport is started again and the cycle is repeated. In order to make the termination of an index word coincident with the termination of the segment of full text preceding the segment to which the index word refers, the tapes are played backwards. The voice signals obtained from the two tapes are fed to an audio mixer, the output of which is recorded on a final master tape that is suitable for use on a high-speed cassette duplicator.

Because of staff shortages, except for work on problems of instrumentation, little progress has been made on this project during the past year. However, with the support provided by the Clark Foundation, it has been possible to employ a research assistant who is spending all of his time on the dictionary project. The development of an efficient procedure for the production of the master tapes needed for cassette duplication should be accomplished within a few weeks.

The next step will be taken in collaboration with the American Printing House for the Blind, which has expressed an interest in making the Talking Dictionary available to blind and physically handicapped readers. Although the intention to collaborate has been agreed upon by the Perceptual Alternatives Laboratory and the American Printing House for the Blind, the nature of this collaboration has not been specified. The Perceptual Alternatives Laboratory could assume responsibility for the recording of index and text tapes and for the preparation of the final master tapes needed for cassette duplication, or it could use index and text tapes recorded at the Printing House to prepare these final master tapes. Alternatively, it may be more convenient to deliver the instrumentation that has been developed, and the procedure it enables, to the Printing House. In any case, the Printing House would assume responsibility for the duplication and distribution of cassettes.

When this step has been completed, other applications for voice indexing will be explored. For instance, it would be a simple matter to index a tape recorded text book with announcements that locate and identify new pages, new chapters, paragraph headings, and so forth.

The Evaluation of the "Running Abstract" as an Aid for Search and Retrieval in Tape Recorded Reading Matter

This project has been undertaken in collaboration with Maxwell A. Kerr, an electrical engineer who directs an educational technology laboratory in Jackson, Michigan. Kerr contributed the concept of the "running abstract." He has developed a procedure for subjecting full text to a kind of scrutiny that permits the rapid abstraction of sequences of crucial words and phrases which form meaningful statements. When these statements are read in sequence, the result is an abstract which exactly parallels the full text, but which is only one-eighth of the full text in length. Kerr has shown that little training is required for mastery of his procedure, and that people without background in the subject matter of the text under scrutiny, who have learned his procedure, can produce satisfactory abstracts of technical reports.

Using the recording technique employed in the preparation of the Talking Dictionary, an abstract of this sort can be recorded on the same track that is used for the full text recording. First, the abstract is recorded on tape. The text of the abstract is displayed for the oral reader who makes the recording by a pacer, which is adjusted to expose text at a rate that will insure its reading in one-eighth of the time required for the reading of the full text to which it refers. If necessary, any further adjustment of the playback time of the abstract tape can be accomplished by time compression or time expansion. The tape containing the abstract is then reproduced at one-eighth of its recording speed which results in a playback time equal to the playback time of the full recorded text. The signal obtained from the abstract tape is mixed with the signal obtained by reproducing the full text tape at the speed at which it was recorded, and the resultant signal is recorded on a final master tape, which is suitable for direct playback or for duplication.

Rapid scanning is an important ability of the visual reader that is not shared by the aural reader. This ability permits the visual reader to gain a general impression of the contents of a book, and to locate sections of particular interest to him for more careful reading. When he is reviewing a book that he has already studied, the ability to scan rapidly permits him to spend his reviewing time efficiently. With Kerr's procedure for preparing a "running abstract," and the recorded format developed for presentation of the Talking Dictionary, scanning can become an ability of the aural reader, as well. Using a cassette with the proper format, and a cassette reproducer with the necessary modifications, the aural reader might start by listening to a recorded book at eight times its normal playback speed. At this fast speed, he would hear the "running abstract," which would suffice 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.

A proposal concerning the development and evaluation of this procedure was prepared by Kerr and myself, and submitted to the Seeing Eye Foundation. It received favorable consideration, and the Seeing Eye Foundation has made a grant of $15,582.96 to the University of Louisville to support work on this project during the 1973-74 fiscal year. In order to realize the terminal objectives specified in the proposal, it will be necessary to provide suitably modified cassette players, train people to prepare "running abstracts," identify reading matter that is suitable for purposes of evaluation, train oral readers in the use of the pacer that presents the text of the abstract, and prepare recordings with the proper format. When this has been accomplished, an evaluation experiment will be conducted to determine the extent to which the availability of a "running abstract" enables the aural reader to realize the advantages of rapid scanning.

The Development of an Aural Testing Instrument

Acquiring test information by listening to the recorded oral reading of a test form 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 person 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 passing over items that seem difficult to him on first reading, responding to the items he finds easy, 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 largely cancelled by the time that must be spent in performing them. Returning to a precise location in a conventionally recorded tape is a task that must be accomplished by a trial and error process of successive approximations. 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 the aural reader will usually elect to forego the advantages he might realize by retracing. If the test score earned by the aural reader 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, his score will not be a valid indicator of the ability the test purports to measure.

To solve this problem, the laboratory arranged for the design and construction of a prototype device by Biotronics, an electronic engineering firm in the Louisville area. This device is designed to be used as an accessory to the cassette recorder sold by the American Printing House for the Blind, which has been modified to reproduce, when it is operated in the fast-forward or fast-rewind mode, and which incorporates an oscillator, the 60 cycle output of which is recorded by pressing a momentary switch when the machine is operating in the record mode. With the device connected to his cassette recorder, the aural test taker listens to a cassette on which test items have been recorded. At the end of each test item, a brief 60-cycle tone is sensed by the device and the tape recorder is automatically turned off. If he wishes to proceed to the next item, he presses a momentary switch on the device, which starts the cassette recorder again. If he wishes to hear the item again, he presses the rewind button on the cassette recorder and releases it when he hears a high-pitched tone. This is the 60-cycle tone that marks the boundaries between test items, but since the tape to which he is listening is being played at approximately 16 times the normal playback speed, the tone he hears has a frequency in the neighborhood of 1,000 cycles-per-second (cps). When, upon hearing the high-pitched tone, the test taker stops his recorder, the tape in the cassette is properly positioned for hearing the test item again. Of course at the conclusion of the second hearing of the test item, the cassette recorder is automatically turned off, as before. He may repeat this operation as many times as he wishes. He may return to any desired test item by holding the rewind 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 operation, he can find his place again by releasing his rewind 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 the fast-forward button on the cassette recorder and listen for the oscillator tone used to locate item boundaries, which will again be heard as a high-pitched tone in the neighborhood of 1,000 cps.

This device, and the procedure it enables, were also described in the last report. It performs the functions for which it was designed. However, experience gained during the current year has revealed problems in human engineering that must be solved before the system is ready for field testing. More attention must be given to the manner in which switches are to be operated by the user. Furthermore, the necessity of operating switches at two different locations--the cassette recorder and the remote device--in order to control a single process, appears to be undesirable. To solve this problem, it will probably be necessary to install the control device in the recorder itself. The manner in which this is to be accomplished will be determined in the next few months. The grant from the Grant Foundation makes specific provision for the support of this project. Next October, when money from this grant becomes available, several cassette recorders will be purchased from the Printing House and the necessary modifications will be made. With the capability provided by this system, the aural test taker can perform the operations that should make aural test taking an attractive alternative for persons with visual reading problems. However, field testing will be required before the system can be recommended for use, and it should be possible to get field testing under way during the spring semester, 1974.

Aural Testing in the Public Schools

An experiment was conducted during the current year to gauge the effectiveness of aural testing. Children in the public schools served as subjects in the experiment. Parallel forms of a group test of intelligence were administered to each student. One form was printed, and the other form was recorded on tape. In addition, a Wechsler Intelligence Scale for Children was administered to each student in order to provide criterion scores for comparison with the scores obtained from the group tests of intelligence. The data of this experiment have not yet been analyzed, but it is evident from inspection that the intelligence of some of the students in the group was assessed more adequately by the aurally administered group test than by the group test in printed form.

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, a child must obtain from printed reading matter the information he needs to succeed in the tasks set for him by his teachers. If he cannot read well, his ability to gather this information is impaired and his performance is adversely affected. Public school educators 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 school performance and their poor reading ability are both the consequences of limited intelligence. This may sometimes be true, 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 was initiated in collaboration with the Jefferson County School System. Parallel forms of a test of comprehension were administered to 275 students in the seventh grade at Valley Junior High School. One form of the test was printed, and the other form was recorded on tape. By analysis of these test scores, it was possible to identify a group of children who are accurately described as poor visual readers, but adequate aural readers.

As a next step in this investigation, a text book scheduled for use by the students who served in the experiment was prepared in recorded form, and one dozen copies were duplicated on cassette. The cassette books were made available to Valley Junior High School in the expectation that the children identified as poor visual readers but adequate aural readers would be given the opportunity to study the books recorded on cassettes instead of its printed counterparts. At this point in the investigation, there was a change in public school personnel, and the program was not effectively implemented. However, it may be possible to resume the investigation in the fall quarter, 1973. The objective is to compare the performance of those who use the cassette books with the performance of students in a control group who use conventional study materials, and with their own performance in courses in which tape recorded books have not been used.

An investigation resembling the one just described is planned in collaboration with the Louisville Public School System. Marilyn Kreisle, Coordinator of Learning Disabilities, will serve as a co-investigator. Through testing and observation, it has been determined that there are a significant number of children in the Louisville Public Schools with better than average intelligence, who have seriously inadequate reading ability. They perform poorly in school, and it is apparent that they do so because they cannot acquire by reading the information they need for success in school tasks. If a proposal prepared by Kreisle, after consultation with members of the Laboratory staff, is accepted by the Louisville Public School System, an effort will be made to determine the extent to which these children can benefit from the opportunity to read by listening. Parallel forms of a test of listening comprehension, one printed and one recorded on tape, will be administered to those children whose poor scholastic achievement appears to be a consequence of reading disability. Those children who, on the basis of test performance, can be described as poor visual readers but adequate aural readers, will be given an opportunity to do all of their studying by listening to recorded text books. The effectiveness of aural reading for the students under investigation will be evaluated by comparing their current performance, as indexed by scores on tests of scholastic achievement, school grades, and subjective appraisals by teachers, with the performance of the same students during the preceding year, when they were required to depend upon visual reading. The Louisville Public Schools will be responsible for the administration of tests of comprehension, supervision of the use of study materials and the collection of evaluation data.

The Development of an Aural Reading Instrument

In one line of investigation carried on in the Laboratory, an effort has been made to identify, by analyzing the reading behavior of visual and aural readers, those operations that account for the efficiency of visual reading and that are not ordinarily available to the aural reader. This analysis has provided the basis for formulating the functional requirements of a satisfactory aural reading instrument.

There is no piece of equipment on the commercial market embodying all of the required functions. However, an office dictating machine manufactured in Switzerland and distributed in this country by Dictaphone Company can, with some modification, be made to incorporate enough of these functions to permit an evaluation of the improvement in reading effectiveness that may be realized through the use of a functionally adequate reading instrument. Two of the dictating machines have been acquired. An effort will be made to modify them, and to prepare reading matter in a manner suitable for reproduction on them. A few aural readers will be given training in the use of these instruments, and their experience will be taken into account in designing and constructing a more suitable aural reading instrument.

An effort will be made to conclude this evaluation in the fall semester of 1973. The period of support provided by the grant from the Grant Foundation will commence in October. This grant makes specific provision for supporting the development of a prototypical aural reading instrument. This instrument will probably reproduce reading matter recorded on an oxide-coated plastic or paper sheet, instead of tape, because of the relative ease with which information recorded on that sheet can be accessed. A magnetic medium is contemplated, since its use will permit the construction of an instrument with the recording capability of a conventional tape or cassette recorder, and this capability should be given high priority in the design of an aural reading instrument. The design and construction of the prototype will be undertaken in collaboration with Biotronics.

The Development of a Print-to-Speech Transducer

The two preceding reports in this series have included discussions of a project in which the ultimate objective is the development of a device that recognizes print letter shapes, transduces each recognized character to one of the sounds for which it stands, and reproduces sounds in the same sequence in which they were recognized. By simulation on the computer maintained by the Psychology Department, it was possible to demonstrate that output constructed in this manner has a speech-like quality, and that its interpretation can be learned without great difficulty. With relatively little training, reading rates in the neighborhood of 130 words-per-minute have been demonstrated.

Because the Laboratory had no funds that could be used to provide a salary for a co-investigator on this project, Glenn Smith served in this capacity for a considerable time without remuneration. However, he could not continue in this manner indefinitely, and he ultimately accepted a position as Director for Computer Services for the Blind (CSB), to be discussed in a later section of this report. His work as Director of CSB has fully occupied his time, and it has been necessary to suspend work on an output suitable for a print-to-speech transducer. This project will be reactivated when suitable arrangements can be made, but it will probably not be possible to do so in the coming year.

Learning a Touch-Tone Code

Dr. Francis Lee, professor of electrical engineering at M.I.T., and President of Lexicon, a firm that manufactures an electronic speech compressor, has given some consideration to the problem of transducing the displays produced by electronic calculators, and other devices with digital readouts to a form that can be appreciated by visually impaired individuals. There are reasons that invite consideration of the signals in the touch-tone code used by the telephone company as audible indicators of the values registered on digital displays. The apparatus required for their generation is small, readily available, and relatively inexpensive. The electronic logic required to interface this apparatus with devices that display their results digitally is well known and easily provided. However, in addition to its feasibility from an engineering point of view, a display must also be perceptually feasible. This means, in the present case, that it must be possible for human observers to make absolute identifications of the tonal dyads in the touch-tone code with sufficient speed and accuracy to warrant their use as code signals in situations in which there is little tolerance for error.

This possibility was examined by an experiment conducted in the Perceptual Alternatives Laboratory. Random permutations of the 12 dyads in the touch-tone code were recorded on tape. Each of the dyads was given a name--one of the numbers from 1 through 12--and a paired associates method was used to teach the names of dyads to subjects. Upon the presentation of each dyad, the subject guessed its name, after which the experimenter announced its correct name. Thus, the subject was immediately informed of correct and incorrect guesses. A trial consisted of one random permutation of the 12 dyads, and each subject was scored for the number of correct identifications on each trial. The intention was to administer trials until a criterion of two consecutive errorless trials was attained. However, it soon became apparent that this criterion was unattainable and the training of each subject was therefore discontinued when the experimenter was convinced that no further improvement would occur.

The results of the experiment are summarized in Table 1.

TABLE 1

Absolute Identifications of the Tonal Dyads in the Touch-Tone Code

Subjects	Trials	Percent Correct
M.J.	47	16
F.T.	47	13
E.M.	59	17
J.W.	47	17
S.S.	83	35
T.K.	47	12
L.F.	47	21
T.C.	47	17

From this data, one may conclude that subjects were responding beyond a chance level, and that some learning was taking place. However, it is also apparent that no useful learning occurred. The numbers of errors made by each subject in consecutive blocks of five trials were counted. These sums were examined for practice effects, but none were found.

The performance of these subjects indicates that the absolute identification of the tonal dyads in the touch-tone code cannot be accomplished with enough reliability to justify their use for purposes of communication. It would probably be possible to identify many of the patterns that can be formed with sequences of two or more dyads. For example, some of the patterns formed by telephone numbers appear to be distinctive and easily identifiable. However, the engineering simplicity of a display in which each digit would be specified by a single dyad is the principle argument for using the touch-tone code. Other sets of tonal dyads would undoubtedly be more perceptually feasible. For instance, the absolute identification of the dyads in a set of dyads in which one member of each dyad was always the same in frequency, while the other members were related to the fixed member as notes in the musical scale, could probably be learned with ease. The practical difficulty with this approach is that devices for the generation of other sets of dyads are not available. They would have to be designed and built, and since their intended application would justify only limited production, they would undoubtedly be expensive.

A Dimensional Analysis of the Productions of Oral Readers

Aural readers express clear preferences regarding oral readers. In some cases, the bases for these preferences are evident. However, in other cases, it is not possible to identify the factors that are evaluated by a listener in forming his preference. Even a superficial analysis suggests that several dimensions must be taken into account in evaluating the production of an oral reader, but the specification of these dimensions and of the way in which the dimensional values represented in the production of a given reader combine to determine the preference of the listener, is not yet possible.

To examine this issue, an experiment was conducted in which subjects were asked to evaluate all of the possible pairings of 12 oral readers--four professional readers, four experienced amateur readers and four readers drawn at random from the student body at the University of Louisville. The production of each reader was recorded, and samples lasting 1 minute were obtained from these recordings. By pairing each sample with every other sample, 66 pairs of samples were formed, and re-recorded in a format that placed the two samples in each pairing on concurrent parallel tape tracks. During playback, each of the samples in a pairing could be reproduced selectively by operation of a switch. The subjects' task was to compare the samples in each pairing and, in each case, to express a preference for one of them.

As would be expected, preliminary analysis of the data thus obtained indicates that professional readers were, with one exception, preferred over experienced amateur readers, and that experienced amateur readers were, without exception, preferred over readers chosen at random. The data have been transcribed to Hollerith cards, so that a computer may be employed in an analysis intended to disclose the multidimensional preference structure expressed by the subjects who served in the experiment. The first step in this analysis has shown that there is no single dimension which will account for the expressed preferences. When completed, this analysis should indicate the number of dimensions needed to account for the expressed preferences, and it should suggest hypotheses concerning the identity of these dimensions that can be tested in further research.

Comparative Evaluation of the Signal Quality of Different Speech Compressors

In the past few years, rapid progress has been made in the development of the technology upon which the time compression and expansion of recorded speech depends and several electronic and electromechanical speech compressors are now commercially available. The Center for Rate-Controlled Recordings, a unit of the Perceptual Alternatives Laboratory, has, for many years, played a prominent role in the conduct of research concerning time-compressed and expanded speech. Because the Center has no commercial interests at stake, it has received requests from several manufacturers (as well as many of their prospective customers) for an objective evaluation of the signals produced by different speech compressors.

In response to this demand, a study has been planned in which the intelligibility of speech compressed on different compressors will be determined. To make this determination, sentences that adequately sample the phonemic spectrum will be recorded on tape, and compressed and expanded by several degrees on each of the compressors under evaluation. The specimen prepared on each compressor will be submitted to the manufacturer of that compressor for examination and, if the manufacturer is not satisfied with its quality, the master tapes used in preparing the specimen will be made available to him, and he will be invited to prepare a specimen that fairly represents the performance of his compressor. When the specimens have been collected, they will be presented to groups of listeners who will be asked to reproduce in writing the sentences they hear. Each sentence will be scored for the number of words correctly reproduced, and an effort will be made to determine the types of error represented in each incorrectly reproduced word.

In another approach, the relative preferences of listeners for the signals of the speech compressors under evaluation will be determined. The listening experience upon which preferences are to be based will be provided by extended samples of fluent speech, prepared on these compressors. With information about intelligibility, and information concerning the preference of listeners, it should be possible to make meaningful comparisons among the output signals of the commercially available speech compressors. The results of this study should be useful to manufacturers and to consumers.

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 haptic perception of form. Experiments in visual perception are also occasionally performed in order to produce data for comparative purposes.

Identification Thresholds for Moving Braille Characters

In an effort to understand the perceptual basis for the reading of braille, Nolan and Kederis (1969) have determined the threshold of identification for all of the characters in the braille code. To do this, they employed a tachistotactometer. This is an instrument which controls the interval 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, 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 thus determined is regarded as its threshold of identification.

The difficulty with this method for determining thresholds 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 interval 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 a line of writing, and hence, there is 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 braille readers are required to identify the braille characters and words embossed on a paper tape, as it passes beneath their fingertips. The tape is handled by a special tape transport, designed and constructed in the Laboratory for this purpose. The tape is transferred from a supply reel across a display surface to a take-up reel. The subject under examination places his fingertip on the moving tape, and is stimulated by the dot patterns embossed on that tape as they pass beneath his fingertip. Tape speed is well regulated, and can be varied through a wide range.

Clients at the Kentucky Rehabilitation Center for the Blind are serving as subjects in the experiment now in progress. The purpose of this experiment is to determine identification thresholds for the characters in the braille code, and for words specified by those characters. To determine the threshold for braille characters, the transport is initially adjusted for a tape speed that is too fast to permit identification of any of the characters 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 regarded as an index of the threshold of identification. When thresholds have been determined for all of the characters in the braille code, the procedure is repeated, but characters are replaced with words. The data thus obtained can be examined for relationships between thresholds for words and thresholds for the letters of which those words are composed.

The Reading Behavior of Exceptional Braille Readers

Much of the research concerning the perceptual basis for the reading of braille has elucidated the perceptual processes underlying typical braille reading behavior. The process depicted by this research is one in which letter percepts, acquired serially, are integrated to form word percepts. Reliance on this process results in the slow reading rate (in the neighborhood of 100 words-per-minute [wpm] for adult braille readers) that is typically observed. However, there are a few braille readers who read so rapidly (200 wpm per minute or faster) that their reading behavior is not convincingly explained by a process involving the integration of serially perceived letters.

In the course of collecting data for the experiment described under the preceding heading, two subjects with exceptionally fast reading rates were encountered. In the phase of this experiment in which whole words were presented on the moving tape, one of these subjects made rapid and accurate identifications at the faster tape speeds employed in the experiment, but at the slower tape speeds, her identification time increased, and she began to make errors. She reported spontaneously that, at the slower tape speeds, word patterns began to disintegrate, compelling her to identify letters one at a time. The report of this subject, together with her reading behavior, suggests that patterns consisting of whole words are the perceptual units of the process in which she engages as she reads.

Observation of this braille reader has revived an earlier interest of mine in an approach to the study of braille reading that seeks an accurate behavioral description of exceptionally fast braille readers in order to formulate and test hypotheses concerning the perceptual processes implied by this behavior. Consequently, a study has now been planned in which a small number of exceptionally fast braille readers will be identified and examined intensively. A variety of measures that might be related to reading rate, such as intelligence, cutaneous acuity, reaction time to cutaneous stimuli, age at which braille was learned, and so forth, will be collected.

In an attempt to obtain an accurate record of the reading behavior of these subjects, an instrument has been constructed that permits their hands to be photographed as they read. A transparent sheet of plastic with braille embossed on it is placed on the plate glass display surface on top of the instrument. An electric timer, with its face down, is also placed on the plate glass surface, to one side of the plastic sheet. A motion picture camera, mounted beneath the plate glass display surface, is focused on that surface. It makes a continuous film record of the reading behavior of the subject, and of the time registered on the face of the timer. Analysis of this film may permit a more accurate and detailed description of the different behaviors employed by the reader, and of the distribution of these behaviors in the time dimension.

If this approach is fruitful, it will lead to an understanding of the perceptual processes upon which rapid braille reading depends. With this understanding, it may be possible to formulate training procedures intended to make these processes available to slow braille readers.

Increasing the Braille Reading Rate

An experiment is now planned that seeks an improvement in 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, a kind of dynamic patterning, involving whole words and phrases 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 this hypothesis is a reality, the ability to control the rate at which braille characters move across the fingertip or fingertips employed for reading may make it possible to establish the condition under which braille readers can learn to become aware of and to interpret this patterning.

The tape transport used to determine thresholds of identification for letters and words presented at controlled rates will be used in this study as well. The study will probably be conducted at the Kentucky Rehabilitation Center for the Blind, in collaboration with its Director, Fred Gissoni.

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 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 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 was conducted to determine the number of letters that can be seen during an exposure which is too brief to permit a change of visual fixation. By means of a tachistoscope, letter 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.

Few errors of identification were made when one or three letters were presented at a time. Beyond this point, errors increased as the number of letters presented at a time was increased. Even under those conditions in which error rates were high, subjects were able to identify several of the letters presented simultaneously, 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 greatly increased the number of correct identifications. This experiment is now completed, and a detailed report of it is in preparation.

The Discrimination, Recognition and Identification of Three-Dimensional Random Shapes

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, only two of these dimensions contained information, since the height of dots was constant. It can be argued that haptic perceptual ability is not fully disclosed when patterns of this sort are employed since the examination upon which their perception depends produces relatively little of the kinesthetic stimulation that informs haptic perception.

This issue was examined by a series of studies conducted by Dr. Richard Baird, and reported in his doctoral dissertation. His experiments were of the cross-modal type, and were designed to permit a comparison of performance supported by haptic perception with performance supported by visual perception, on tasks requiring discrimination, tasks requiring recognition, and tasks requiring identification. His dissertation, entitled "The Haptic and Visual Capacities for Perceiving Shapes that Vary in Three Dimensions," is now on file in the library at the University of Louisville, and articles based upon it are being prepared for publication in appropriate professional journals.

The Multi-Sensory 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 stimulation in his visual environment, and that he will learn to interpret this stimulation in order to acquire information about the external world. 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 show considerable variability in the extent to which they consult the stimulation available to them for the information they need about the external world in order to interact appropriately with it. Many blind children give the appearance of having evolved an adjustment that minimizes attention to external stimulation, and that maximizes attention to internal, self-produced stimulation.

Several years ago, I developed, in rudimentary form, a test that was intended to estimate the extent to which blind children acquired the information contained in the external 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 cue used for classification. They could be sorted in terms of texture (rough or smooth), height (tall or short), shape (round or square), surface detail (presence or absence of a small dimple in the center of the top surface), color (blocks of two colors gave partially sighted children the opportunity to use color as a cue), weight (light or heavy), and sound (half of the blocks rattled when picked up and shaken).

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 research was published (Foulke, 1964) but other commitments made it necessary to suspend work on this project before procedures for test administration and scoring could be developed, and the project became dormant.

Although I was unable to carry forward the development of the test, I made a set of test blocks 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. Recently, I have received an increasing number of requests for information about the test itself, and about its cost and availability. These expressions of interest have led to a decision to reactivate the project.

Betty Herz, a volunteer worker in the Laboratory, is supervising the construction of new sets of blocks, more satisfactory than earlier sets in terms of uniformity, durability, ease of construction and expense of materials. One of the new sets has been made available to Lily Oatfield, Director, Psychological Services, State of North Carolina Department of Human Resources, who has agreed to provide a report of her experience with the test. Another set of blocks will shortly be sent to Dr. Rachel Rawls, a member of the Special Education faculty at North Carolina State University at Raleigh, who has also agreed to report her experience. Further work on development of the test will be initiated in this Laboratory 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 haptic examination, graphic information that is displayed in tangible form on a two-dimensional surface, has been an enduring interest of the Laboratory. Techniques have been developed for producing such displays, and the Laboratory owns a vacuum-forming machine, used for duplicating master displays on plastic sheets. However, the techniques currently used for the construction of tangible displays 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, has developed a method 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 joy-stick type, and a teletypewriter. The information required for the specification of symbols is stored in the computer. The supply of symbols includes 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, dashed lines, dotted lines, broad and narrow lines, etc.; and symbols for area consisting of a variety of surface textures. Teletype commands cause these symbols to be displayed on the VDU, where they can be positioned by operating the joy-stick. Dot patterns corresponding to the dot patterns of the braille code can also be added to the display by teletype commands, and positioned by the joy-stick. When a satisfactory graphic display has been composed in this manner, the information that is needed to specify the composition of this graph is encoded on punched paper tape. This tape is used to operate a numerically controlled milling machine that engraves a negative of the graphic display in a sheet of plastic. From this negative, a rubber positive is made that serves as a master for use on a vacuum-forming machine. The advantages of this system include the relative ease with which graphic displays can be composed, the nearly inexhaustible supply of symbols for points, lines and areas, to which the composer has access, and the remarkably high quality of the end result. The use of a milling machine provides better control over the formation of tangible symbols than has heretofore been possible, and the reduced variability among symbols of the same type permits a more reliable and a more finely graded differentiation among symbols of different types. The equipment required for this method is expensive, and if it were dedicated solely to the production of tangible graphic displays, the method would probably not be economical. However, the method does not make excessive demands on computer capacity, and almost any general purpose computer with analog-to-digital conversion may be used. Plans are now underway to implement this method on the Supernova computer that is a component of the ARTS System, to be discussed later. Gill has offered to make available the necessary software, and to assist in its installation. A VDU and a numerically controlled milling machine will have to be purchased, and the money needed for these purchases is now being sought.

If the effort to implement this method is successful, maps, graphs, and diagrams needed by students in a variety of educational settings will be prepared. An effort will be made to generate a body of user experience that can be consulted to evaluate the effectiveness of the method. The system will also be employed to produce research materials for use in experiments concerning orientation and mobility, experiments concerning factors affecting the information that can be acquired from tangible displays, and so forth.

Finally, the system will be made available for demonstration. Descriptions of the system and 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 University in order to study its construction and operation.

A Re-examination of Thresholds with an Improved Tachistotactometer

In their investigation of the perceptual factors involved in the reading of braille, Nolan and Kederis determined the thresholds of identification for the characters in the braille code. To do this, they employed a tachistotactometer, an instrument that provides for temporal control of the intervals during which dot patterns are made available for tactual examination. The dot patterns to be examined are embossed on a sheet that is mounted on a platform beneath the display surface. In order to present a pattern, the platform is elevated by solenoids, and the dots embossed on the sheet mounted on it are pressed through holes in the display surface, a thin membrane of tightly stretched metal with holes in it at locations corresponding to the dot positions in braille cells. The dots embossed on the sheet beneath the display surface protrude above it when the platform is elevated, and recede again when the platform is returned to its resting position. Up to 30 characters, or an entire line of braille writing, may be displayed at one time. The interval during which dot patterns are available for examination is controlled by an interval timer, connected in the power supply of the instrument.

Nolan and Kederis defined threshold as the minimum time of exposure needed for the identification of a character, and used a method of limits to estimate thresholds. Because of the time consumed in changing the sheets on which characters are embossed for presentation by the tachistotactometer, they found it expedient to emboss several characters on a sheet, and to determine thresholds for all of the characters on this sheet before replacing it with a new sheet. Since a subject could quickly memorize the characters embossed on a single sheet, he could eliminate most of the characters in the code from consideration and thereby greatly reduce his uncertainty regarding the identity of any character presented to him for examination. To solve this problem, it was necessary to eliminate those series of stimulus administrations, ordinarily employed in a method of limits, in which the stimuli were initially above threshold, and to retain only those series of stimulus administrations in which the stimuli were initially below threshold. Estimates of thresholds obtained by this attenuated procedure are apt to be unduly influenced by errors of habituation.

Due to design limitations of the tachistotactometer, stimulus presentations could not be made brief enough to permit the administration of complete series of stimuli. The mass of the platform that had to be moved from one position to another and back again in order to present a stimulus in an interval of controlled duration was so great that its movement could not be accomplished in the time required for very brief stimulus presentations, and it was not possible to make the time of exposure for some of the characters in the code brief enough to preclude their identification. Consequently, thresholds for these characters could not be determined.

More precise estimates of the thresholds of identification for the characters in the braille code may be useful in further analysis of the perceptual basis for the reading of braille. Consequently, a study has been planned that seeks to eliminate the sources of error in the results reported by Nolan and Kederis. An instrument has been constructed that permits the presentation, one at a time, of all of the characters in the braille code. Dot patterns are formed by pins that rise through holes in the display surface. Each pin is driven by its own solenoid. The interval during which a character is available for examination is determined by an interval timer, connected in the common return of the power supply that energizes the solenoids. Since the mass of the pins that must be moved from one position to another and back again in order to present a dot pattern for an interval of controlled duration is much smaller than the mass of the platform used for this purpose on the tachistotactometer, and since the distance traveled by pins is much less than the distance traveled by the platform, much briefer stimulus presentations are possible with the new instrument, and stimulus values below threshold can easily be produced. Since any character in the braille code is immediately available for presentation on this instrument, the entire set of characters in the code can be brought under examination at one time. With appropriate interfacing, the instrument can be operated by a computer, and the use of a computer permits the efficient determination of thresholds by the Parameter Estimation through Sequential Testing (PEST) procedure, an interactive procedure in which each stimulus presented to the subject is contingent upon his preceding response.

This experiment is scheduled for the 1973-74 school year. It will be conducted by Beth Challman, a member of the Laboratory's research staff, and reported in her master's thesis.

Development of a Braille Page Embosser

As a result of developments now in progress, such as the APTS System, it will soon be feasible to deliver computer-generated services to blind persons by telephone. These services could include the production of hard copy in braille, but the braille page embossers currently available that would be suitable for use as terminal devices are so expensive that, in most cases, individual ownership is not feasible. To solve this problem, an effort has been undertaken, in collaboration with Biotronics, an engineering design firm in the Louisville community, to develop a braille page embosser that will operate at teletype speeds, and that can be manufactured at a low enough price (under $1,000) to make individual ownership feasible.

Preliminary designs have been completed, and a prototype of the embossing mechanism has been constructed, but lack of money has prevented further hardware construction. However, the grant received from the Grant Foundation makes specific provision for the support of this developmental effort, and it will be activated again when grant funds become available for spending next October.

THE PERCEPTUAL BASIS FOR MOBILITY

The perceptual basis for the skill that enables the blind pedestrian to reach his objective independently, safely, comfortably and gracefully, is one of the Laboratory's continuing research interests. 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 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 for the information needed by the blind pedestrian for orientation and mobility. Research activity in this area has been limited by the lack of funding, and it has not been possible to sustain an organized program of research. However, with the general Laboratory support provided by the grant from the Clark Foundation, it has been possible to initiate some research, and the general support provided by the grant from the Grant Foundation will make it possible to continue research in this area.

A Rudimentary Theory of Mobility

A rudimentary theory of mobility has been formulated in an effort to account for the behavior of the blind pedestrian (Foulke, 1971). This theory seeks to identify the operations upon which the blind pedestrian depends in gathering the information he needs to pursue a course of travel successfully, and provides guidelines for a programmatic research effort. The theory will be one of the topics of discussion concerning mobility theory organized by the American Foundation for the Blind, and St. Dunstans Association for the War Blind. The conference is scheduled for September 23, 1973 through September 26, at Cambridge University, England. Those attending the conference will be able to offer a level of criticism that should permit evaluation and refinement of the theory.

The Development of an Improved Cane for Use by the Blind Pedestrian

Earlier research conducted in this Laboratory has demonstrated the significance of weight, length, rigidity, and form of tip as factors affecting the efficiency of the cane as a tool for gathering information. These factors have been taken into account in a project now in progress, in which the objective is to develop a cane that is more informative to its user than canes currently available. The aluminum tubing selected for construction of the new cane will permit a shaft that is a little lighter and more rigid than the shafts of canes now in general use. It will be be equipped with a grip that fits comfortably in the hand, and this grip should permit more accurate manipulation of the cane when it is used as an exploring tool to gather information about the path ahead. A new tip has been designed which permits the cane to explore surface discontinuities without becoming lodged in cracks. The Design Engineering Division of General Electric's Appliance Park has agreed to design and build an injection mold so that this tip can be formed in plastic, and will provide the tips needed for current evaluation and ultimate production. Initially, tips made from several different plastics will be produced and evaluated for strength, wear, resistance to humidity and other relevant factors. The first canes assembled will be given to experienced blind pedestrians in the Louisville community. Their criticisms will be taken into account in designing the second generation of canes. The redesigned canes will be subjected to more formal evaluation in field tests in which an effort will be made to develop measures of their effectiveness, and to compare them with conventional canes in terms of measured effectiveness. If the new canes survive these tests, arrangements will be made for their production and distribution. Charles Ned Cox, Director of Kentucky Industries for the Blind, has expressed an interest in evaluating the feasibility of their production in the workshop maintained by his agency.

The Preservation of Cues to Distance and Direction in Tape Recordings Used for Training in Mobility

Ordinarily, the cues that specify the distance and direction of sound sources are lost when sounds are recorded on tape or record. This is largely true, even when conventional stereophonic recording techniques are employed. However, Batteau (*Annual Report of Listening, Inc.*, July 1967), has shown that if exact replicas of human external ears, including the canals leading to the ear drums, are mounted on a replica of the human head, and if microphones are placed inside this head in the positions that would be occupied by ear drums, the signals generated by these microphones, when fed through independent channels to earphones, retain the cues that specify the distance and direction of sound sources. These cues are preserved when the microphone signals are recorded on tape and reproduced binaurally. The effect is startlingly realistic. It is difficult for the observer to believe that the sounds he hears are emanating from the earphones he is wearing. They appear to be clearly localized in the space surrounding him.

The vividness of this experience has suggested a possible role for tape recordings of this sort in the courses of instruction in orientation and mobility provided for blind persons. Such recordings might, for instance, make it possible for trainees to receive initial instruction in the interpretation of the sounds of traffic and other street sounds in the safety of the classroom, before they received actual training in the environments in which those sounds occur naturally. Accordingly, a project has been initiated with the assistance of John Kilpatrick, a graduate student who works in the Laboratory, in which an effort is being made to build the necessary equipment and to prepare training tapes for evaluation. With the assistance of Dr. Charles Wagner, a member of the medical faculty at the University of Louisville, and Robert Stockler, of Gates-Stockler Optical Company, exact impressions of the external ears of a cadaver were made, and from these impressions, replicas of the external ears were formed. These replicas have been mounted on a mannequin head of the sort used to model wigs in store windows. Information needed for the selection of microphones and other components in the system is now being gathered. When these components have been acquired, they will be assembled and the system will be tested. If it functions in the expected manner, training tapes will be prepared and evaluated. Fred Gissoni, Director of the Kentucky Rehabilitation Center for the Blind, has agreed to assist in the preparation and evaluation of training tapes.

OTHER PERCEPTUAL ALTERNATIVES

Though the three areas of research on listening, touch and mobility have received major emphasis in the Laboratory's program of research, other perceptual alternatives have received some attention during the current year. Following are accounts of these activities.

A Communication Device for Use by Children with Profound Motor Disability

Last year's report included a description of a communication device that could be operated with the minimal movements remaining to persons with profound motor disabilities. This device enabled the selective backlighting of 64 transparencies, arranged in eight columns and eight rows. Selection of the transparency to be backlighted was accomplished by the operation of two switches. Repeated operation of one switch caused the backlighting to be transferred from column to column across the display, while repeated operation of the other switch caused the backlighting to be transferred from row to row down the display. When backlighting had progressed to the end of a column or row, the next operation returned it to the beginning of the column or row again. By switch operations varying from a minimum of one to a maximum of 14, any transparency in the display could be backlighted.

The switches were designed for operation by poorly controlled arm movements, because a girl at the Cerebral Palsy School in Louisville who might be benefited by this device was capable of such movements. However, the switches could have been designed for operation by any pair of independent movements, regardless of the parts of the body involved, or even by the myoelectric potentials that are generated when muscles are contracted.

A child unable to speak because of motor impairment could use the device for simple communication by backlighting a transparency that had some bearing on a current need. A picture of a glass of water might suggest to others that the operator was thirsty; a picture of a bed might signal the desire for sleep, and so forth. In addition, it was hoped that the device might enable steps leading to the ability to read by promoting an improved understanding of the relationships between written words and the objects for which they stand. After a student had learned to select a given object, the word naming that object could be added to the transparency, and later, the student might discover that it was possible to achieve the same communicative outcome by selecting a transparency which displayed only the word.

Initial experience with the device was quite encouraging. Children seemed to enjoy using it, perhaps because it enabled them to exercise some control over the environment--to make something happen. However, the attempt to use the device for instructional purposes revealed shortcomings. Prolonged switch closures resulted in damage to the control electronics. The inability to transfer backlighting in both directions, horizontally and vertically, proved to be a serious inconvenience.

It was determined that these problems could be corrected without difficulty in a second generation prototype, but there was no money to pay for the design and construction of this prototype. However, the grant received from the Grant Foundation makes specific provision for the support of further work on this project. Accordingly, when money from the grant becomes available for spending next October, Biotronics will build a second generation prototype. If it appears to function satisfactorily, several additional devices will be built and limited field testing will be initiated.

Sex Education for the Blind

In the course of growing up, the child who sees has many opportunities to learn about sexual differences. He continually observes differences in body conformation, and most children have occasional glimpses of normally concealed parts of the body. 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 other bodies, 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 to gain 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 been found to show the blind child what the sighted child can see. A convincing case can be made for the desirability of sex education for blind children, but its validity depends, for the most part, on anecdotal experience. There has been none of the systematic observation that would permit an accurate description of the state of ignorance of blind children, and no search for the relationships between that ignorance and the consequences that presumably ensue.

Thomas Uhde, a medical student at the University of Louisville, visited the Laboratory last year to learn about its program of research, and to explore the posssibility of participating in a research project involving blind children. He had been working part-time at the Kentucky School for the Blind, and his experience 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 in Uhde by his experience at the school, together with the school's current interest in providing sex education, seemed to provide a climate that would be congenial to an investigation of the sex knowledge and sex attitudes of blind children.

Accordingly, a plan was made that called for Uhde to interview blind subjects, ranging in age from prepubescence to early adulthood. The objectives of the interview were to elicit reports from his subjects of their knowledge of sexual anatomy and the manner of its involvement in sexual behavior, and to obtain expressions of their attitudes concerning sexual behavior and its regulation. In order to insure uniformity with respect to the topics to be explored during the interviews, he prepared an interview schedule, the construction of which was guided by consultation with members of the Laboratory staff, and members of the faculty at the Kentucky School for the Blind. In addition, he has prepared questionnaires for administration to parents, houseparents and teachers of blind children. These questionnaires are designed to elicit expressions of attitudes concerning sex education, and opinions concerning the methods and content appropriate to a course of sex education.

A few of the interviews have been conducted and analyzed. Preliminary versions of the questionnaires have been administered to several trial groups. Using the data thus obtained, the preliminary questionnaires have been revised, and the final questionnaires that are to be sent to parents, houseparents and teachers have been prepared.

A summer fellowship, funded by the Rauch Foundation and administered by the Association of Educators for the Visually Handicapped, has been obtained for Uhde. The income provided by this Fellowship has made it possible for him to devote his entire summer to work on this project. His objectives for the summer are to complete and analyze the interviews, and to distribute the questionnaires. Some completed questionnaires may be returned before the summer is over, but many of them cannot be completed until school personnel return in the fall. Consequently, the project cannot be brought to a conclusion this summer, but Uhde intends to finish analyzing the data, and to write the final report during the 1973-74 school year, as time permits.

Teaching Voluntary Facial Expression to Blind Subjects

Different situations elicit different emotional responses from humans. Facial expression is one component of the emotional response, and the facial expressions associated with different emotional responses are discriminable enough to permit fairly accurate inferences by those who observe them of the emotional states or feelings with which they are associated. By observing facial expressions in the contexts provided by the various situations in which they occur, children learn, in the course of development, to make these inferences. They also learn, by observing the facial expressions of others and the reflections of their own facial expressions, to control expressive behavior, so that they can display facial expressions voluntarily as well as spontaneously.

Blind children manifest facial expression spontaneously, in response to different situations. However, since they lack the opportunity to observe the facial expressions of others and the reflections of their own facial expressions, they are cut off from an important source of feedback, and they acquire only rudimentary ability to control facial expression. They are conspicuously lacking in the ability to produce different facial expressions voluntarily.

Facial expression is employed, by those who can control it, for communicative purposes. A person may smile deliberately because he wants another person to make the inference that he is happy. The poker player wears a poker face because he does not want others to infer from his face the feelings aroused by the hand he draws. Lacking the ability to control facial expression, the blind person cannot engage in this kind of communication with others.

If facial expressions could be made to produce feedback, and if the author of those expressions could learn to differentiate the feedback produced by different facial expressions, it should be possible for a blind person to gain control of facial expression, and to produce different expressions voluntarily. This possibility was explored by Nancy Colleen Webb with an experiment reported in this issue of the Research Bulletin.

For feedback, she used auditory signals controlled by the myoelectric potentials that are generated when muscles are contracted. Myoelectric potentials were sensed by electrodes attached to the facial muscles that are contracted in order to produce facial expressions, so that, for each pattern of muscular contractions, there was a corresponding pattern of auditory signals. Before training, motion pictures were made of the blind subjects who participated in the experiment, as they attempted to obey requests for different facial expressions. The inability of subjects to obey these requests was established by showing the motion pictures to a panel of judges, selected for their skill in judging facial expressions. Judges were largely unable to identify the pictured expressions. Subjects were then trained, under the feedback condition, to produce requested facial expressions voluntarily. After training, subjects were again filmed as they attempted to produce the same facial expressions requested for the earlier film. The post-training film was viewed by the panel of judges, who demonstrated substantial ability to identify the pictures expressions.

A small number of subjects received brief training and were taught only a few of the many facial expressions commonly employed. Nevertheless, the experiment succeeded in demonstrating that blind persons can, with appropriate feedback, learn to produce facial expressions voluntarily.

Computer Services for the Blind

The Audio Response Time Sharing System (ARTS) was conceived by Dr. Kenneth Ingham, and he has directed the project that has brought the system to its present state of development. The ARTS system is a configuration of computing machinery that is programmed to provide a variety of services useful to 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, which is also connected to the user's telephone. Services provided by the system include dictionary consultation, composition of letters and other manuscripts, bookkeeping, filing, the mathematical computations available on a sophisticated electronic calculator, print-to-braille transcription, computer aided instruction, computer programming and so forth.

Last year's report included an account of the events I initiated that led to the establishment, by an action of the Kentucky State Legislature, of Computer Services for the Blind Corporation (CSB), a public corporation charged with the implementation of the ARTS system and the delivery of its services to blind citizens of Kentucky. The state provided $173,000 to meet CSB's costs during the first two years of its operation.

The transactions of CSB are supervised by a board that includes the Director of Division for the Blind, Bureau of Rehabilitation Services; the Superintendent of the Kentucky School for the Blind; the Director of Industries for the Blind; and six members appointed by the Governor of the state, of whom I was one and am currently serving as Chairman of the Board. The board appointed Glenn Smith, a member of the Laboratory's research staff, as the first Director of CSB, and he is currently serving in that capacity. The University of Louisville has made available to CSB, without charge, the space it needs for computing machinery, and for the administration of its business.

Initially, we believed that the development of the ARTS system was substantially complete, and that it could be implemented quickly and with ease. However, as the attempt to implement proceeded, it became apparent that considerable development of both hardware and software was still needed. As a result, we were unable to adhere to the schedule set forth in our agreement with the State of Kentucky. By the time of this writing, the system was supposed to be delivering services and earning income to defray operating expenses. Instead, it is not yet operational. The principal hardware components of the system have been delivered, and will shortly be interconnected. The configuration of devices needed to provide the necessary storage of information has only recently been determined. A final decision regarding the source of user terminals is still to be made. Although some software has been developed, a major developmental effort is still required in order to provide the software needed for implementation of the full spectrum of ARTS services.

It is now clear to us that what we originally regarded as a service project will have to be regarded, for the time being, as a research and development project, and we are currently exploring the possibility of continued support of the project, under these terms, by the State of Kentucky. In spite of the difficulties we have encountered, we remain convinced that the ARTS system can provide the services originally claimed for it, but we now know that a developmental effort of considerable magnitude will be required before full implementation can be achieved. The time required for this developmental effort will depend upon the level of support we receive. With adequate funding, it can be accomplished within three years. We expect to implement some of the services of which the ARTS system is capable within the coming year.

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 include the dissemination of information, the preparation of research materials, the development of equipment and the consultation with educators concerning the exploitation of perceptual alternatives.

The Center for Rate-Controlled Recordings

The Center for Rate-Controlled Recordings is a unit of the Laboratory. It was established to provide a source for time-compressed or expanded recorded speech, of high quality and at a moderate cost, for use in research and education, and to disseminate information concerning rate-controlled recorded speech. During the current year, the Center has continued to meet the demand for time-compressed and expanded recordings, and has continued its monthly publication of the *CRCR Newsletter*. Many requests for information have been met through correspondence, telephone conversations and consulting visits.

The most serious impediment to the useful application of recorded speech that has been compressed or expanded in time, has been the lack of suitable equipment at a moderate price. However, efforts to develop moderately priced equipment of satisfactory quality have been underway at several locations, compressors from five different manufacturers have become available within the last two years, and other compressors, now under development, will be available soon. Because of the prominent role played by the Laboratory in the development of time-compressed and expanded speech, three manufacturers have donated compressors to the Laboratory, and others have indicated an intention to do so shortly. The Laboratory is now able to provide speech that has been compressed or expanded in time by computer, as well. The Center is becoming a museum of contemporary compression technology, and this should result in a further expansion of its role in the dissemination of information.

It was expected that the increasing availability of relatively inexpensive speech compressors would largely eliminate the demand for the compression service provided by the Center. However, this has not been the case. Apparently, the publicity attending the commercial introduction of new compressors has stimulated interest in the possibilities suggested by the ability to control the rate of recorded speech, and many interested persons have wanted to gain some experience before making a decision to invest in equipment. In any case, the current year has seen an increase in the rate of requests for time-compressed and expanded recordings.

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 tape 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 recording is accompanied with a set of written behavioral objectives which specify the student behavior that will constitute 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 instructional materials. Over the past two years, these facilities have been used to prepare the materials required for the audio-tutorial presentation of an Introductory Psychology course 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 more than usual variability in intelligence, prerequisite learning, severity of handicapping condition 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.

Discussions have been held with faculty members at the Kentucky School for the Blind, in order to acquaint them with the possibilities offered by audio-tutorial instruction, and an offer has been made to assist the school in the training of teachers and the preparation of instructional materials. There has so far been no implementation of audio-tutorial instruction at the school. However, several teachers have expressed an intention to explore its possibilities, and if their interest leads to action, the next step may be an application for funding to support a collaborative effort on the part of the Perceptual Alternatives Laboratory and the Kentucky School for the Blind to develop the facilities, materials and training needed to incorporate audio-tutorial instruction as a regular component of the school's program of instruction.

Consultation

The Laboratory continues to provide consultation to such agencies as the American Foundation for the Blind, the American Printing House for the Blind, Recording for the Blind, State Department of Education and so forth. Consultation covers psychology, education and educational technology, as they apply to blindness and other perceptual impairments.

PUBLICITY

The Laboratory, during the current year, received publicity from interviews concerning its activities, summaries of which were published in *Behavior Today* and *Psychology Today*. Descriptions of its activities were also included in programs broadcast on radio stations WHAS and WFPL. Recently, the Director of the Laboratory was interviewed by Grahame James, a doctoral candidate at Warwick University, who visited the Laboratory in order to become more familiar with its program of research. The interview was recorded, and an edited version of this recording is scheduled for broadcast on BBC.

REFERENCES

Foulke, E. A multi-sensory test of conceptual ability. *The New Outlook for the Blind*, 1964, 58(3), 75-7.

Foulke, E. Perceptual basis for mobility. *Research Bulletin No. 23*, American Foundation for the Blind, 1971, 1-8.

Nolan, C. Y., and Kederis, C. J. *Perceptual factors in braille word recognition*. New York: American Foundation for the Blind, Research Series No. 20, 1969.

AN INFRARED SEEING AID: INQUIRY REPLY AND BRIEF DESCRIPTION

January 5, 1973

Dear Sir:

Thank you for your inquiry about the Seeing Aid, a miniature infrared travel aid for the blind. This device is described more fully in the attached information sheet. In the past 60 days several hundred inquiries have been received from more than 20 countries, and the late reply to some inquirers is regretted. The delay was unavoidable as my secretary and I have been occupied full time on a book I have just authored.

Hopefully this letter will answer some of the questions which have been received. The Seeing Aid is not yet commercially available, but two prototypes purchased from me for $225 each are currently undergoing preliminary test and evaluation by the Veterans Administration and I am working with a third. The Southwest Research Institute has agreed to seek funding to permit them to complete development and comprehensive testing of the concept. If test results warrant, the aids will be made commercially available by an as yet unselected manufacturer. Inquirers interested in receiving information about the introduction of commercial Seeing Aids are asked to write a brief note explaining their interest. All such inquiries will be retained and information will be forwarded as developments warrant.

While many inquiries have been received from blind persons, universities, and medical personnel, a substantial number have also been received from organizations with no obvious interest in aids for the blind. The Seeing Aid has secondary applications which may interest some of these inquirers. For example, the existing device has a *communications* range in excess of 100 meters. This range can be significantly increased by reducing transmitter beam divergence or increasing receiver lens area. A pulse rate modulated eyeglass communicator having a range greater than 100 meters and capable of interference-free, covert voice transmissions is now being designed. This device will be mounted completely on eyeglasses. The concept can also be adapted to intrusion detection systems, counting and detection schemes, automobile "radar," and other applications. Inquiries about these secondary applications are welcomed.

Some inquirers have asked about Sensory Aids Research. This company is non-existent, and the name was created to ease the procurement of prototype aids by the Veterans Administration. It should be noted that I am a professional science writer and consultant by occupation, and the Seeing Aid is a part time development for which I have received no financial assistance. Since 1966 I have developed a series of electronic aids for the blind including several light sensitive probes and a urinanalysis machine with audible output for blind diabetics. Specific inquiries are welcomed. I am prepared to consult with inquirers about aids for the blind and the secondary applications which require a comprehensive knowledge of optical radar and communications range equations, near infrared reflectance measurement techniques and data, and the design of detection and communication systems incorporation LEDs, injection lasers, and other infrared sources.

Sincerely,

/s/ Forrest M. Mims

Forrest M. Mims

FMM/mc

PROTOTYPE SPECIFICATIONS

Transmitter:

Peak Optical Power	70 milliwatts
Wavelength of Emission	950 nanometers
Beam Divergence	0.08 radian (4.6°)
Pulse Width	20 microseconds
Pulse Repetition Rate	120 Hertz
Power Supply	6.8 volts (TR175)
Current Drain	5.5 milliamps
Dimensions	0.54" x 3.6" (1.4cm x 9.1cm)

Receiver:

Sensitivity (Optical)	70 nanowatts
Frequency Response	20 kilohertz
Rise Time	10 microseconds
Gain	95 db (voltage)
Field of View	0.08 radian (4.6°)
Power Supply	6.8 volts (TR175)
Current Drain	3.0 milliamps
Dimensions	0.54" x 3.6" (1.4cm x 9.1cm)

REFERENCES

F. Mims, An infrared eyeglass mobility aid for the blind, *Proceedings of the Southwest IEEE Conference*, April 1972.

F. Mims, Eyeglass mobility aid for the blind, *Journal of the American Optometric Association*, June 1972, 673-6.

F. Mims, An infrared mobility aid for the blind, *Proceedings of Electro-Optics '72*, September 1972.

F. Mims, *Light emitting diodes.* Howard W. Sams & Co., Inc. to be published Spring 1973.

The Seeing Aid is an independent development conceived and designed by Forrest M. Mims, a professional science writer and engineering consultant. Inquiries are welcome.

Forrest M. Mims, 6901 Zuni SE A-12, Albuquerque, New Mexico 87108. Phone: (505) 256-9281.

DIRECTIVE INFORMATION IN EDUCATIONAL MEDIA

Mats Myrberg*

Abstract

Directive information in educational media; its effect on the legibility of abstract figures, and the possibilities of conveying visual material to media accessible to the visually handicapped.

The concept *directive information* was borrowed from an analysis of general information systems and applied to educational media in an attempt to determine how textbook illustrations are structured for the reader. An experiment was made to measure the importance of the directive information in abstract figures. The results were related to the difficulties of the visually handicapped to understand verbal descriptions and tactile sketches of figures in textbooks.

The study showed that figures with directive information give about 45 percent more information than figures without directive information. This result had also been predicted from knowledge of the importance of directive information in other contexts. It had also been predicted that the directive information would be more important the more complex a figure was. This was however not confirmed by this study. No difference in efficiency between different kinds of directive information (color vs. black and white for example) could be found.

*Pedogogiska Institutionen, LHU, O. Agatan 9, 75322 Uppsala, Sweden

ELECTROMECHANICAL BRAILLE COPIER*

I. M. Neou**
W. F. Erwin, Jr.

West Virginia University
Morgantown, W. Va. 26506

INTRODUCTION

In typing on conventional typewriters, several "carbon copies" can be produced simultaneously as by-products of the typing operation. In braille embossing on braillewriters no copy other than the original can be obtained. One method of duplicating a limited number of copies from a braille page is by using a vacuum forming process. In the thermoform vacuum forming machine (price $450), made by American Thermoform, Inc., a sheet of plastic paper is placed over the braille master copy dot side up, and locked in the forming machine to be processed in a heated vacuum supplied by a heating oven and a vacuum pump. There are other processes, such as the American Printing House for the Blind's vacuum-formed plate system, the French Aquerin process, the Uformite process, etc., in which a plastic or plaster master plate must first be prepared from the original braille copy.

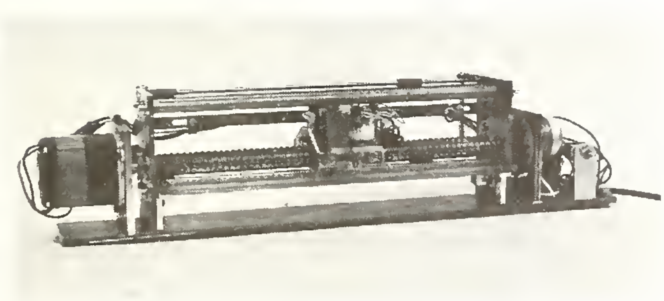


Figure 1. Automatic Braille Copier (Covers Removed)

The Electromechanical Braille Copier, Model BC 10, (Fig. 1) is an automatic dot-to-dot facsimile copying machine which operates without the use of heat, vacuum, special papers, master plates, etc. The machine has in its traveling duplicating carriage or copying head three sensing styli to scan the raised dots on the braille paper, and three embossing pins to make corresponding raised dots on a blank paper. Embossing by the duplicating carriage, in both its backward and forward passes, and simultaneous advancing of the braille and blank papers are electromechanically controlled without human intervention except in the initial stage of inserting and aligning the papers. The machine works with ordinary papers and takes about seven minutes to copy a standard braille page without the *operator*'s attention while the machine is working. The cost of the machine, were it to be produced in large quantities, would be approximately $100.

Beyond making extra copies for record-keeping and classroom uses, the machine may also be modified and used as an automatic composing machine, employing the embossed braille copy as a source of actuation instead of setting the pins manually.

THE TRAVELING DUPLICATING CARRIAGE

The duplicating carriage (2) (Figs. 2 and 3) consists of three separate sensing-embossing units. The three dot-sensing styli (3) underneath the carriage are held in their respective pivoted arms (4) and normally rest on the braille paper (5).

---

*The project was supported by the Office of Education, Department of Health, Education, and Welfare (Grant No. OEG-0-9-58127-3739-032).

**Professor of Mechanical Engineering.

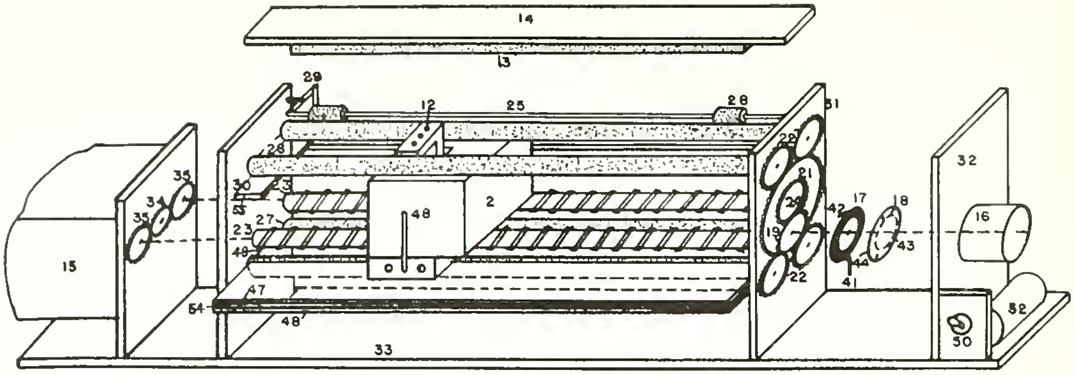


Figure 2. Exploded View of Automatic Braille Copier

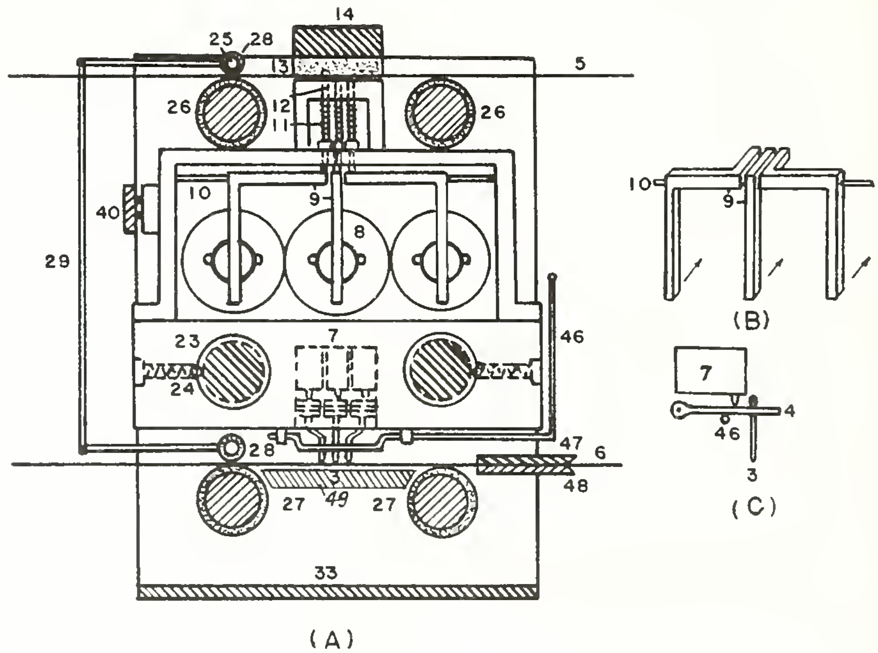


Figure 3. Left Side View of Duplicating Carriage

On going over a raised dot (about 1/16 inch in diameter, and from 1/32 to 1/16 inch high), the stylus is forced to rise, and its pivoted lever swings upward to close a microswitch (7) leading to a solenoid (8), Electro-mechanisms, Inc. Model P.O. 75 110 Vac pull-type. The energized solenoid pulls a bell-crank (9) to raise a spring-returned embossing pin (11) and (12) into the blank paper (5), against a stationary rubber-faced flat platen (13) and (14). Because of the close formation of the braille dots in a braille cell (3/32 inch apart) and the relatively large size of the solenoids (1/2 inch in diameter), the two side bell-cranks have their levers offset on the fulcrum pin (10) (Fig. 3B).

PROGRAMMED ACTUATION AND DRIVE SYSTEMS

Electricity from a 110 Vac household line (Fig. 4) supplies power to the three solenoids (8) for embossing, a reversible motor (15) to move the duplicating carriage (2) back and forth across the copying machine, and a timing motor (16) to drive a timing disc (17) and the gear trains for simultaneously advancing the master and the blank papers.

Solenoid Powered Embossing Pins

The traveling carriage (Fig. 4) has two copper brushes (36) and (37), kept in constant contact with the two printed circuits (38) and (39) on a crossbar (40) in the rear of the left and right supporting brackets (30) and (31). The brushes serve as sliding contacts between a stationary ac source and the three solenoids in the moving carriage.

Bidirectional Movement of the Duplicating Carriage

A reversible Hurst synchronous motor (15), Model GA 300 rpm, 110 Vac, 600 in-oz torque, is used to drive the two leadscrews (23) (3/8 inch in diameter and four threads-per-inch) through gears (34) (PIC 65-32) and (35) (PIC 65-48) (Figs. 2 and 3). Four spring-loaded ball locks (24) in the carriage housing (2) engage the carriage loosely to the twin lead-screws so that the carriage can be shifted manually to any position on the lead-screws and stopped while the embossing pins hit the paper without causing damage to the machine.

The reversible rotations of the motor and the twin lead-screws are controlled by a programming timer (Figs. 2 and 3) which consists of a Haden synchronous motor, Model GA 366 LA5-71, 2 rpm 110 Vac, a rotating timing disc (17) and a stationary annular timing disc (18). The rotating disc is driven by the timing motor (16) and has a full conducting ring to conduct electricity from its brush (42) to a stationary brush (41) leading to the neutral terminal (black wire) of the Hurst motor. The stationary timing disc (18) is mounted on the bracket (32) with a bore for the passage of the timing shaft, and has two circular (142.5° arc) conducting segments (43) and (44) which are connected to the positive (red wire) and negative (white wire) poles of the Hurst motor, respectively. As the disc (17) turns, its brush (42) keeps in sequential contact with the conductors (43) and (44) and thus connects the neutral terminal of the Hurst motor cyclically to its positive and negative poles except when the brush (42) sweeps over the insulated gaps between the two conducting segments. The switching of the polarities of the motor causes cyclic reversals of the directions of rotation of the twin drive leadscrews and hence the movements of the duplicating carriage across the papers.

Automatic and Simultaneous Line Advancing of the Braille Master and the Blank Paper

On the back of the rotating disc (17) is a modified gear (19), PIC G11-48, which has all its teeth removed, except two groups of five teeth in diametrically opposite locations, with one middle tooth positioned opposite the brush (42) on the disc (17). When the carriage reaches the end of its right-ward travel and the brush (42) sweeps across the insulated (bottom) gap between the conductors (43) and (44) to cut off the electric current to

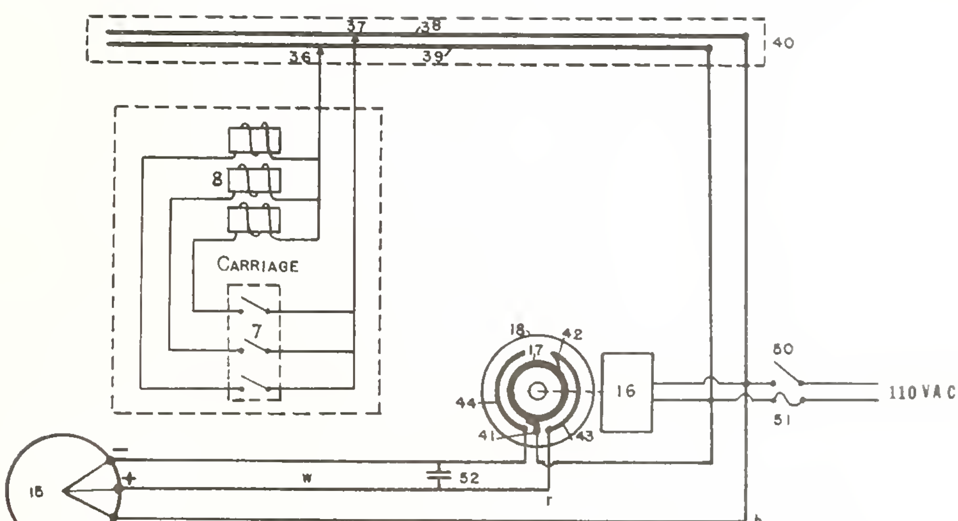


Figure 4. Schematic Wire Diagram of Actuators and Timer

the Hurst motor, the other five teeth on the gear (19) come to mesh with the gear (20), PIC G11-48, and turn the gears (20) and (21), PIC G11-160, through 360 x 5/48 degrees. The gear (21) then turns the four satellite gears (22), PIC G11-64, on the spindles of the four rubber rollers (26) and (27), each having a diameter of 0.4894 inch. The lower and upper pairs of the rubber rollers thus advance the master and the blank paper respectively through $(2\pi \times 5/48)(160/64)(.4894/2) = 0.4$ inch, which is the standard space between braille lines. As soon as the last of the five teeth band on the gear (19) is out of mesh with the gear (20) and the papers stop moving, the brush (42) comes into contact with the conductor (44) and turns the motor on, running in the opposite direction. The carriage is thus compelled to move left-ward until the brush (42) enters the top insulated gap between the conductors (43) and (44) and the second group of teeth turn the gear trains to advance the papers another line.

As the timing motor runs at 2 rpm and copying action takes place in both backward and forward passes (10-inch travel), the machine can copy four lines-per-minute, including the time for line advancements.

FEEDING AND ALIGNMENT OF PAPERS

In preparation for the entrance of the braille copy and the blank paper, one must first lift the three sensing styli off the crossbar (49) by turning a lever (46) in front of the carriage, to make way for the passing of the braille copy between the duplicating carriage and the crossbar. The pressure rollers (28) can be moved away from the rear upper and lower rollers simultaneously by swinging back the top pivoted link of the paper release linkage (29).

The braille copy is first fed into a narrow opening between two transparent guide plates (47) and (48) until its top edge passes the rear lower roller. Now the paper is adjusted so that the three rows of the raised dots in the fifth braille line lie directly below the three white guidelines on the top guide plate (47), and the left edge of the paper is pressed against the edge-line guide (54) between the plates (47) and (48). Since the three guide lines are exactly five line spaces from the three sensing styli (3), we are assured that the braille cells under the duplicating carriage must all lie in the paths of the sensing styli. If the machine is to be operated by a blind person, the three white guidelines could be replaced by three fine wires spanning an opening in the top guide plate (47).

Next, the blank paper is fed through a clearance between the platen and the duplicating carriage and adjusted to have its left and top edges aligned respectively with the right and rear edges of an edge-line guide (55) on the left bracket (30) below the top rollers. Finally, the linkage (29) is released to let the pressure rollers press the braille copy and the blank paper firmly on their respective rollers.

REMARKS AND SUGGESTIONS

The line-at-a-time braille copier takes about seven minutes to complete a 25-line braille page, including the time needed for inserting and adjusting the papers, and is thus good only for making a few duplicates, but it has the advantages of being inexpensive, easy to operate, and taking ordinary papers, in contrast to conventional processes. The copying process can be greatly accelerated by increasing the speed of the drive motor propelling the traveling carriage, and using more powerful solenoids for "impact" embossing. Another way to speed up the duplicating process is by using a traveling carriage having a column of 25 copying heads (each has three sensing-embossing units), so that it covers all the rows of a braille page in a single pass without the need of reciprocating scanning and line advancements of the papers. However, the cost of such a device will be much higher than the single-head duplicator.

The braille copier may also be modified and used as a composing machine for setting up braille galleys. Instead of making raised dots in a blank paper, the three embossing pins of the machine may serve as push-rods for transferring the steel braille pins from the font containing a matrix of braille pins to the chase above the traveling carriage (taking the place formerly occupied by the blank paper and the stationary platen). The transferred pins can be temporarily retained in the holes of the chase by a removable magnetic retaining plate 1/16 inch above the chase. A barrier plate is then inserted between the font and the chase and the magnetic retaining plate removed to allow the transferred pins in the holes of the chase to fall down on the barrier plate. The raised pins, appearing 1/16 inch above the face of the chase, form a braille galley from which an unlimited number of braille copies can be produced. The transferred pins can later be returned to the font after completing the production by removing the barrier plate so that they fall back into home bases in the font.

REFERENCE

Zickel, V. E. Small scale braille production and duplicating systems. In L. L. Clark (Ed.) *Proceedings of the International Congress on Technology and Blindness*. New York: American Foundation for the Blind, 1963, Vol. 3, 121-9.

PROGRESS AFTER VISUAL RESTORATION: TWO PRELIMINARY CASE REPORTS AND A REQUEST FOR COMMUNICATION

Linda J. Anooshian*
David H. Warren*
Pat Apkarian-Stielau**

The past several years have produced significant progress in developing and refining operations designed to restore vision. Sight-restoration operations are not new of course, isolated cases have been reported in the medical literature for centuries. The realization that there may be severe problems of adjustment to the visual world is also not new, although because of the limited number of cases, very little in the way of a typology of problems, let alone tested ways to deal with the problems, has been developed.

Recently Valvo (1971) has provided a detailed review of the progress of several patients whose vision was restored monocularly by means of the osteo-odonto-keratoprosthesis operation developed by Strampelli. Valvo's report provides an important model, since in a single paper, he reviews not only the neurological and perceptual progress of the patients, but also their psychological progress. He notes, for example, various types of depression that have also been reported in previous literature. Some patients become depressed because of the suddenness of the demands on them to operate as sighted people, relative to the slow, arduous process of learning to use vision. Another problem relates to disillusionment with the greater difficulty in making use of visual information, compared to the habitual, well-learned modes of unsighted perception. It is not surprising that in many cases a resistance to the difficult process of visual learning occurs.

*University of California, Riverside.

**Smith-Kettlewell Institute of Visual Sciences.

In view of the increasing number of cases of visual restoration, and of the likelihood that the techniques will continue to be refined so that visual restoration may be attempted with new categories of blindness, it seems important to begin to develop a technology of postoperative perceptual training and psychological treatment. This quest will become especially important as more restoration operations are done with children.

Such a technology depends on adequate answers to at least two general and related questions. First, what types of problems occur? How do the types of problems vary in occurrence and severity with various individual characteristics of patients such as history of preblindness vision, age, mobility, and various personality characteristics? Second, how can the various types of problems be handled successfully? What approaches are most successful with different types of patients?

For such a technology to be developed, communication among many people working with many cases of visual restoration is necessary. Not only would such communication increase the pool of cases whose characteristics are known, but it would also increase the available information about the successes and failures of the various approaches that will surely be represented. Each person involved in visual restoration cases would then not have to work through many mistakes that others have made, but instead could use a pool of common information to develop optimal training procedures.

The intent of this report is twofold. First, we would like to encourage the communication necessary for developing the technology described briefly above. Second, we hope to initiate this communication by presenting preliminary reports on two cases of visual restoration with children. Both cases will be reported more fully in subsequent papers.

CASE 1: SM

Perceptual training and testing sessions were initiated with SM two months after bilateral cataract operations, performed in August, 1972, when SM was 3-1/2 years old. Prior to the operation, SM could differentiate only brightness extremes. Her visual acuity, as measured by optokinetic-mystagmus techniques, has gradually improved from (postoperative) 20/200 to approximately 20/80 (April, 1973), and it is expected to improve eventually to approximately 20/40.

Training sessions have been held twice a week, for 15-30 minutes a session, in the home. However, the schedule has been somewhat variable because of varying attentional and motivational states of SM, her parents' schedules, and some sickness in the home. The number and variety of specific types of tasks has been somewhat limited because of the necessity for extensive familiarization with the materials before adequate assessment of abilities could begin. Observations have been made on form board, shape discrimination, spatial language, auditory localization, and copying task performances. Despite performance variability and the difficulty of assessing the role of attentional involvement in task performance, several tentative conclusions about SM's capabilities seem justified at this time.

SM does not use her visual capabilities to aid performance on form board and copying tasks. She generally does not orient visually to the shapes that she handles or to the paper on which she is copying. In addition, although she can visually identify familiar geometric forms (square, circle, rectangle, oval), she shows no deterioration of form board performance when her sight of these forms is blocked. Our observations, like those of her parents, indicate that SM generally uses vision to guide her locomotion only in unfamiliar environments. However, she always efficiently orients her eyes to, and tracks auditory stimuli, before reaching for the sound producers.

There appear to be specific spatial deficits which cannot be attributed to poor visual acuity. Although SM can correctly follow instructions that make reference to the labels for specific geometric forms, this ability does not transfer to other forms with the same shapes. Training efforts have revealed that SM has great difficulty acquiring generalized concepts of the dimensions of shape. Related to this is a deficit in understanding simple spatial terms such as on, in, top, etc.

Capabilities within different modalities vary considerably. Form board and tactual identification task performances are characterized by an absence of coordinated tactual exploration. SM also shows poor motor control in copying tasks. Yet, locomotion is efficient and is not typically characterized by slow or cautious movement. Auditory localization is fairly good.

Although these conclusions must remain tentative because of attentional and motivational variables, and because of lack of performance measures before the cataract removal, our observations definitely indicate that SM shows specific types of deficits which cannot be attributed solely to poor visual acuity. Perhaps not surprisingly, she tends to persist in habits acquired during her blindness, and she has not made good progress toward integrating vision into modes of performance that were already successful during blindness. Although overtly this may be interpreted as "resistance" to visual learning, we are optimistic about her future progress, partly because she was well-adjusted and mobile before the operation, and partly because she does not show overt signs of the depression typically reported in case studies of older patients.

CASE 2: CM

CM is a 12 year old girl who was brought to the Pacific Medical Center, San Francisco, from the Azore Islands in October, 1971. She was known to not have functional vision since the age of 3 months. On April 14, 1972, she was operated on her left eye. The operation was successful, but no spontaneous utilization of the new visual abilities developed. CM was referred to the Smith-Kettlewell Institute of Visual Sciences, San Francisco, for visual training which began on June 15.

Visual training, as well as training for perceptual limitations of other modalities, consisted of shape perception, object recognition, size discrimination, eye-hand co-ordination, etc. Practical tasks such as picking flowers and baking were also incorporated into testing and training procedures. Though CM performed well in laboratory tasks, it was soon apparent that in conjunction with visual training, CM was sorely in need of occupational and physical therapy, as well as psychotherapy.

To date (April, 1973), CM has been visually trained for approximately 10 months. Training sessions have been limited to 2-4 per month because of her family's inability to come to San Francisco more often. Her progress is painfully slow, though her entire world has been expanded visually as well as via other modalities. It appears that the paramount problems with CM are her lack of motivation and the lack of reinforcement in her home environment. She does not use her newly acquired visual abilities. Objective examination (VER) with pattern stimuli has provided suggestive evidence of central nervous system visual pattern processing; however, CM reported no subjective visual response.

An extended report of this case is being prepared by the staff of the Pacific Medical Center and the Smith-Kettlewell Institute of Visual Sciences.

We invite comments and discussion on these cases, and we request communication about other cases, especially cases of children, who have been or are currently being studied. Such communication should be directed to David H. Warren, Department of Psychology, University of California, Riverside, California 92502.

REFERENCE

Valvo, A. *Sight restoration after long-term blindness: the problems and behavior patterns of visual rehabilitation.* New York: American Foundation for the Blind, 1971.

Name: Acoustic Beacon

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: In production

Price: $38.00

The Acoustic Beacon is a small, self-contained unit operated on a single 9-volt battery. The circuit is designed to have a very low current drain, giving the battery an exceptionally long life. It has been evaluated by mobility instructors for the blind as a training aid in direction orientation, as a homing beacon, and as a tracking trainer. The Beacon can be heard easily at distances up to three hundred feet, even with a fair amount of background noise.

Name: Audio Ball

Source: Columbine Council of the Telephone Pioneers of America
Colorado Springs
Colorado

Availability: From Telephone Pioneers of America

A therapy recreational device for the blind. The ball emits a constant beeping sound from a battery-operated sound chamber in the center of its protective stuffing.

Name: Audiographic Learning Facility

Source: Vladimir Slamecka
School of Information and Computer Science
Georgia Institute of Technology
Atlanta, Georgia 30332

Availability: Experimental prototype

A computer-based system storing the voiced and kinetic-graphic contents of live blackboard lectures in the form of homogeneous, randomly addressable learning units (lessons). The audio and graphic signals are recorded on the right and left tracks of standard audio tape, respectively. The graphic component of the lesson is recorded from a standard telewriter. The remote terminals, which can serve optionally a single learner or a classroom, consist principally of telewriter receivers. These units receive the line graphics signal over a standard business telephone line. A second standard telephone line terminated with a touchtone dialing unit is equipped with a speaker output. The video-graphic terminal used in the system can be replaced by a tactual/kinesthetic device when the learner is visually impaired.

Name: Auditory Braille

Source: Worcester Polytechnic Institute
Worcester
Massachusetts

Availability: Experimental system

Coding system consists of indicating dot positions in each braille cell by means of tones to the user's ears. Tone frequency indicates position of dot in the vertical plane. Tones corresponding to dots in the left column of the braille cell are presented to the left ear, those representing dots in the right column to the right ear.

Name: Braille Display System

Source: Clarke & Smith Manufacturing Co., Ltd.
Melbourne Works
Wallington, Surrey, England

Availability: Laboratory prototype

The device displays material encoded on magnetic tape as Grade 1 braille, one line at a time. It consists of three sections: the playback deck for the magnetic tape, the control electronics and the braille display unit. Originally developed as a personal reading machine it could also function as a computer terminal.

Name: Braille Strip Printer

Source: Peter Grisafi
Multiplex Communications, Inc.
Hauppaug, Long Island, New York

Availability: From Multiplex Communications, Inc.

The braille strip printer translates communication data into braille-on-line to teletype equipment, time sharing systems or the off-line units. Produces 60 to 100 words-per-minute output on paper tape in Grade II braille.

Name: Braille Teaching Aid

Source: Donald F. DeKold
Santa Fe Junior College
723 West University Avenue
Gainesville, Florida 32601

Availability: Feasibility model

A hardware system comprising a conventional stereo tape recorder and auxiliary electromechanical apparatus intended to present simultaneously a tactual stimulus to the fingertips and audible naming of the braille character presented.

Name: Braillomat-Series

Source: Thiel.
6104 Jugenheim a.d.B.
Postfach 88, West Germany

Availability: From Thiel

The original Thiel Teleprinter Unit for the Blind (listed in the AFB International Catalog of Aids and Appliances for the Blind) has been augmented by a series of variations on the Braillomat theme. In addition to the Standard device, allowing fast braille printing, and the Telex variation, permitting teletransmission of braille characters, there are now: the Braillomat TBK, meant especially for the deaf-blind as a telephone aid; the Braillomat Korrespondenz, using an IBM Model 73 machine for inkprint typewriting, along with a Braillomat device for simultaneous braille embossing of the same text for office work; and the Braillomat EDV, used in conjunction with an IBM Model 735, producing number characters for those working in electronic data processing. Specially produced furniture suitable for office and data processing center installation is provided by the firm for use with these several systems, through the cooperation of C. u H. Leuthaüsser, 8631 Wisenfeld-Coburg. Further details and prices will be provided upon request by the Ingenieur-Buro, Thiel.

Name: Braillophon

Source: Werner Boldt
Padagogische Hochschule Ruhr, Abt. f. Heilpadagogik,
46 Dortmund-Eichlinghofen
Baroper Str. -AVZ Geschossbau 4
West Germany

Availability: Experimental prototype

A device for programmed learning. The blind student and the Braillophon system are linked communicatively through two input and two output channels (presentation--response). The output of the teaching machine is acoustic, through headset or loudspeaker and/or in braille. The student's response (input) can be in the form of braille, by means of a keyboard, or of answers to multiple-choice questions.

Name: Briall (Braille-All-Output)

Source: Electronic Processing Center, Inc.
Philadelphia, Pennsylvania

Availability: Through Honeywell's application sharing system

A software package which allows blind programmers to verify their own programs. It is used with a plastic strip fitted over printer hammers.

Name: Communication System for the Deaf-Blind

Source: Prof. Dr. W. L. van der Poel
Technische Hogeschool Delft
Julianalaan 132, Delft-8
The Netherlands

Availability One-off working model

A system of communication devices including a telephone connection.

Name: Compressed Speech Cassette Recorder

Source: Magnetic Video Corporation
23434 Industrial Park Court
Farmington, Michigan 48024

Availability: Magnetic Video Corporation

Using a tiny solid-state module called Variable Speech Control (VSC) smaller than a sugar cube, C-103, a new tape-playback system compresses speech up to two-and-a-half times normal speed with no change in pitch or tone. The speed at which the listener receives information is comparable to visual reading rates; with training, the listener may learn to "speed listen" just as he learns "speed reading." In addition to "VSC" this recorder makes duplicates of other cassettes, edits, can make two recordings at once, and serves as a standard recorder-player.

Name: Deaf Alert System

Source: Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

Availability: Experimental prototype

The system is based on a NASA-developed accelerometer. The sensor can be attached to a doorway, doorbell or telephone. Attention is called to a signal from any of these by means of vibration or a flashing light.

Name: Digital Position Readout System for the Blind

Source: Elm Systems, Inc.
Arlington Heights, Illinois

Availability: One-off working model

The device could be hooked up to any binary-coded digital output. The tactile readout unit provides BCD information for each of seven digits and indicates polarity. Each digit is represented by a line of four holes containing a solenoid-operated pin. The pin positions are BCD-weighted as 1, 2, 4, and 8. The actual number is the sum of the weighting of raised pins.

Name: Digital Voltmeter

Source: American Foundation for the Blind
15 West 16th Street
New York, New York 10011

Availability: Pre-production prototype

The device is a digital voltmeter with tactile readout.

Name: Double-Electrode Wet Sensor

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: In production

Price: $60.00

The Double-Electrode Wet Sensor performs a dual activity in the toilet training process. First, it informs the patient and therapist of the release of the first drops of urine. Second, it provides the therapist with a powerful two-level logic system which can be a useful tool in altering wetting behavior. The unit consists of a small box containing electronics, battery, speaker, and switch, and a long cable terminating in specially designed electrodes. The electrodes are taped to the outside of the diaper near the source of urine flow. When the primary electrode is moistened by the first drops of urine released, a steady, high-frequency tone is emitted, warning the child and the therapist. If the child ignores the warning and saturates the diaper, the secondary electrode is activated causing the speaker to emit a high-pitched warbling sound. With proper training, this double sound capability can be made an effective stimulus for the child.

Name: Electromechanical Perforated Tape Reader

Source: J. Reszel & R. Sawa
Computing Center of the Polish Academy of Sciences
PAN, 10th Floor
Palac Kultury i Nauki, Warsaw

Availability: Pre-production prototype

The device consists of a standard, adapted, reader of eight-track perforated tape and a braille countershaft. The countershaft is a miniature console with two reader windows in which eight moving pins reproduce the characters on the perforated tape. (See Current Research Note in this issue for further details.)

Name: Heel Contact Sensor

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: In production

Price: $64.00

This instrument is designed to help children with neurological impairments, such as cerebral palsy, who toe-walk. It consists of a small box containing electronics, battery, speaker, and switch. A pair of pressure sensitive pads, which are plugged into the jacks at the bottom of the box, are taped to the child's heels in such a way that when the child steps on his left heel, a tone is heard. The right heel produces a higher tone, and both heels simultaneously sound a third tone, still higher.

Name: Intra-Ocular Projector

Source: National Institute for Rehabilitation Engineering
59 Hamburg Turnpike
Pompton Lakes, New Jersey 07442

Availability: Experimental prototype

A microminiaturized battery-operated low-vision aid. It is worn on the chest, suspended by a neck strap, and the user looks down into the device. It is driven by TV camera output and can show indoor scenes, distant outdoor scenes or, with close-up lens, written material. The device can also be used for viewing regular TV programs.

Name: Kinesthetic Terminal for Motion Graphics

Source: Vladimir Slamecka
School of Information and Computer Science
Georgia Institute of Technology
Atlanta, Georgia 30332

Availability: Experimental prototype

The terminal, designed for blind persons using the Audiographic Learning Facility, is an electromechanical pantograph which performs its function by automatically guiding the user's hand. Its main components are a linkage mechanism with a hand-held "pen," two servomechanisms, and associated electronics. The input consists of two signals (x,y,) stored on an audio tape or generated live from a telewriter. The signals, transformed in the terminal's electronic circuits, control the servomechanisms. The reaction time of the latter is sufficiently fast to allow on-line reproduction of handwriting generated by a sighted operator.

Name: Laser Cane for the Blind

Source: The Research Institute of the
Swedish National Defence Ministry

Availability: Experimental prototype (possible future distribution through
De Blindas Forening,
Sandsborgswagen 50,
S-122 33 Enskede, Sweden)

Long cane designed to give head and chest level protection in addition to its conventional function. The optronic device is located in the upper part of the cane and consists of an optical system including a pulsed GaAs-transmitter with a peak power of about 10 W and an optical wavelength of 900 nm. The receiver, which picks up the optical laser signals when reflected from an obstacle and transforms them to an electrical current, consists of an analogous optical system and a Si-detector. When the current produced exceeds a certain value an audible warning signal is generated. The system includes a nickel-cadmium accumulator of 6 V, 100 mA as power supply and a dc voltage transformer for the transmitter.

Name: Minitimer

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: In production

Price: $17.50

The Minitimer is an easy-to-operate timer. It can be used by teachers to start and stop entire classes, or several of the instruments can be distributed to self-starting students to allow them to do their own timing in counting of specific actions over precisely timed intervals. After the instrument is turned on, the timing interval is initiated by pressing a button. A random time passes after depressing the button, depending on how long the button is held down, before the first beep is heard as a starting signal. Following this initial tone, subsequent beeps occur at 60-second intervals (±2%). This acoustic method provides an accurate audible means of starting and stopping events without involving the child's or the teacher's visual channel in the timing process. It is powered by a 9-volt battery which is easily replaceable.

Name: Mowat Sonar Sensor (revised listing)

Source: Mowat Developments, Ltd.
37 Cliff Road
St. Heliers, Auckland S.
New Zealand

Availability: Mowat Developments, Ltd.

Price: C. I. F. $N.Z. 87-50; $U.S. 105-78

A small, self-contained device which indicates objects within its range by means of vibrations.

Name: Night Viewing Goggles

Source: Electron Tube Division of
International Telephone & Telegraph Corp.
7635 Plantation Road
Roanoke, Virginia 24019

Availability: Experimental prototype

Originally developed for military use, the device is being tested and adapted as an aid to low-vision night travelers whose rod vision has deteriorated. The Goggles consist of electronic wafers in combination with highly specialized optics mounted in a plastic headset. The wafers include a photocathode deposited on a fiberoptic input window, a microchannel-plate current amplifier, and a green phosphor screen fabricated on an output window of twisted fiberoptics. Images focused on the input window are converted, by means of the photocathode, to electron images. These are amplified by the microchannel plate. The image is rendered visible by the phosphor and inverted for viewing by means of a fiberoptic twist in front of the output window.

Name: Paper Currency Identification Device

Source: Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

Availability: Laboratory prototype

Bill is scanned by means of a light wand and phototransistor. Light and dark patterns from designs on different denominations are translated into tone differences.

Name: Patient Assist Device

Source: Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284

Availability: Experimental prototype

The device enables the severely paralyzed patient to control conveniences such as motor lowering or raising bed, telephone, radio, etc. The apparatus utilizes solid state logic circuitry and solid state relays. It is controlled by the patient by means of a switch which responds to minimal voluntary movements, such as residual muscle function or eye movements.

Name: Philips TV Magnifier

Source: Instituut voor Perceptie
Eindhoven
Holland

Availability: Philips Nederland B.V.
Groep Ziekenhuizen
Eindhoven, Holland

The magnifier consists of a TV camera, a TV receiver and a two-level table. The lower table top has a sliding panel for the material to be viewed. The upper tabletop bears the TV set with the camera fitted underneath. Magnification is continuously adjustable between five and twenty-five. Contrast reversal is provided. (See Current Research Notes in this issue for additional details.)

Name: Pool Cue Aiming Aid

Source: Charles E. Leonard
Electrical Equipment Engineering
General Electric Co.
Lakeside Avenue
Burlington, Vermont 05401

Availability: Construction information from C. E. Leonard

The battery operated device locates the target by means of a photocell, and produces an audible signal. It requires the cooperation of the blind player's partner who must indicate the position of the ball by means of a penlight.

Name: Record Reader

Source: William R. Behn
Educational Testing Service
Princeton, New Jersey 08540

Availability: Production prototype

The device is designed to permit reading of Hollerith-coded cards by blind persons. A photoelectric sensor scans a selected column to detect punches and transmits this information to a tactile indicator. Optional audio hook-up could allow teaching of braille.

Name: Remote Acoustic Beacon

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: Pre-production prototype

The Remote Acoustic Beacon (RAB) is designed to provide a source of sound which can be activated with a dog whistle or some other ultrasonic device. The unit, when activated, produces a warbling sound, thereby providing a point of reference for the blind traveler. An automatic timing circuit returns the beacon to the "off-listening" status after about 15 seconds. The RAB is quite small and, therefore, can be carried in a pocket or purse. If location needs arise while the traveler is away from his home, the RAB may be used to provide a location reference as, for example, during an outing to the seashore.

Name: Single-Electrode Wet Sensor

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: In production

Price: $48.00

This instrument is designed to detect small amounts of urine. While the Double-Electrode model is probably more effective in difficult cases of modifiable incontinence, this version has also been used by skilled personnel to extinguish wetting behavior. The Single-Electrode type is used most frequently, however, in nontrainable cases where it is necessary to notify an attendant that wetting has taken place. The unit is equipped with a single small electrode which is taped to the diaper near the source. When contact with the electrode is made by the first few drops of urine, the speaker emits a high-pitched warbling tone. This acoustic signal can be heard from over a hundred feet away.

Name: Stereotoner (revised listing)

Source: Mauch Laboratories, Inc.
3035 Dryden Road
Dayton, Ohio 45439

Availability: Mauch Laboratories, Inc.

Price: $1,020 f.o.b. Dayton

Reading machine which translates letter shapes into stereophonic sound patterns. Training in the use of the device is provided for veterans at the V.A. hospitals at Hines, Illinois and Palo Alto, California. A course is also available from the Hadley School for the Blind, Winetka, Illinois.

Name: Swallow Reminder

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: In production

Price: $45.00

The Swallow Reminder is a precision electronic instrument designed to provide a gentle, persuasive reminder to children who tend to drool due to failure to swallow at regular intervals. The reminder is in the form of a quiet beep in the ear of the wearer at thirty-second intervals. With proper training, a non-swallowing child should learn very quickly to respond to this sound with a swallow. Subsequent training can then eliminate the use of the Swallow Reminder.

Name: Syringe for Blind Diabetic

Source: Boers & Co. B. V.,
Schiedamse vest 148
Rotterdam, Holland

Availability From Boers & Co.

The glass cylinder of a regular 2cc syringe is encased in a metal cover which has a screw-thread on its exterior. Dosage is controlled by means of a nut moving along this thread and producing audible clicks at each 0.05cc increment. A brace attached to the nut in turn controls the movement of the piston and thereby the amount of liquid in the syringe.

Name: Tactile Speech Indicator

Source: Hugh L. Moore
Assistant Dean
Los Angeles Valley College
Van Nuys, California

Availability: Direct inquiries to:
Dr. Ray L. Jones,
Center for Deafness,
California State University, Northridge
1811 Nordhoff Street
Northridge, California 91324

A communication device for the deaf-blind, enables the user to communicate by telephone.

Name: Talking Chess

Source: Arsen Surlan
Dipl. Electro. Ing.
Faculty of Electrotechnics
University of Ljubljana
Yugoslavia

Availability: Demonstration prototype

Chessboard and chessmen electronically equipped to speak out position when a chessman is lifted off a square or put down on one. All moves thus become both audible and verifiable.

Name: TEDI Bear

Source: Sam L. Sparks, Ph.D.
Sensory Engineering Laboratory
17505 - 68th N. E.
Bothell, Washington 98011

Availability: In production

Price: $162.00

The TEDI (Twinkling Eye Dialog Inducer) Bear consists of a stuffed toy bear with bright lights for eyes. The stuffed animal responds to sound by flashing its eyes. The appearance of the toy appeals to children of many ages who are readily captivated by the lights. Once the child sees the correlation between his own voice and Bear's flashing eyes, a highly motivating reinforcement stimulus is established. The control box features a gain control which allows the teacher or therapist to adjust the sensitivity of the system, thus determining the intensity of the input stimulus required to produce a response. It also has a REJECT button which permits the therapist to select those utterances by the child to which the system will respond.

Name: Transicon

Source: The Scientific Research Foundation
P.O. Box 3745
Jerusalem
Israel

Availability: Pre-production prototype

An automatic braille transcriber which can be operated by a blind individual without external help. The device is an electro-optical character recognition machine which can handle input in the form of books or single pages, in the six major Latin fonts used in English language publications. The tracking system is automatic and self-focusing. Output in the present model is in Grade 1 braille embossed on paper tape at an average speed of 15 characters-per-second. The machine pauses between one inkprint line and the next, and the reader can vary line to line time from 4 to 8 seconds. The design has been kept compatible with future development to include coupling with a computer for the production of Grade 2 braille and/or with a page brailler, and the production of an output in the form of magnetic tape for subsequent use with other devices.

REVISED LISTING

Name: Sonar Sensor Cane

Source: Adams Enterprises, Inc.
6800 Southeast Boulevard
Derby, Kansas 67037

Availability: The cane is no longer available as the manufacturer has gone out of business.

PUBLICATIONS OF NOTE

Allen, R. G., & Antonacci, R. A. A VU meter for the blind operator. *Journal of the Audio Engineering Society*, December 1972, 20(10), 845-7.

Berlá, E. P. Strategies in scanning a tactual pseudomap. *Education of the Visually Handicapped*, March 1973, 5(1), 8-19.

Berlin, C. I., Lowe-Bell, S. S., Cullen, J. K., Thompson, C. L., & Loovis, C. F. Dichotic speech perception: An interpretation of right-ear advantage and temporal offset effects. *Journal of the Acoustical Society of America*, March 1973, 53(3), 699-709.

L. L. Clark (Ed.). *International Catalog: Aids and appliances for blind and visually impaired persons*. New York: American Foundation for the Blind, 1973.

Cromwell, L., Weibell, F., Pfeiffer, E., & Usselman, L. *Biomedical instrumentation and measurements*. Englewood Cliffs, N.J.: Prentice-Hall, April 1973.

Dalrymple, George F. *Development and demonstration of communication system for the blind and deaf/blind.* (Project No. 14-P-55016/1-03, Final Report) Cambridge, Mass.: Sensory Aids Evaluation and Development Center, MIT, February 26, 1973.

El-Afandi, M. H. *Educating blind children: The adaptation of curriculum at the primary level in the U.S.A. to meet the need of a child who is blind.* Cairo: The Anglo-Egyptian Bookshop, May, 1971. Price $3.95.

Fish, R. M. A method of coding complex shapes for the blind by auditory display. *Journal of the Audio Engineering Society* (Project Notes/Engineering Briefs), June 1973, 21(5), 378-81.

Geldard, F. A., & Sherrick, C. E. The cutaneous "rabbit": A perceptual illusion. *Science*, 13 October 1972, 178, 178-9.

Hermelin, B., & O'Connor, N. Functional asymmetry in the reading of braille. *Neuropsychologia*, 1971, 9, 431-5.

Kahn, H. A., & Moorhead, H. B. *Statistics on blindness in the model reporting area 1969-1970.* DHEW Publication No. (NIH) 73-427. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402. Price: $2.10 domestic postpaid, or $1.75 GPO Bookstore Stock Number 1740-00356.

Kuck, J. H. *A TV reader with some novel design features.** Silver Spring, Maryland: The Johns Hopkins University, Applied Physics Laboratory, December 1972.

Lee, F. F. Time compression and expansion of speech by the sampling method. *Journal of the Audio Engineering Society*, November 1972, 20, 738-42.

Linvill, John G. *Research and development of tactile facsimile reading aid for the blind.* Stanford Electronics Laboratories, Stanford University, Stanford, California, March 1973. (Final report, Project No. 142112, Grant No. OEG-0-8-071112-2995, U.S. Department of Health, Education, and Welfare, Office of Education, Bureau of Education for the Handicapped.)

Lorimer, J. A summary of research in braille reading. *The Teacher of the Blind*, October 1972, 61(1), 15-24.

Mims, F. Build a light probe: Electronic help for the blind. *Popular Electronics*, March 1973, 42-3.

---
*Editor's Note: This report has been published, and copies may be obtained upon request from IRIS.

Myrberg, M. *Direktiv information i laromedel* (Directive information in educational media). O. Agatan 9, 75322 Uppsala, Sweden: Pedogogiska Institutionen, LHU, 1972 (Report No. 33).

Nolan, C. Y. (coordinator). *Educational Research, Development, and Reference Group report on research and development activities--fiscal 1972.* Louisville, Kentucky: American Printing House for the Blind. (Copies available upon request to Mr. Carson Y. Nolan, American Printing House for the Blind, P.O. Box 6085, Louisville, Kentucky 40206.)

Perrott, D. R., & Higgins, P. Notes on the electrophonic hearing effect. *The Journal of the Acoustical Society of America*, May 1973, 53(5), (Letters to the Editor), 1437-8.

Robinson, Robert L. (Ed.). *Blinded veterans of the Vietnam era.* American Foundation for the Blind, 1973. (Report of a conference held in Washington, D.C. on April 6 and 7, 1972.)

Safir, A., Julikowski, C., Crocetti, A. F., Kuo, M. I., & Deuschle, K. A new method of vision care delivery. *Health Services Reports*, May 1973, 88(5), 405-15.

Slamecka, V., Jensen, A. P., Valach, M., & Zunde, P. A computer-aided multisensory instruction system for the blind. *IEEE Transactions on Bio-Medical Engineering*, March 1972, 19(2), 157-60.

Yarbus, A. L. *Eye movements and vision.* (Translated from Russian by Basil Haigh; Translation Editor Lorrin A. Riggs.) New York, London: Plenum Publishing Corporation, 1973, 222 pages, Price $19.50.

Based on the experimental results obtained by the author, this book examines the perception of pictures which are motionless relative to the retina, analyzes the principles governing the movements of the human eye, and discusses their role in the visual process.

Zachrisson, B., & Smedshammar, H. *Typografi för Synsvaga.* (Report No. 39, Project: PUSS XII.) Uppsala, Sweden: Grafiska Institutet, Pedagogiska Institutionen, Lärarhogskolan, 1973. Text in Swedish, 26 pages.

This report is intended to give a survey of early research in legibility for persons with normal and partial sight; from its development in the 1870s, when systematic research in the field was started, to the present time. Methods used to measure legibility for different texts are described, and results obtained, which are now considered reliable. Earlier research in typography for the partially sighted is reviewed; and the need of careful categorization of the partially sighted is stressed. The PUSS research projects are listed.

Zinchenko, V. P., & Vergiles, N. Yu. *Formation of visual images.* (Translated from Russian by Basil Haigh.) New York, London: Plenum Publishing Corporation, 1973. 58 pages. Price $15.00.

Investigating the intricate components of behavior, this important work concentrates on the interactions between eye movements and higher mental processes. The relationship between this external activity of the eye and the internal intellectual activity is thoroughly examined.

From their experimental data, Zinchenko and Vergiles formulate a new hypothesis of how the mind and the eye, by a continuing feedback loop system, translate visual images into motor responses. Some experimental methods used are recording eye movements by means of an electromagnetic detector and using electroluminescent sources in investigating visual perception.