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ABSTRACT

Seven studies of the ability of blind students (grades 4-12) to use tactile maps are reported in the last volume of a three-volume final report. The first study involving 36 blind students is explained to have suggested that line tracing and shape recognition skills differentiated good map readers from poor ones. The second study is reported to show that a frame of reference with specific instructions on how to search the display facilitated the performance of Ss in the lower grades, but interfered with or had no effect on Ss in the upper grades (total N=72). Described in the third study is the lack of effect of a frame of reference on the performance of 79 Ss who were asked to locate shapes on a tactile political pseudomap. Students in lower grades are reported in the fourth study to have benefited most from training in scanning a tactile display. The effects on map reading of training 92 blind students to use a distinctive features analysis strategy and line tracing are cited in the fifth study, while the sixth deals with the effects of noise on the location by 72 Ss of point symbols on a tactile pseudomap. The final study describes 72 braille readers' superior performance on a broad raised line map (shapes recessed) rather than a broad incised line map (shapes raised). (CL)

Final Report

Grant No. OEG-0-73-0642

# Facilitating the Education of the Visually Handicapped through Research in Communications

15 November 1972-30 April 1976

## Part Three

## Facilitating Tactile Map Reading

Carson Y. Nolan, Editor

The research reported herein was performed pursuant to a grant with the Bureau of Education for the Handicapped, U.S. Office of Education, Department of Health, Education, and Welfare. Contractors undertaking such projects under government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official position of the Bureau of Education for the Handicapped.

Department of Health, Education, and Welfare

U.S. Office of Education
Bureau of Education for the Handicapped

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## FOREWORD

The seven studies described in this report are part of a broad and longitudinal research effort on the design and use of tactile graphics conducted over the last 15 years at the American Printing House for the Blind (APH). The program was initiated through a series of studies on legibility of tactile symbology which were supported by grants obtained from the then Office of Vocational Rehabilitation (OVR-RD-587) and from the Bureau for Education for the Handicapped, U.S. Office of Education (OEG-32-27-0000-1012). The results of these studies have been widely applied in the design of maps, diagrams, educational aids, and toys produced by APH. In addition, they have been applied in Sweden and Great Britain in the production of various tactile graphics.

This research led to a series of studies of behavioral strategies and techniques for searching tactile displays which are essentially two dimensional. This series of studies was supported by APH. Both of these research programs stimulated the research reported here. Results of this research as well as much of the earlier research will be used in writing a manual for teachers to show them how to apply the results to train students to read tactile maps and diagrams more efficiently, to provide guidelines to teachers for design of their own tactile graphics, and to provide kits of symbolic material for this purpose.

Carson Y. Nolan
Project Director

## ACKNOWLEDGEMENTS

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The authors wish to express their indebtedness to their colleagues at the American Printing House who contributed to the studies through constructive criticism. Special thanks are due Mr. John Siems for his aid in processing the data for these studies.

## DESCRIPTION OF THE PROBLEM

In the education of blind children and youth there has long been a need for research on techniques for reading tactile displays and on designing tactile displays. Tactile maps represent the largest category of embossed graphic displays in braille textbooks. For example, Arampatta (1970) found that of the embossed graphic displays found in one series of braille textbooks 89.7% (937) were maps. Despite the frequency of occurrence of embossed maps, Wiedel and Groves (1969) reported that in a sample of 367 visually impaired students (ages 10-21 years), 72% reported receiving little or no training in map reading. Consistent with this interview data was a map reading study by Nolan and Morris (1971) who showed that students lacked basic map reading skills such as line tracking, systematic search patterns, and determining the extent of the field to be searched. Subsequent research (Berla', 1973; Berla' & Murr, 1974) showed that there can be significant improvement in some of these skills with short periods of training.

Research on map design has mainly focused on the much needed creation of a legible symbology to be used in designing maps (Nolan & Morris, 1971; Schiff, Kaufer, and Mosak, 1966). However, a search of the literature revealed no attempt to investigate empirically any other aspect of map design other than symbol legibility.

The objectives of this project were fourfold:

1. To identify map reading skills used by good map readers.

2. To determine if brief periods of training are effective in increasing the tactile map reading skills of visually handicapped students as suggested by Nolan and Morris (1971).

3. To determine whether the skills identified under objective 1 can be trained in poor map readers.

4. To explore the efficacy of different map designs to determine if map reading accuracy and speed of reading can be improved.

The reports that follow are the results of several experiments conducted to meet these objectives.

STUDY I

# TACTILE READING OF POLITICAL MAPS BY BLIND STUDENTS: A VIDEOMATIC BEHAVIORAL ANALYSIS

Edward P. Berla', Lawrence H. Butterfield, Jr.,

and Marvin J. Murr

## Abstract

The problems in map reading by blind students were investigated with 36 blind students in grades 4-12 who were given the task of locating each of six shapes (U.S. states) on a tactile pseudo-political map. Maps of two levels of complexity were used and each subject's performance was videotaped. Accuracy (number of shapes located) and latency in locating the shapes showed no significant differences between map complexity or grade groupings. The videoanalysis indicated a number of map reading behaviors, primarily line tracing and shape recognition skills, that differentiated good readers from poor readers. Specific skills and concepts are suggested for remediation.

## STUDY I

## TACTILE READING OF POLITICAL MAPS BY BLIND STUDENTS:

## A VIDEOMATIC BEHAVIORAL ANALYSIS

Reading tactile maps is an enormously difficult task for blind students. To a large extent, teachers have considered tactile maps to be of poor quality and difficult to read; therefore, have used them infrequently. The avoidance of maps by both teachers and students has resulted in a situation where blind students are severely deficient in geographical concepts (Franks & Nolan, 1970, 1971) and map reading skills (Berla', 1973 & Murr, 1974; Nolan & Morris, 1971; Wiedel & Groves, 1969). For example, Wiedel and Groves (1969) have reported that in a sample of 367 visually impaired students (ages 10-21 years), 72% reported receiving little or no training in map reading. These deficiencies exist in spite of the fact that of the embossed graphic displays included in one series of braille textbooks, maps represented the largest category (937 maps or 89.9% of the embossed displays) and of the 937 maps, 837 were raised line representations (Arampatta, 1970).

In order to acquire information from a raised line map, such as a political map, the fundamental task for the student is to differentiate a specified shape from among a mass of intersecting lines. The blind student is required to do this by exploring the tactile display with his fingertips in a serial piecemeal inspection. This task is analagous to a difficult embedded figures test. Locating and differentiating a shape (county, state, country, etc.) from other shapes is a fundamental and necessary perceptual skill that needs to be developed before political maps can be used in the classroom.

The research questions asked were: Given a raised line map format, can blind students at their current level of skills locate and trace a shape (state) on a map? What behaviors differentiate those who can (good readers) read a map from those who can't (poor readers)? It was felt that a study of this nature would serve as a heuristic device both for further research and to call attention to those skills and/or concepts in which poor map readers are deficient.

In the present study braille students were presented with a raised line map, given a series of cue cards (one at a time) that showed different shapes, and asked to locate and trace the same shapes on the map. During the course of performing the task, each student's performance was taped using a video camera.

### Method

#### Subjects

The subjects were 36 students of both sexes enrolled at the Ohio State School for the Blind. All students used braille as their primary reading medium. Four students from each of grades 4-12 were randomly selected and participated as subjects. The means and standard deviations of the ages according to grade grouping and sex are presented in Table 1.

Table 1

Means and Standard Deviations of Ages of Subjects According to Grade Grouping and Sex

| Group | Male | Female | Total |
|---|---|---|---|
| Grade levels 4-5-6 | M = 13.01<br>SD = .93<br>n = 8 | M = 12.00<br>SD = 1.07<br>n = 4 | M = 12.67<br>SD = 1.06<br>n = 12 |
| Grade levels 7-8-9 | M = 14.75<br>SD = 1.12<br>n = 5 | M = 14.64<br>SD = 1.92<br>n = 7 | M = 14.69<br>SD = 1.57<br>n = 12 |
| Grade levels 10-11-12 | M = 18.37<br>SD = 1.71<br>n = 8 | M = 13.96<br>SD = 1.39<br>n = 4 | M = 18.56<br>SD = 1.57<br>n = 12 |
| Total | M = 15.47<br>SD = 2.73<br>n = 21 | M = 15.09<br>SD = 3.06<br>n = 15 | M = 15.31<br>SD = 2.84<br>n = 36 |

## Materials

Two pseudomaps were constructed and are shown in Figures 1 and 2. The maps were drawn in the following way: Six states of the United States were chosen on the basis of approximately equivalent sizes. The states with their areas in square miles were:

| State | Area in Square Miles (km) |
|---|---|
| Alabama | 51,078 (82,199.83) |
| Arkansas | 52,725 (84,850.34) |
| Florida | 54,262 (87,323.84) |
| Illinois | 55,947 (90,035.51) |
| Iowa | 55,986 (90,098.27) |
| Wisconsin | 54,715 (87,183.83) |

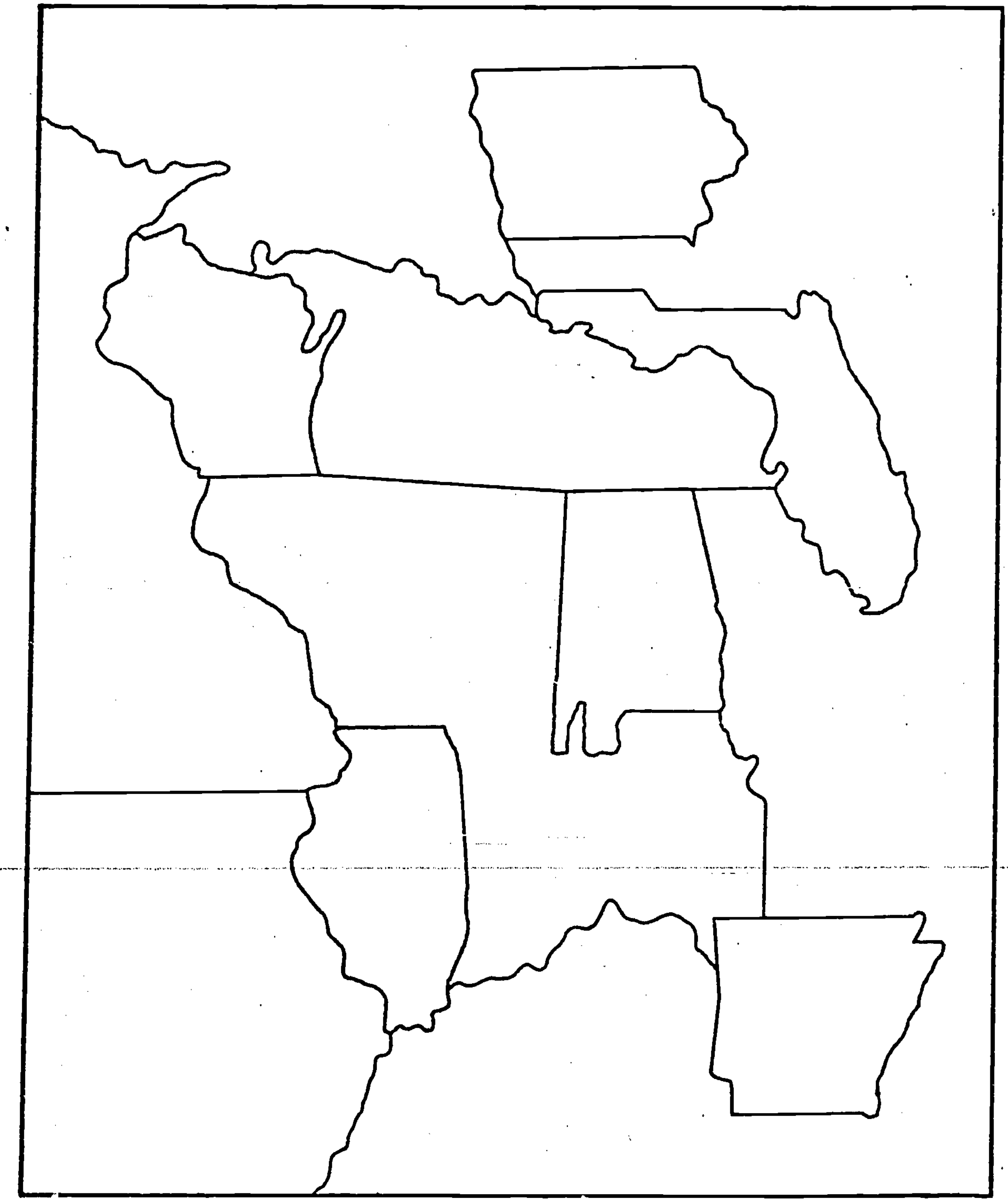

Figure 1. Tactile pseudomap A which had 10 additional boundary lines. The size of the map was 10 X 12 inches (25.40 X 30.48 cm) with the height and width of the lines being .025 inch (.064 cm) and .020 inch (.051 cm), respectively.

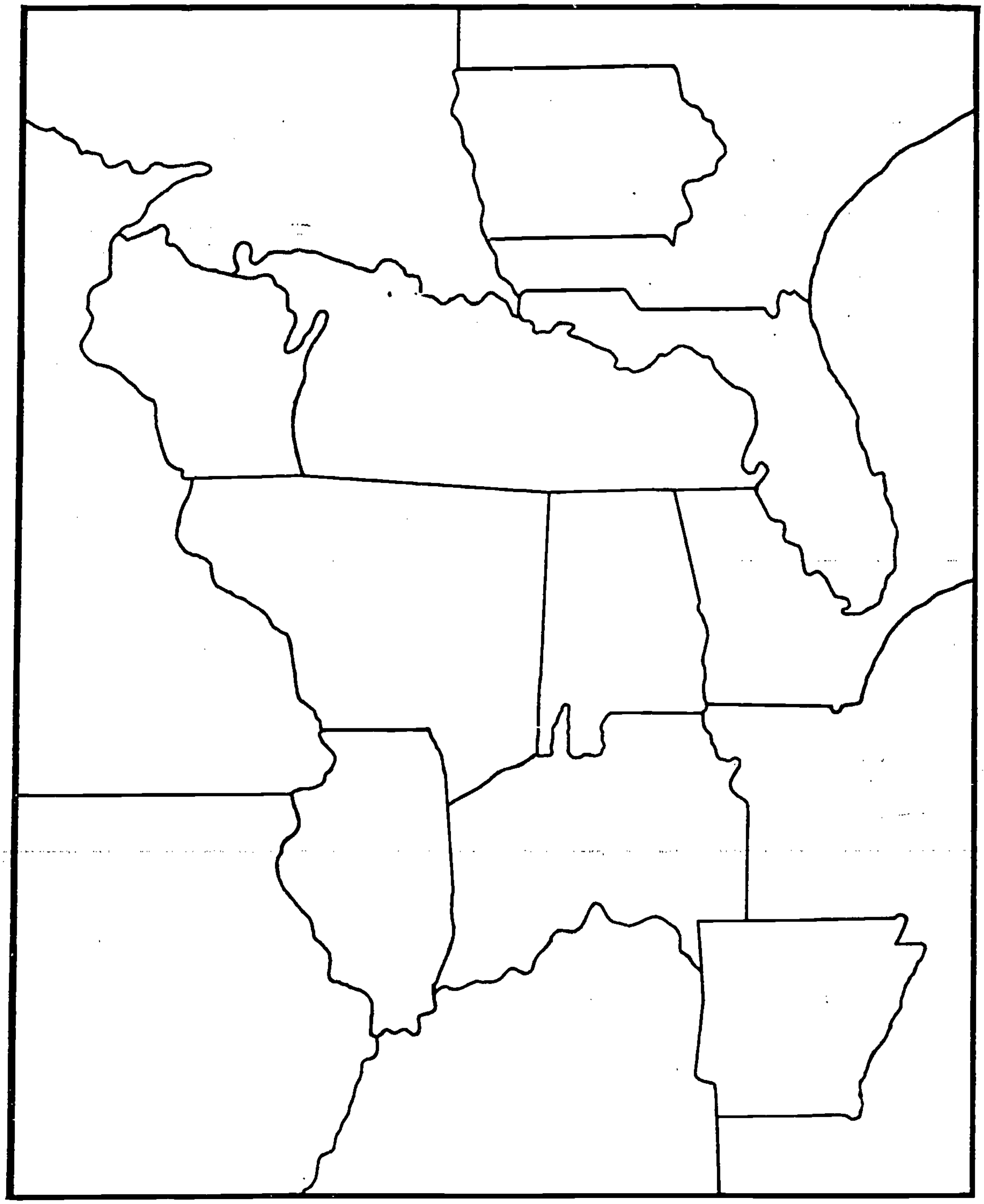

Figure 2. Tactile pseudomap B which had 15 additional boundary lines. The size of the map was 10 X 12 inches (25.40 X 30.48 cm) with the height and width of the lines being .025 inch (.064 cm) and .020 inch (.051 cm), respectively.

The six states' boundaries were drawn from a base map in Readers' Digest Great World Atlas (1963, p. 47). The map scale was 1 inch (2.54 cm) to 142 miles (228.52 km) or 1 = 9,000,000. A braille page was divided into a grid having five rows and four columns. One of the six states was randomly chosen and this state was randomly assigned to one of the 20 cells on the page. Each state was placed in one of the cells with the restriction that no two states could occupy adjacent cells in the same column or row. Two identical drawings of the pseudobase map were made and additional boundary lines were added to each map to increase their complexity. Map A was constructed by adding 10 lines to the base map. Map B was constructed by adding five more lines to Map A. Consequently, Map A had 10 additional boundary lines and Map B had 15 additional boundary lines. The additional boundary lines were actual boundary lines of adjacent states taken from the U.S. base map and shortened where necessary to fit within the size of the paper.

Two tactile map molds were made from these line drawings using a photoetching process. The resulting male molds were used in a drape molding process to produce plastic copies. The height of the lines were .025 inch (.064 cm) and the width of the lines was .020 inch (.051 cm). Each plastic map was mounted on cardboard with a nonskid backing. The size of the maps was 10 X 12 inches (25.40 X 30.48 cm). Six cue cards were made, with each card showing one of the six bounded areas (states). The six shapes were made by cutting the shapes from one of the plastic copies of the pseudomap. Each shape was mounted on 5 X 5 inch (12.70 X 12.70 cm) cardboard with a nonskid backing.

The practice-familiarization diagram consisted of four geometric figures (triangle, circle, square, and rectangle) placed in juxtaposition to one another. Plastic raised line drawings were made using the photoetching and drape molding process described previously. The practice diagram was 9 X 11 inches (22.86 X 27.94 cm). Four cue cards were made each showing one of the geometric forms.

Design and Procedure

In order to familiarize the subject with the nature of the task, each subject was given the geometric diagram for practice before being shown the pseudomap. Each subject was given a cue card which showed a geometric form and asked to locate the shape on the larger display and to trace it with his finger. All four shapes were given to each subject in this manner. Following the practice task, the subject was presented with a test map (either A or B) and given 2 minutes of free exploration of the map. Following the inspection period, the subjects were presented with each state and asked to locate the state on the larger display. Each subject was required to inspect the cue card showing the state for a minimum of 30 seconds and a maximum of 1 minute. Each subject had up to 5 minutes to locate and trace the target state with his fingertips. Throughout the test period, the subjects were not given any instruction or corrections. If the subject was unable to locate the target state within 5 minutes, the experimenter continued to the next shape. Each subject was given a different order of the six states. Each subject's performance was videotaped using a Sony sound videotape recorder.

Videoanalysis

The videoanalysis consisted of a qualitative analysis in which a particular subject was classified as either engaging in a behavior or not engaging in a behavior.

In order to obtain a list of descriptors for classifying the behaviors of the subjects on the map reading task, each of the 36 tapes was viewed by the senior author and a list of descriptors was compiled. There were three separate lists of descriptors, one for each component of the map reading task: preliminary scan of the map, inspection of the cue card, and the map search. On the basis of the accuracy and time scores, videotapes of the nine best and nine poorest map readers were chosen for further analysis. The nine best map readers were those subjects who located all the shapes with the lowest time scores and the nine poorest readers were those subjects who located the fewest shapes with the highest time scores.

The choice of the nine best and nine poorest map readers resulted in five males and four females in each group. The mean number of shapes located, the mean time in seconds to locate each shape, the mean age, and the mean grade level for each of the groups is presented in Table 2. The mean number of shapes located and the mean time in seconds to locate each shape for the whole sample is also shown in Table 2. In order to determine whether there were differences in age or grade level between the good and poor readers, separate $t$ tests (two-tail) were computed. There were no significant differences between ages ($t$ [16] = .05, $p > .05$) or grade levels ($t$ [16] = 1.33, $p > .05$).

Table 2

Mean Performance Scores, Mean Ages, and Mean Grade Level for Good Map Readers, Poor Map Readers, and Total Sample

| Behavior | Good readers | Poor readers | Total sample |
|---|---|---|---|
| Mean number of shapes located | 6.00 (SD = 0.00) | 2.89 (SD = 1.27) | 5.06 (SD = 1.45) |
| Mean time per shape (in seconds) | 58.15 (SD = 14.13) | 210.74 (SD = 40.46) | 117.92 (SD = 68.18) |
| Mean age (in years) | 15.69 (SD = 3.00) | 15.61 (SD = 3.53) | 15.31 (SD = 2.84) |
| Mean grade level | 9.22 (SD = 2.44) | 7.44 (SD = 3.17) | 8.00 (SD = 2.62) |

In order to insure agreement on the precise definition of the various descriptors, two of the authors viewed four videotapes of students who were not included in the final set of 18, and categorized their behavior using the list of descriptors. Agreement was reached on each of the descriptors and the final set of 18 videotapes were viewed and analyzed in an alternating sequence of a good reader followed by a poor reader (G. P. G. P. . .).

## Results

The three phases of the map reading task were analyzed separately:

### Preliminary Scan

Since each subject in each of the two groups scanned the map once, the maximum possible score for each group was nine, (i.e., each of the nine subjects in each group could engage in a particular behavior or not engage in a behavior). Fischer's exact probability test was used to determine whether there were significant differences between the frequencies with which subjects in the two groups engaged in specific behaviors. Table 3 lists the various descriptors, the percentage of subjects who engaged in the behavior, and whether the differences in the frequencies were significant. As shown in Table 3, there were two behaviors which good readers engaged in more frequently than poor readers. A subject's scan was labeled complete if all six of the target states were touched during the course of the 2-minute scan. All of the good readers searched the map completely while only 44% of the poor readers searched the map completely. Second, although both good and poor readers traced at least one line during the preliminary scan, good readers traced lines significantly more often than poor readers (100% vs. 56%). Characteristically, good readers appear to set themselves the task of inspecting and following lines, while poor readers not only inspect lines, but also inspect the area between good and poor readers on the preliminary scan of the map.

Except for the differences between good and poor readers noted, the preliminary scan of both good and poor readers can be characterized as a two-handed, rapid, global, and unsystematic inspection with the fingertips. As has been reported elsewhere, (Nolan & Morris, 1971) very few of the students determined the extent of the display they were searching before beginning their inspection.

For the most part, both good and poor readers appeared to perceive the map as a series of interconnected lines rather than a composite of juxtaposed shapes. The students followed the lines haphazardly without differentiating the shape, size, or distinctive features of a shape from other adjacent shapes. Consequently, it appeared as if very little useful information about the nature of the shapes was extracted by the students during the preliminary scan.

Table 3

Frequency of Occurrence of Different Map Reading Behaviors by Good and Poor Map Readers during Preliminary Scan

| Behavior | Good readers | Poor readers |
|---|---|---|
| Systematic | 0% | 11% |
| Unsystematic | 100% | 89% |
| Complete[a] | 100% | 44% |
| Incomplete[a] | 0% | 56% |
| Traces lines[c] | 100% | 67% |
| Traces lines frequently[b] | 100% | 56% |
| Traces target areas | 78% | 44% |
| Traces nontarget areas | 33% | 11% |
| Defines extent of display | 22% | 0% |
| Searches map with one hand | 11% | 11% |
| Searches map with two hands | 100% | 89% |
| Uses fingertips | 100% | 89% |
| Uses flat of hands | 0% | 11% |
| Uses fingernails | 0% | 11% |
| Notes distinctive features | 44% | 44% |

[a] $p = .015$
[b] $p = .041$
[c] $p = .10$

Inspection of Cue Card

Since each of the nine subjects inspected six separate cue cards in each of the two groups, there was a total of 54 opportunities for a specific behavior to be engaged in by each group of readers. The percentage of instances a particular behavior was engaged in was tabulated and differences in the percentages between good and poor readers was tested using a test of significance for the differences between proportions. Table 4 lists the descriptors, the percentage of instances good and poor readers engaged in a behavior, and the $z$ scores for the differences in percentages between good and poor readers. Table 4 shows a number of significant differences between good and poor readers in the frequency with which they engaged in different behaviors. Good readers (100%) completely traced the shapes significantly more often than poor readers (61%). The good readers characteristically picked out a point of origin and traced around the shape in a continuous motion and returned to the point of origin. Poor readers engage in this behavior less frequently. Their tracings were typically incomplete because of their failure to return to the point of origin or they haphazardly skipped around the shape feeling different parts without tracing the shape in one continuous motion. In addition, their inspections of the shape were significantly less detailed than good readers (57% vs. 96%). Poor readers did not follow the contour of the shape as closely as good readers. For example, a common response by some poor readers was to rapidly move their finger in a circular motion around the shape skipping distinctive features and corners and failing to follow the contour faithfully. Both the lack of a complete tracing and a detailed tracing were very striking differences between good and poor readers.

Table 4

Frequency of Occurrence of Different Map Reading Behaviors by Good and Poor Map Readers during Inspection of Cue Card

| Behavior | Good readers | Poor readers | Z score |
|---|---|---|---|
| Detailed tracing | 96% | 57% | 4.80** |
| Complete tracing | 100% | .61% | 5.12** |
| Picks out distinctive features | 74% | 56% | 2.01* |
| Traces key with: | | | |
| Left hand | 0% | 9% | 2.29* |
| Right hand | 31% | 20% | 1.32 |
| Both hands | 69% | 70% | .21 |
| Right dominant | 24% | 3% | 2.67** |
| Left dominant | 0% | 18% | 2.76** |
| Neither dominant | 76% | 79% | .31 |
| Traces shape with two fingers on same hand | 9% | 2% | 1.68 |
| Feels shape between thumb and other fingers | 20% | 9% | 1.63 |
| Feels shape with flat of hand | 2% | 17% | 2.66** |
| Feels empty space inside of key | 0% | 9% | 2.29* |
| Fingers used in tracing key: | | | |
| Index alone | 93% | 67% | 3.34** |
| Index and middle | 7% | 11% | .33 |
| Index and middle and ring | 0% | 22% | 3.67** |

* $p < .05$
** $p < .01$

Good readers also picked out distinctive features significantly more often than poor readers (74% vs. 56%). The operational definition used for determining this behavior was perseveration and inspection of a part of a shape to a greater extent than other parts of a shape. Except for the fact that good readers engaged in this behavior more frequently, there did not appear to be any differences in the location or consistency with which certain features were chosen by good or poor readers.

Poor readers also engaged in a number of other behaviors in inspecting the shape which good readers did infrequently or not at all. Poor readers inspected the shape with the flat of the hand significantly more often than good readers (17% vs. 2%), and felt the area on the inside of the shape significantly more often than good readers (9% vs. 0%).

One striking observation was the fact that both good and poor readers primarily used the index finger(s) to trace the shape, but good readers used the index fingers significantly more often than poor readers (93% vs. 67%), and poor readers tend to use their index, middle, and ring fingers collectively to trace the shape more often than good readers (22% vs. 0%).

Both good and poor readers used two hands (69% and 70%) more frequently than either hand alone (31% and 30%). However, the left hand was dominant significantly more often for poor readers (18%) as compared to good readers (0%). The right hand was dominant significantly more often for good readers (24%) as compared to poor readers (3%). Poor readers also used their left hand alone significantly more often than good readers (9% vs. 0%).

Map Search

Each subject was asked to locate each of six shapes separately. Consequently, there was a total of 54 opportunities for a specific behavior to be engaged in by each group of readers. Table 5 lists the descriptors, the percentage of instances good and poor engaged in a behavior, and the $\underline{z}$ scores for the differences in percentages between good and poor map readers.

The map search consisted of locating the target shape and tracing its contour. Both good (100%) and poor (94%) readers searched the map with their fingertips. However, good readers (77%) searched the map significantly more often with the index finger than poor readers (59%), while poor readers depended more heavily on the first three fingers (index, middle, and ring) to a significantly greater extent than good readers (28% vs. 9%). Poor readers searched with the flat of the hand (15%) while none of the good readers engaged in this behavior and poor readers persisted significantly more often on one part of the map than good readers (15% vs. 2%). In addition, a small but significant proportion of the time, poor readers (9%) failed to search the map completely and their hands never touched the target shape at all, while all of the good readers made contact with the target.

The two most striking differences between good and poor readers in the whole study occurred during the map search. First, poor readers had an enormously difficult time tracing lines. Poor readers were observed to have difficulty tracing lines 48% of the time, while only 4% of the good readers had difficulty. Specifically, poor readers were observed to fall off a line they were tracing significantly more often than good readers (35% vs. 0%). Poor readers also followed intersecting lines, while attempting to trace a shape, significantly more often than good readers (35% vs. 4%).

Second, good readers located the target shape 83% of the time by picking out one or more distinctive features of the shape on the map, while poor readers were observed to engage in this behavior 35% of the time. Good readers also checked the cue card significantly more often than poor readers (87% vs. 63%) as a means of determining if they had found the shape.

Table 5

Frequency of Occurrence of Different Map Reading Behaviors by Good and Poor Map Readers during Map Search

| Behavior | Good readers | Poor readers | Z score |
|---|---|---|---|
| Uses fingertips | 100% | 94% | 1.76 |
| Use one hand: | 37% | 24% | 1.46 |
| Left hand | 77% | 80% | .21 |
| Right hand | 23% | 20% | .21 |
| Both hands: | 76% | 63% | 1.46 |
| Left dominant | 0% | 9% | 1.94 |
| Right dominant | 5% | 3% | .43 |
| Neither dominant | 95% | 88% | 1.09 |
| Primary fingers used: | | | |
| Index alone | 77% | 59% | 2.01* |
| Index and middle | 13% | 13% | ---- |
| Index and middle and ring | 9% | 28% | 2.48* |
| Searches with flat of hand | 0% | 15% | 2.94** |
| Searches with one hand on key | 31% | 22% | 1.09 |
| Finds distinctive feature on target | 83% | 35% | 5.09** |
| Same distinctive feature as found on preliminary scan | 21% | 5% | .95 |
| Same distinctive feature as inspection of key | 84% | 84% | ---- |
| Checks key after locating distinctive feature of shape on map | 87% | 63% | 2.89** |
| After locating target, finds it on target, then on key | 76% | 53% | 1.81 |
| Traces target and key simultaneously | 56% | 34% | 1.43 |
| Hand never touches target | 0% | 9% | 2.29* |
| Difficulty in tracing | 4% | 48% | 5.27** |
| Falls off line while tracing | 0% | 35% | 4.80** |
| Follows intersecting line while trying to trace target on map | 4% | 35% | 4.13** |
| Finds target but can't trace it | 0% | 6% | 1.76 |
| Persists on one part of map | 2% | 15% | 2.44* |
| Finds target and completes task | 100% | 48% | 6.15** |
| Traces target with both hands | 48% | 46% | .16 |
| Traces target with one hand: | 52% | 54% | .17 |
| Traces target with left | 71% | 59% | .81 |
| Traces target with right | 41% | 29% | .76 |
| Traces target with index finger only | 100% | 92% | 2.06* |
| Traces target with index and middle fingers | 0% | 4% | 1.45 |
| Traces target with index and middle and ring fingers | 0% | 4% | 1.45 |

* $p < .05$

** $p < .01$

Lastly, once the target shape was located, good readers traced the target with their index finger more frequently than poor readers (100% vs. 92%).

The search strategy of the good readers can best be characterized as mainly a search for a critical distinctive feature rather than a search for a whole shape. The good readers appeared to search the map looking for a distinctive feature with occasional checking of the cue card to determine if they had located the target feature. Once a critical distinctive feature had been located, this would serve as a signal to trace the contour of the shape to determine whether it matched either the cue card or their memory of the shape. It is difficult to characterize the strategies of the poor readers because they frequently engaged in a variety of irrelevant behaviors and did not engage in many relevant behaviors. However, it appeared that in some instances, the poor readers appeared to be looking for a whole shape based on its overall size and/or its general configuration. Other poor readers appeared to search for a critical distinctive feature but had difficulty differentiating it from similar distinctive features of other shapes on the map. Sometimes a poor reader would locate the critical distinctive feature, but would not know which way to trace the line. It appeared in these instances that the poor reader had little notion of the relationship or position the critical feature had in relation to the rest of the shape. Finally, in some instances, poor readers would fall off the line they were tracing and/or follow an intersecting line and lose their place and/or decide to go to a different part of the map.

## Distinctive Features of Shapes

During each phase of the map reading task the distinctive features of each shape chosen by the subjects were circled on line drawings of each of the target shapes. Inspection of these figures indicated that during the preliminary scan very few of the subjects picked out distinctive features of the target shapes.

For the other two phases of the task, good readers picked out more distinctive features than poor readers, but there was little difference in the nature or location of the distinctive features chosen by good and poor readers. The nature of the distinctive features chosen, apparently depended on the variation in the contour of the shape itself, rather than the skills of the reader. Shapes which had a greater variation in contour showed less consistency in the location and nature of the distinctive feature chosen, (e.g., Florida). The less the variation in the contour of the shape or the more prominent a distinctive feature was, the greater the consistency in the distinctive feature chosen by the subjects (e.g., Alabama). Examples of the distinctive features chosen by good readers for Florida and Alabama during the map search are shown in Figure 3. The lines around the shapes show the features chosen and the numbers inside the line indicate the number of subjects who chose that particular feature. Furthermore, the overwhelming majority of good and poor readers chose one or two distinctive features during the inspection or search phases. Very few subjects chose more than two features.

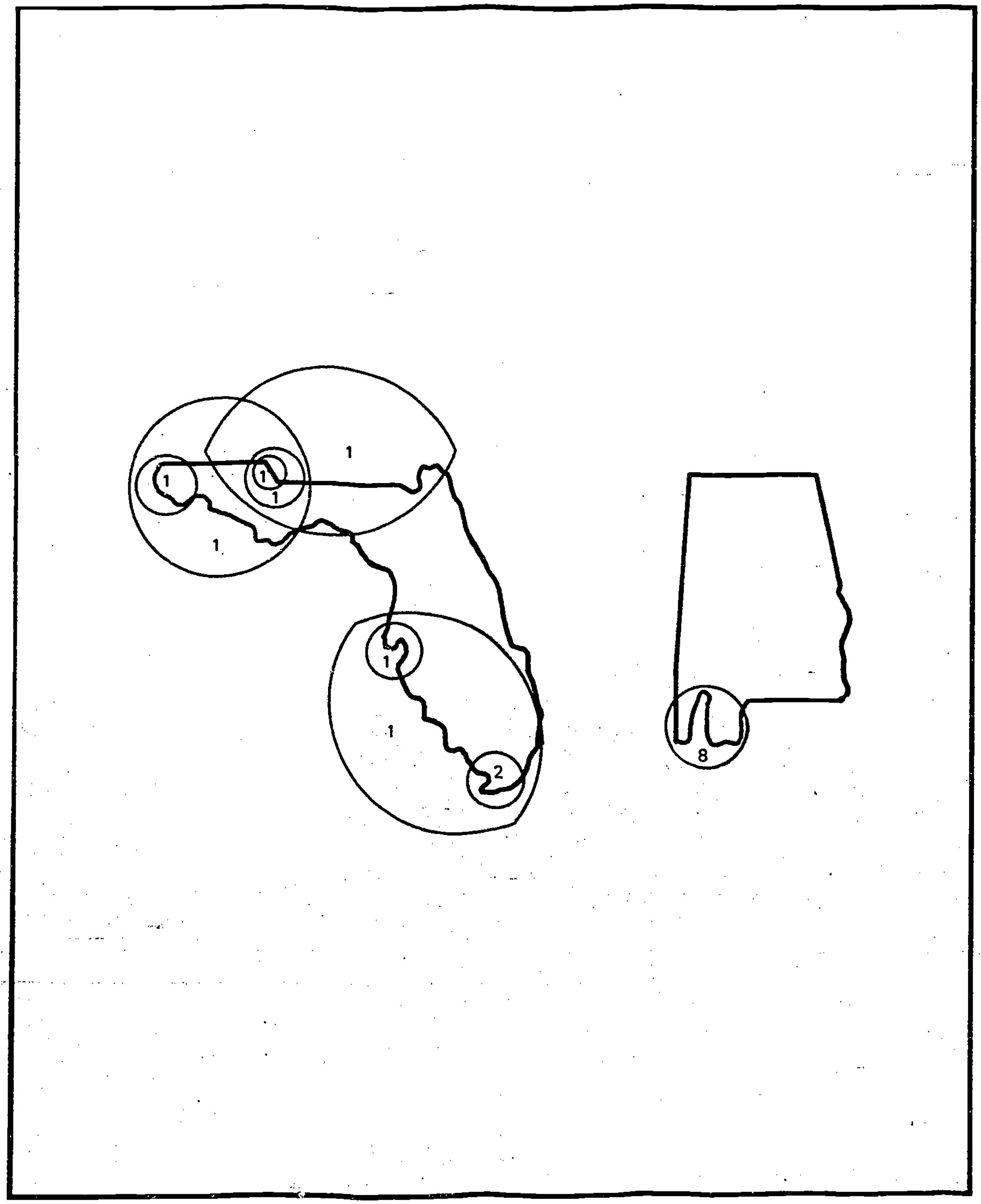


Figure 3. Examples of the distinctive features chosen by good readers for Florida and Alabama during the map search. The lines around the shapes show the distinctive features chosen and the numbers inside the lines indicate the number of subjects who chose that particular feature.

Map Design and Complexity

At the completion of the map reading task, the subjects were asked four questions, namely:

1. Why was the map hard to read?
2. What do you think was wrong with the map?
3. How could we make it better?
4. When I showed you a shape, what did you look for on the map?

Of the 36 subjects, 22 (61%) responded with a specific answer to one or more of the first three questions. Of the 22 who responded, 20 (91%) indicated that the shapes on the map were too close together and/or needed to be separated.

In order to determine whether there were differences in the accuracy or the time to locate the shapes on Map A and Map B, separate analyses of variance were performed for each measure. The first analysis, using an arcsin transformation of the percentage of correct responses, consisted of a two-way analysis of variance for independent groups with Maps (A vs. B) and Grade Groupings (4-6, 7-9, 10-12) constituting the two variables. There were no significant differences between any of the variables or the interaction. A summary of the analysis is shown in Table 6.

A second analysis was performed on the location time data with the time necessary to locate each shape as the dependent measure. A three-way analysis of variance was performed using a reciprocal transformation of the data. Grade Groupings (4-6, 7-9, 10-12) and Maps (A vs. B) constituted the between subjects variables and Shapes (1-6) constituted the within subjects variable. The analysis showed no significant differences between any of the variables or their interactions. A summary of the analysis is shown in Table 7.

Table 6

Analysis of Variance on Percentage of States

Located as a Function of Grade Groupings and

Map Complexity Using an Arcsin Conversion

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 11.072143 | 35 | | |
| Between subjects | 11.072143 | 35 | | |
| Grade | .441791 | 2 | .220895 | .63 |
| Map complexity | .012837 | 1 | .012837 | .04 |
| Grade x map | .021382 | 2 | .010691 | .03 |
| Error | 10.596133 | 30 | .353204 | |

Table 7

Analysis of Variance on Mean Task Time to Locate a State as a Function of Grade Groupings, Map Complexity, and Order of Presenting States Using a Reciprocal Transformation

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | .142225 | 215 | | |
| Between subjects | .044427 | 35 | | |
| Grade | .004831 | 2 | .002416 | 2.08 |
| Map complexity | .004010 | 1 | .004010 | 3.45 |
| Grade x map | .000682 | 2 | .000341 | .29 |
| Error | .034904 | 30 | .001163 | |
| Within subjects | .097798 | 180 | | |
| Order | .002919 | 5 | .000584 | 1.13 |
| Grade x order | .007989 | 10 | .000799 | 1.54 |
| Map x order | .001734 | 5 | .000347 | .67 |
| Grade x map x order | .007368 | 10 | .000737 | 1.42 |
| Error | .077788 | 150 | .000519 | |

Locating a shape on a map, differentiating it from adjacent shapes, and tracing its contour are fundamental prerequisites for reading any raised line tactile map. Yet, a substantial proportion of the sample of students tested lacked the necessary skills to perform the task quickly and accurately. By comparing good map readers with poor map readers, it was possible to delineate a number of skills and concepts that need to be emphasized in the teaching of map reading skills.

Line tracing was the largest and most obvious problem the students encountered in working with the map. Their inability to trace a line was a persistent problem that was not confined to the lower grades, but permeated all the grades tested (4-12). The teaching and remediation in this skill is absolutely essential if raised line displays are to be used in any educationally meaningful way, whether they be maps, graphs, or diagrams. It should be noted that the authors have observed the line tracing problem informally while conducting other research. In fact, in one study it was necessary to train students in line tracing before it was possible to begin the investigation. One technique found effective was to have the subject use the index finger of both hands, with one finger following the line while the other finger trailed behind. Then, when a line curved, or was broken, or interrupted by another symbol, or if the lead finger fell off the line, the trailing finger would hold its place while the lead finger located the continuation of the line. Training in line tracing should begin with straight lines, then extend to multicurved lines and crisscrossing lines. Proficiency in this skill would not only aid map reading, but also be useful in reading graphs and diagrams in mathematics and science texts.

Shape concepts and methods for inspecting shapes represented another major area of difficulty for the students. Although the students were able to discriminate and recognize simple geometric forms (triangle, circle, square, and rectangle), they frequently did not have general perceptual-conceptual skills to discriminate or recognize shapes that differ from the simple geometric forms they know so well. Good map readers located and discriminated the shapes by locating and comparing the distinctive features of the shapes. Teachers need to emphasize the concept of distinctive features ("parts that stick out or go in") and to teach students to compare shapes and recognize shapes by comparing and recognizing distinctive features. A shape can be conceived as an array of distinctive features. Consequently, the contour of a shape should be traced in a systematic way in order to convey information about the sequential order and relative positions of the distinctive features to each other. Students could be taught to trace the contour of a shape in a clockwise or counterclockwise direction as an initial introduction to the concept. In addition, the students should be taught to trace a shape in one continuous motion and return to the point of origin or what Piaget calls decentration (Piaget & Inhelder, 1967). This would enable the student to gain some conception of the spatial relationships of the distinctive features and would also insure a complete tracing of the shape.

The videoanalysis also indicated that some students inspect the area between the edges or lines of a shape rather than the edge or contour line of the shape. While this may communicate information about size, it provides little information about the identity of a shape. Teachers need to emphasize that the most informative aspect of a shape is its contour or edge.

One can readily appreciate the difficulty students had in locating a shape on a map when they lacked both the ability to trace and the concept of a distinctive feature of a shape.

It was apparent that the best readers primarily used the fingertips of the index fingers to locate distinctive features on the map and to trace the shapes. Research in braille (Foulke, 1964; Lappin & Foulke, 1973) and letter recognition (Hill, 1973, pp. 95-105) indicates that performance is best when only the index finger is used. Using other fingers alone or in addition to the index finger either resulted in no improvement or decreased performance. Teachers need to emphasize the use of the fingertips of both index fingers for reading embossed displays. Students should be observed carefully to detect irrelevant or uninformative behaviors, such as the use of fingernails, scratching, passive placement of the hand, and searching a map with the flat of the hand.

In working with maps or any large embossed display, students should begin by defining the extent of the display and systematically search the display. These behaviors should enable the student to acquire general information about the display before beginning a detailed inspection or a specific task. As has been reported elsewhere (Berla', 1972; Nolan & Morris, 1971), few students spontaneously engaged in these behaviors. However, a few minutes of training students to search a display with a two-handed vertical scanning technique has been shown to be an effective method for searching a display (Berla', 1972; Berla' & Murr, 1974).

Once students have acquired the skills and concepts described above, training should be begun to teach a child to recognize and trace a shape which is juxtaposed to other shapes. A tactile political map can be perceived either as a series of intersecting lines or as a collection of juxtaposed shapes sharing common borders. The ability to recognize a shape from a mass of intersecting lines, sometimes called disembedding, is an absolutely essential skill for reading raised line maps. Perceptual training in this skill could be begun by having students locate and trace common geometric forms which have been placed next to each other, as is shown in Figure 1. Training could then proceed to similar formats using unfamiliar geometric forms and simple political maps. In teaching the skill, the teacher needs to emphasize a systematic search for the distinctive features of the shapes.

In addition to improving the skills of the map reader, maps could also be redesigned to ameliorate some of the more obvious problems; like line tracing and the inability to perceptually separate juxtaposed shapes. For example, instead of using a very narrow line on maps, a relatively broad raised line could be used. The student could then trace the inside edge of the contour line of a shape. This might reduce his probability of following an intersecting line and aid his understanding that a map is a collection of juxtaposed shapes rather than a series of intersecting lines. Another alternative might be to have solid raised shapes that are separated by a broad incised line. One could liken this design to a dissectable map in which each of the raised shapes is spaced about .25 inch (.64 cm) from all the neighboring shapes. It is not suggested that all maps be redesigned in this fashion, but these types of map designs might be effective teaching aids when a student is first introduced to political maps. Once the student has learned the elementary skills and concepts, he may be able to use the typical raised line display more effectively.

Delay in training these skills or introducing these concepts until a student is forced by the nature of the subject matter to use embossed displays may be the reason teachers report having so much difficulty in using maps in social studies. Lack of training in the early grades allows the student to develop inappropriate skills, irrelevant habits, and distorted concepts about maps. It then becomes even more difficult to use embossed displays in the classroom.

STUDY II

# LOCATING SYMBOLS ON A TACTILE PSEUDOMAP BY BRAILLE READERS OPERATING UNDER DIFFERENT FRAMES OF REFERENCE

Edward P. Berla' and Marvin J. Murr

Abstract

Previous research has shown that students neither define the extent of a tactile display nor initiate a preliminary scan prior to attempting a detailed search. The specific focus of this study was to determine the effects that a frame of reference, acquired from a 2-minute preliminary scan, would have on students' ability to locate symbols on a tactile pseudomap. The test task consisted of locating as many of 16 point symbols and 6 area symbols as could be found in a 5-minute period. The results showed that a frame of reference with specific instructions on how to search the display facilitated the performance of the students in the lower grade levels (4-6), but interfered with or had no effect on students performance in the upper grades.

## STUDY II

## LOCATING SYMBOLS ON A TACTILE PSEUDOMAP BY BRAILLE READERS OPERATING UNDER DIFFERENT FRAMES OF REFERENCE

Provision of useful and legible tactile maps for the education of the blind has long been a problem. Although attempts have been made to provide the same kinds of materials for the braille reader as those provided for the print reader, success has been limited by a lack of information regarding the symbology and design of tactile maps. Furthermore, research to determine the efficacy of different map designs and formats has vividly demonstrated the lack of fundamental map concepts and psychomotor skills on the part of blind students. For example, blind students fail to search tactile displays either systematically or completely (Berla', 1973; Berla' & Murr, 1974; Nolan & Morris, 1971) and fail to give tactile displays a preliminary scan before attempting a detailed inspection (Nolan & Morris, 1971). However, research has demonstrated the efficacy of a few minutes of training in improving students' ability to systematically search a tactile display (Berla', 1973; Berla' & Murr, 1974).

The major impetus for the present study was the fact that students neither define the extent of a tactile display nor initiate a preliminary scan prior to attempting a subsequent detailed search (Nolan & Morris, 1971). A preliminary scan of a display should provide the student with information about the size of the display, the kinds of symbols, the number of symbols, the location of symbols, and the shapes of bounded areas. The information acquired from a preliminary scan should establish an informative frame of reference and should facilitate subsequent understanding and performance. Therefore, the specific focus of this study was to determine the effects that a frame of reference, acquired from a preliminary scan, would have on students' ability to locate symbols on a tactile pseudomap. The test task consisted of locating as many of 16 point symbols and 6 area symbols as could be found in a 5-minute period.

There are four conditions in the experiment: In two conditions the subjects were given a frame of reference in the form of a 2-minute preliminary scan, with different instructions on how to search the display. In the remaining two conditions the subjects were not provided with a frame of reference, but were given identical instructions on how to search the display as the first two conditions.

### Method

#### Subjects

The subjects were 41 male and 31 female braille readers in grades 4 through 12, enrolled in residential schools for the blind.

The means and standard deviations of the ages according to grade level are presented in Table 1. The schools participating in the research were the Georgia Academy for the Blind, the Lavelle School for the Blind, and the Wisconsin School for the Visually Handicapped.

Table 1

Means and Standard Deviations of Ages in Years

According to Grade Grouping and Sex

| Group | | Grade Grouping 4-6 | 7-9 | 10-12 |
|---|---|---|---|---|
| Male | *M* | 12.60 | 15.60 | 17.76 |
| | *SD* | 1.74 | 1.36 | 1.97 |
| | *n* | 18 | 10 | 13 |
| Female | *M* | 12.30 | 15.42 | 18.18 |
| | *SD* | 2.32 | 1.55 | 1.81 |
| | *n* | 6 | 14 | 11 |

## Materials

A tactile pseudomap was constructed having point, line, and area symbols. The pseudomap was made through a photoengraving process. A male mold was made from this process and copies were made by drape molding styrene plastic over the male molds. A photographic reproduction of the map is shown in Figure 1. The height of the point, line, and area symbols were respectively: .035 inch (.089 cm); .025 inch (.064 cm); and .015 inch (.038 cm). The separation between symbols was .150 inch (.381 cm). The outer dimensions of the map were 15 X 15 inches (38.1 X 38.1 cm). The target symbols consisted of 16 point symbols (raised circles) indicated in Figure 1 by the numbers 1-16 and 6 textured area symbols indicated in Figure 1 by the letters A-F. The target symbols were randomly positioned on the pseudomap. In addition, two cue cards were made, each showing one of the target symbols.

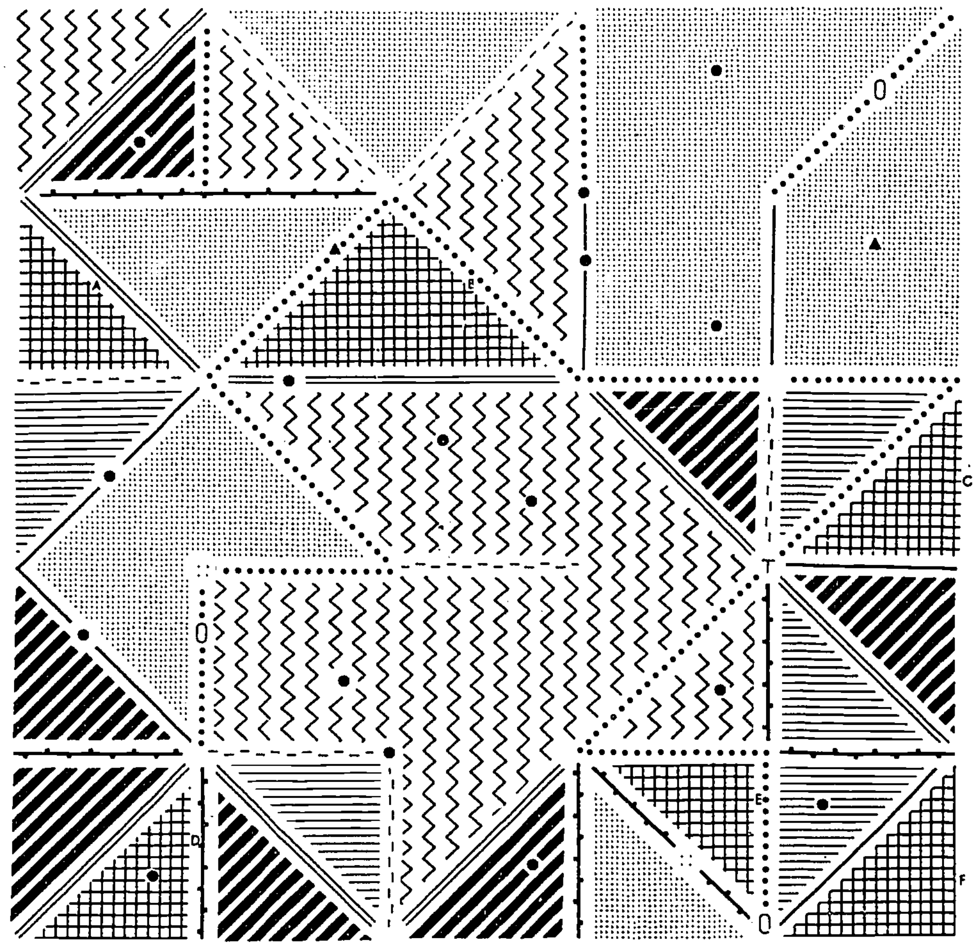

Figure 1. Psuedomap used in the study.

Design and Procedure

The students were randomly chosen from the population of braille students in each school and randomly assigned to the four conditions in the experiment. The four conditions were counterbalanced within a given testing day and each student was tested individually. For all subjects the test task was to locate as many of the 16 point symbols and the 6 area symbols as could be found in a 5-minute period. Prior to being informed as to the nature of the test task, the subjects were provided with different frames of reference depending upon the condition they were assigned to. The four conditions were:

1. No Preliminary Scan, Noninstructed Search Control--the subjects were shown the target symbols on the keys and then given the

test task without having had a preliminary scan of the map or any information on how to search the map.

2. No Preliminary Scan, Instructed Search--the subjects were not given a preliminary scan of the map, but were instructed to find the target symbols on the map by searching it systematically and completely, including the borders and the center of the map. The subjects were shown what the terms borders and center meant on a plain piece of cardboard which was the same size as the pseudomap. Following these instructions, the subjects were shown the target symbols on the keys and given the test task.

3. Noninstructed Preliminary Scan, Instructed Search--the subjects were told to search the pseudomap for 2 minutes "to get an idea of what the map is like," but not given any additional instructions. Following the preliminary scan, the subjects were informed as to the nature of the test task and instructed to locate the target symbols on the map by searching it systematically and completely including the borders and the center. The subjects were shown what the terms borders and center meant on a plain piece of cardboard which was the same size as the pseudomap. The subjects were then shown the target symbols on the keys and given the test task.

4. Instructed Preliminary Scan, Instructed Search--the subjects were told to search the map for 2 minutes and to notice the different shapes, patterns, and lines on the map. In addition, they were told to search the map systematically and completely including the borders and the center of the map. They were shown what was meant by the terms borders and center on a plain piece of cardboard. At the beginning of the preliminary scan, the subjects were told to first search the borders, then the center, and then to systematically search the entire map. At the end of 2 minutes, the subjects were shown the target symbols on the keys and then given the test task.

The subjects were told that the map was of a park and that the circles represented trees and the texture, area symbols represented grass. They were told that they had to find as many different trees and different areas of grass as they could in 5 minutes. Each subject was scored on the number and location of point symbols and area symbols that were found during each successive 1-minute period. This resulted in five time periods.

## Results

The data were scored in terms of two dependent measures: the percentage of target symbols correctly located by each subject and the total errors of duplication made by each subject.

Two separate three-factor analyses of variance were performed on the arcsin transformations of the percentage of target symbols correctly located. One analysis was performed on the percentage of point symbols located and a separate analysis was performed on the percentage of area symbols correctly located. For each analysis grade groupings (4-6, 7-9, and 10-12) and instructional conditions (4) constituted between subjects variables, and time periods (1-5) constituted a within subjects variable. The analysis of the point symbol data showed that there was a significant effect associated with time periods ($F = 23.57$; $df = 4, 240$; $p < .01$). The means and standard deviations of the percentage of point symbols located during each successive 1-minute period are shown in Table 2. As shown in Table 2 the percentage of the total number of point symbols located decreased with each successive 1-minute period. The greatest percentage of symbols was located within 1 to 3 minutes. There were no significant differences between instructional conditions ($F < 1$) or between grade groupings ($F = 1.68$; $df = 2, 60$; $p > .05$). The means and standard deviations of the percentage of point symbols located for each instructional condition and for each grade grouping are shown in Table 3. A summary of the analysis of variance is shown in Table 4.

Table 2

Means and Standard Deviations of the Percentage of Total Target Point Symbols Located within Each Successive 1-Minute Period

| | Minutes 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| M | 19.01 | 17.27 | 10.42 | 6.94 | 4.95 |
| SD | 13.53 | 11.22 | 9.50 | 8.02 | 8.32 |

Table 3

Means and Standard Deviations of Percent of Target Point Symbols

Located by Grade Groupings and Training Conditions

| Conditions | | No Preliminary Scan, Noninstructed Search (Control) | No Preliminary Scan, Instructed Search | Noninstructed Preliminary Scan, Instructed Search | Instructed Preliminary Scan, Instructed Search | Total |
|---|---|---|---|---|---|---|
| Grades | | | | | | |
| 4 - 6 | M | 52.08 | 63.54 | 69.79 | 55.21 | 60.16 |
| | SD | 9.41 | 14.48 | 19.13 | 13.36 | 15.29 |
| 7 - 9 | M | 55.21 | 57.29 | 55.21 | 59.38 | 56.77 |
| | SD | 15.01 | 17.42 | 19.93 | 25.85 | 18.70 |
| 10 - 12 | M | 60.42 | 58.33 | 65.63 | 61.46 | 61.45 |
| | SD | 21.53 | 9.41 | 21.92 | 12.13 | 16.24 |
| Total | M | 55.90 | 59.72 | 63.54 | 58.68 | |
| | SD | 15.53 | 13.60 | 20.14 | 17.30 | |

Table 4

Analysis of Variance of Percentage of Point Symbols Located during Each Successive 1-Minute Period for Each Training Condition and Grade Grouping Using an Arcsin Transformation

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 359 | 34.435687 | | |
| Between subjects | 71 | 2.588071 | | |
| Conditions | 3 | .032154 | .032154 | .84 |
| Grade groupings | 2 | .127430 | .063715 | 1.68 |
| Conditions x grade groupings | 6 | .090599 | .015100 | .40 |
| Error | 60 | 2.273581 | .037893 | |
| Within subjects | 288 | 31.847615 | | |
| Time periods | 4 | 8.182029 | 2.045507 | 23.57** |
| Conditions x periods | 12 | .995619 | .082968 | .96 |
| Grades x periods | 8 | .448309 | .056039 | .65 |
| Conditions x grades x periods | 24 | 1.392827 | .058034 | .67 |
| Error | 240 | 20.828832 | .086787 | |

** $p < .01$

The analysis of the textured area symbols also showed a significant effect associated with time periods ($F = 21.88$; $df = 4, 24$; $p < .01$). The means and standard deviations of the percentage of area symbols located during each successive 1-minute period is shown in Table 5. With each successive 1-minute period there was a decrease in the percentage of area symbols located. The greatest percentage of area symbols was located in 1-3 minutes. There was a significant interaction of conditions x grades ($F = 2.37$; $df = 6, 60$; $p < .05$). The interaction is plotted in Figure 2 and shows that the instructional conditions facilitated performance in grades 4-6, lowered performance in grades 7-9, and had no effect in grades 10-12. A summary of the analysis of variance is shown in Table 6.

Table 5

Means and Standard Deviations of the Percentage of Total Target Area Symbols Located within Each Successive 1-Minute Period

| | Minutes 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| M | 28.94 | 15.05 | 13.66 | 8.33 | 3.94 |
| SD | 22.55 | 14.57 | 16.15 | 15.32 | 9.89 |

Table 6

Analysis of Variance of Percentage of Texture Area Symbols Located during Each Successive 1-Minute Period for Each Training and Grade Grouping Using an Arcsin Transformation

| Source | *df* | *SS* | *MS* | *F* |
|---|---|---|---|---|
| Total | 359 | 55.710203 | | |
| Between subjects | 71 | 4.999408 | | |
| Conditions | 3 | .246529 | .082176 | 1.29 |
| Grade groupings | 2 | .030402 | .015201 | .24 |
| Conditions x grades | 6 | .903952 | .150659 | 2.37* |
| Error | 60 | 3.818524 | .063642 | |
| Within subjects | 288 | 50.710795 | | |
| Time periods | 4 | 12.026303 | 3.006576 | 21.88** |
| Conditions x time periods | 12 | 1.336715 | .111392 | .81 |
| Grades x time periods | 8 | .527719 | .065965 | .48 |
| Conditions x grades x time periods | 24 | 3.850243 | .160427 | 1.17 |

*$p < .05$
**$p < .01$

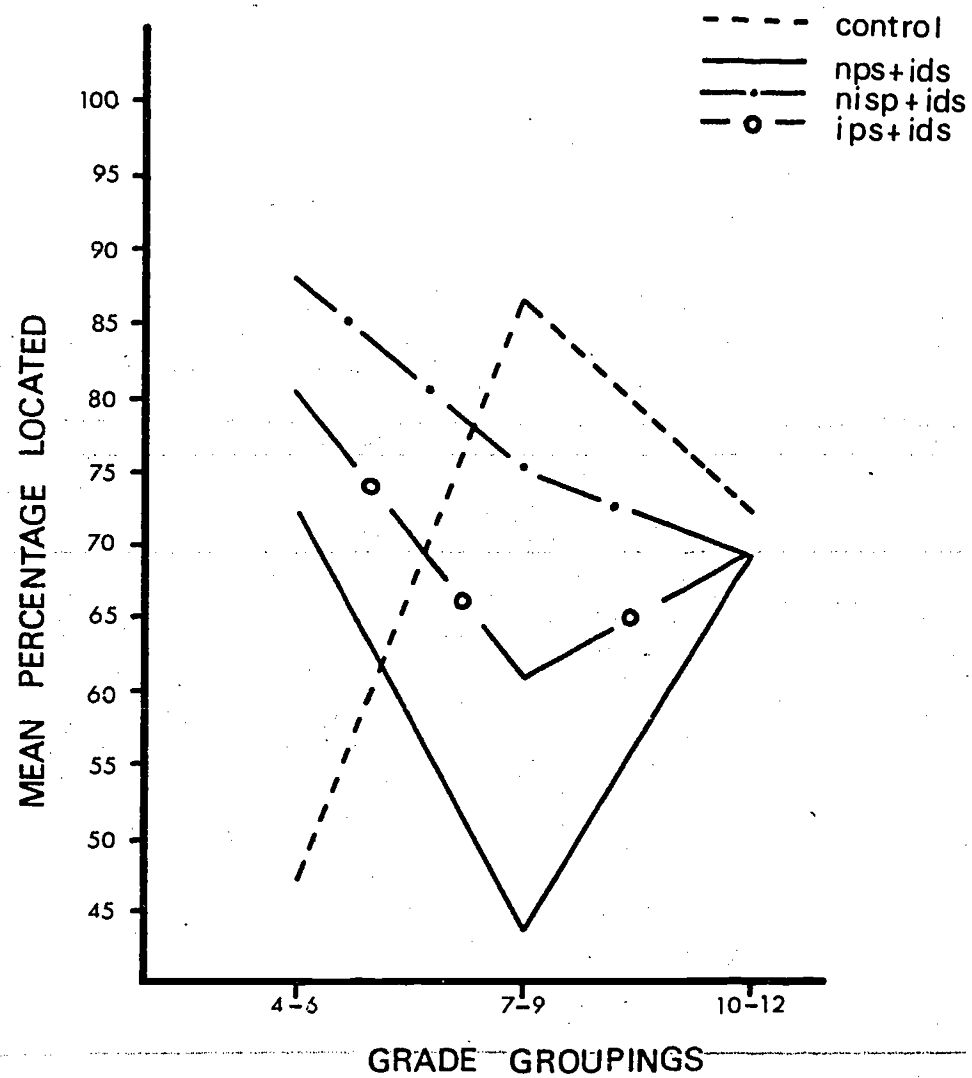


Figure 2. The percentage of target area symbols correctly located as a function of condition and grade grouping.

The data were also scored for errors of duplication (i.e., a duplication consisted of locating the same target symbol on two or more occasions as being a newly located symbol). A plot of these data showed extreme departure from normality and, consequently, in order to assess differences between grade groupings and conditions of training, separate Kruskal-Wallis one-way analyses of variance were performed. For the point symbol data there were no differences between instructional conditions in the number of errors of duplication ($\underline{H}$ = 1.20; $\underline{df}$ = 2; $\underline{p}$ > .05; corrected for ties), but there was a significant difference between grade groupings ($\underline{H}$ = 10.34; $\underline{df}$ = 2; $\underline{p}$ < .01; corrected for ties). Pairwise post hoc comparisons, using Nemenyi's procedure (Kirk, 1968), showed that the two higher grade groupings (7-9 and 10-12) had significantly lower mean rank error scores (29.04 and 33.17, respectively) than the lowest grade grouping (grades 4-6; mean rank = 47.25) [$\underline{dKW}$ = 12.26; $\underline{df}$ = 2; $\underline{p}$ < .01, two-tail].

Two separate Kruskal-Wallis analyses of variance were performed on the errors of duplication for the area symbols data. There was a significant difference between training conditions ($H = 6.85$; $df = 3$; $p < .05$ one-tail corrected for ties). Pairwise post hoc comparisons of the mean ranks of the four training conditions, using Nemenyi's procedure, showed that the Instructed Preliminary Scan--Instructed Detailed Scan condition had a significantly lower mean rank error score (27.94) than the mean rank of the control condition (41.81) [$dKW = 11.02$; $df = 3$; $p < .005$, one-tail]. A significant difference was found between grade groupings ($H = 7.84$; $df = 2$; $p < .02$, two-tail). Post hoc pairwise comparisons, using Nemenyi's procedure, showed that grade grouping 7-9 had a significantly lower mean rank error score ($M = 29.81$) than grade grouping 4-6 ($M = 44.88$) [$dKW = 12.26$; $df = 3$; $p < .01$; two-tail]. There was no significant difference between grade grouping 10-12 ($M$ rank = 34.81) and the other two grade groupings.

## Discussion

The results were not well defined with respect to the effects a frame of reference and scanning instructions had on the map reading task. The conclusions that can be drawn depend upon the nature of the dependent measure as well as the grade level of the students. One dependent measure was the total number of symbols located, which can be assumed to reflect the thoroughness with which the map was scanned. For the area symbols, the frame of reference and instructions facilitated performance in the lower grades (4-6), but lowered performance in the middle grades (7-9), and had no effect in the upper grades (10-12) when compared to the control group. This suggests that a preliminary scan and instructions can have a facilitating effect on students' performance when strong habits have not been established, but once the motor habits begin to be established, instructions which differ from the established pattern tend to interfere with or have no effect on the thoroughness with which students scan a display. On the contrary, previous studies (Berla', 1973; Berla' & Murr, 1974), which have used a brief training period in scanning a map, resulted in significantly superior performance across all grade levels.

The second dependent measure, errors of duplication, can be assumed to reflect the degree to which the students remembered what areas of the map had previously been searched and, consequently, what symbols they had found. For the texture area symbols, there were significantly fewer errors of duplication for those students given detailed instructions on how to give the map a preliminary scan and how to scan the map during a detailed search. A preliminary scan of a tactile display, in combination with instructions on how to scan the display, aided the student in organizing and remembering the position of the area symbols on the display. This conclusion should be tempered with the fact that a preliminary scan and detailed instructions did not reduce the errors of duplication for the point symbols. The point symbols were extremely small as compared to the area symbols and the students may have failed to notice the point symbols during the preliminary scan. Thus, the preliminary scan had no effect on subsequent performance. The area symbols, on the other hand, were quite large and could have been more noticeable during the preliminary scan. Consequently, the students may have obtained more information concerning the location of these symbols on the display than the point symbols.

A second factor was the differential memory load placed on the subjects by the 16 point symbols and the 6 area symbols. Even if the subjects noticed the point symbols during a preliminary scan, it would have been difficult to accurately remember the location of the point symbols, since 16 items or positions far exceed the average memory capacity of 7 ± 2 items (Miller, 1956). The 6 area symbols were well within the average memory capacity, and the positions of these symbols were more likely to be remembered. Further research could focus on the total number of symbols as well as the number of identical symbols that can be placed on a tactile display and still enable the student to retain information about their locations.

There were also significantly fewer errors of duplication for the upper two grade groupings (7-9 and 10-12) as compared to the lower grade grouping (4-6). This probably reflects their greater experience with tactile displays, in general, as well as greater memory capacity and motor skills.

One consistent but minor finding in this study was the fact there was a decreasing percentage of target symbols located during each successive minute. Since the total number of target symbols located reflects the completeness with which the map was covered, it indicates that there is a limitation to the amount of time that should be spent in searching a tactile display for general information. A map of this size or smaller could be covered fairly completely in 3 minutes or less, without any considerable loss in information.

Comparison of the outcome of this study with previous studies in map reading suggests that instructions on how to scan a display or how to perform a map reading task are much less effective than instructions with a few minutes of training and practice. Future studies investigating the effects of a frame of reference on a subsequent map reading task should incorporate a specific training condition into the design.

STUDY III

# THE EFFECTS OF DIFFERENT FRAMES OF REFERENCE ON THE LOCATION OF SHAPES ON A TACTILE POLITICAL PSEUDOMAP

Edward P. Berla' and Marvin J. Murr

40

## Abstract

Seventy-nine braille readers from grades 4-12 were tested under three different conditions to determine if a frame of reference, in the form of a preliminary scan, would facilitate performance in locating shapes on a tactile political pseudomap. Subjects were shown a series of 6 shapes (U.S. states) and asked to locate them on a map after having had: (a) no preliminary scan of the map, (b) no preliminary scan but trained to search the map with a vertical search pattern, (c) a preliminary scan using a vertical search technique. A multivariate analysis of covariance was performed using IQ (WAIS and WISC) as the covariate with the following dependent measures: the percentage of shapes correctly located without recognition errors, the number of shapes located regardless of the number of recognition errors, and task time. The only significant treatment effect was in increase in performance over grade levels. A frame of reference had no effect on performance. The inability of subjects to read tactile political maps was discussed with suggestions for improving educational materials and training procedures.

## STUDY III

## THE EFFECTS OF DIFFERENT FRAMES OF REFERENCE ON THE LOCATION OF SHAPES ON A TACTILE POLITICAL PSEUDOMAP

A typical tactile political map consists of a series of interconnecting lines forming a number of embedded shapes. A preliminary scan of such a display should provide the student with specific information as to the nature of the figures on the display, certain distinctive features of the display, and where these distinctive features are located. Videotapes of students working with tactile pseudomaps (Study I) in which they were permitted a preliminary scan indicated that some students appeared to remember where certain distinctive features of some bounded areas were located and quickly located them when presented with cue cards showing the shapes.

A pervasive problem with the map reading performance of blind students is their lack of ability to systematically and completely search a tactile display. Consequently, even when they are instructed to search a tactile display systematically, their search pattern is, at best, incomplete. However, it has been found that a few minutes of training students to use a vertical search pattern facilitates their performance and leads to a more complete search of the display (Berla', 1973; Berla' & Murr, 1974).

The present study was designed to determine whether a frame of reference in the form of a systematic preliminary scan of a raised line political pseudomap would facilitate blind students' performance in locating bounded political entities. There were three conditions:

1. No frame of reference, no training (baseline control): Students were asked to locate shapes on a political pseudomap without having had a preliminary scan of the display or any training on how to search the display.

2. No frame of reference with vertical trained search: Students were asked to locate shapes on a political pseudomap without having had a preliminary scan of the display. However, all students were trained to search the display using a systematic vertical search in order to locate the shapes.

3. Vertical frame of reference with vertical trained search: Students were trained to search the display using a systematic vertical search. They were then given a 3-minute preliminary scan of the political pseudomap using the vertical technique. The students were asked to locate the shapes on the pseudomap using the vertical search technique.

### Method

#### Subjects

The subjects were 79 students in grades 4-12 who used braille as their primary reading medium at the W. Ross MacDonald School for the

Blind in Ontario, Canada. The means and standard deviations of their ages according to grade groupings (4-6, 7-9, 10-12) and sex are presented in Table 1.

Table 1

Means and Standard Deviations of Ages of Subjects

According to Grade Grouping and Sex

| Grade Grouping | Male | Female | Total |
|---|---|---|---|
| 4-5-6 | *M* = 12.66<br>*SD* = 1.62<br>*n* = 18 | *M* = 11.98<br>*SD* = 1.37<br>*n* = 8 | *M* = 12.45<br>*SD* = 1.56<br>*n* = 26 |
| 7-8-9 | *M* = 15.15<br>*SD* = 1.58<br>*n* = 15 | *M* = 14.24<br>*SD* = 1.29<br>*n* = 12 | *M* = 14.75<br>*SD* = 1.51<br>*n* = 27 |
| 10-11-12 | *M* = 17.85<br>*SD* = .89<br>*n* = 46 | *M* = 19.06<br>*SD* = 1.56<br>*n* = 33 | *M* = 18.45<br>*SD* = 1.39<br>*n* = 26 |
| Total | *M* = 14.94<br>*SD* = 2.55<br>*n* = 46 | *M* = 15.59<br>*SD* = 3.27<br>*n* = 33 | *M* = 15.21<br>*SD* = 2.87<br>*n* = 79 |

## Materials

Two tactile pseudomaps were constructed. The test map consisted of six states of the U.S. of equivalent sizes. The states with their areas were:

| State | Area in Square Miles | Area in Square Kilometers |
|---|---|---|
| Alabama | 51,078 | (132,292.02) |
| Arkansas | 52,725 | (136,557.75) |
| Florida | 54,262 | (140,538.58) |
| Illinois | 55,947 | (144,902.73) |
| Iowa | 55,986 | (145,003.74) |
| Wisconsin | 54,715 | (141,711.85) |

The six states' boundaries were drawn from a base map in Reader's Digest Great World Atlas (1963, p. 47). The map scale was 1 inch (2.54 cm) to 142 miles (228.52 km) or 1 = 9,000,000. A braille size page was divided into a grid having five rows and four columns. One of the six states was randomly chosen and this state was randomly assigned to one of the 20 positions on the page. Each state was placed in one of the cells with the restriction that no two states could occupy adjacent cells in the same column or row. In order to add degrees of complexity to the map, 20 additional lines were added to the map to interconnect the states and to divide up the remaining space on the map. Twenty lines were used because in Study I there was no difference in performance between students using a 10 line map and a 15 line map. In order to make the task more difficult it was decided to use 20 additional lines. The additional lines were actual boundary lines taken from the U.S. base map and shortened where necessary to fit within the size of the paper. The test map was 10 X 12 inches (25.40 X 30.48 cm) and is shown in Figure 1.

The second map was a familiarization-practice map. It was constructed using the same format as the test map. For the practice map three states were selected:

| State | Area in Square Miles | Area in Square Kilometers |
|---|---|---|
| New York | 47,929 | (124,136.11) |
| North Carolina | 49,142 | (127,277.78) |
| Georgia | 58,518 | (151,561.62) |

Each of these states was arbitrarily placed on a braille size page and five additional lines were added to the map to interconnect the states and divide up the remaining space. The practice map was 10 X 12 inches (25.40 X 30.48 cm).

The tactile maps were made from line drawings of these maps through a photoetching process. The male molds obtained were used in a drape molding process to produce plastic copies. The height of the lines was .025 inch (.064 cm) and the width of the lines was .020 inch (.051 cm). Each plastic map was mounted on cardboard with a nonskid backing. For the test map six cue cards were made with each cue card showing one of the six states. The six states were cut from one plastic copy of the map and each state was mounted on 3.5 X 3.5 inch (8.89 X 8.89 cm) cardboard with a nonskid backing. The same procedure was used for the familiarization-practice map except that there were only three cue cards showing each of the three states.

## Design and Procedure

The subjects' basic tasks were to inspect the state presented on the cue card and then to locate the same state on the map. The shapes were presented in their familiar orientation.

There were three conditions and they were respectively:

1. No frame of reference, no training (baseline control): Subjects were told that they would be presented with a map that had several shapes on it and series of three cue cards showing each of the shapes. The subjects were shown one of the cue cards first and told to inspect the cue card and to locate the same shape on the map. The subjects were not permitted to explore the map prior to locating the shape on the map. Following the practice map they were presented with the test map and required to perform the same basic task only this time locating six shapes.

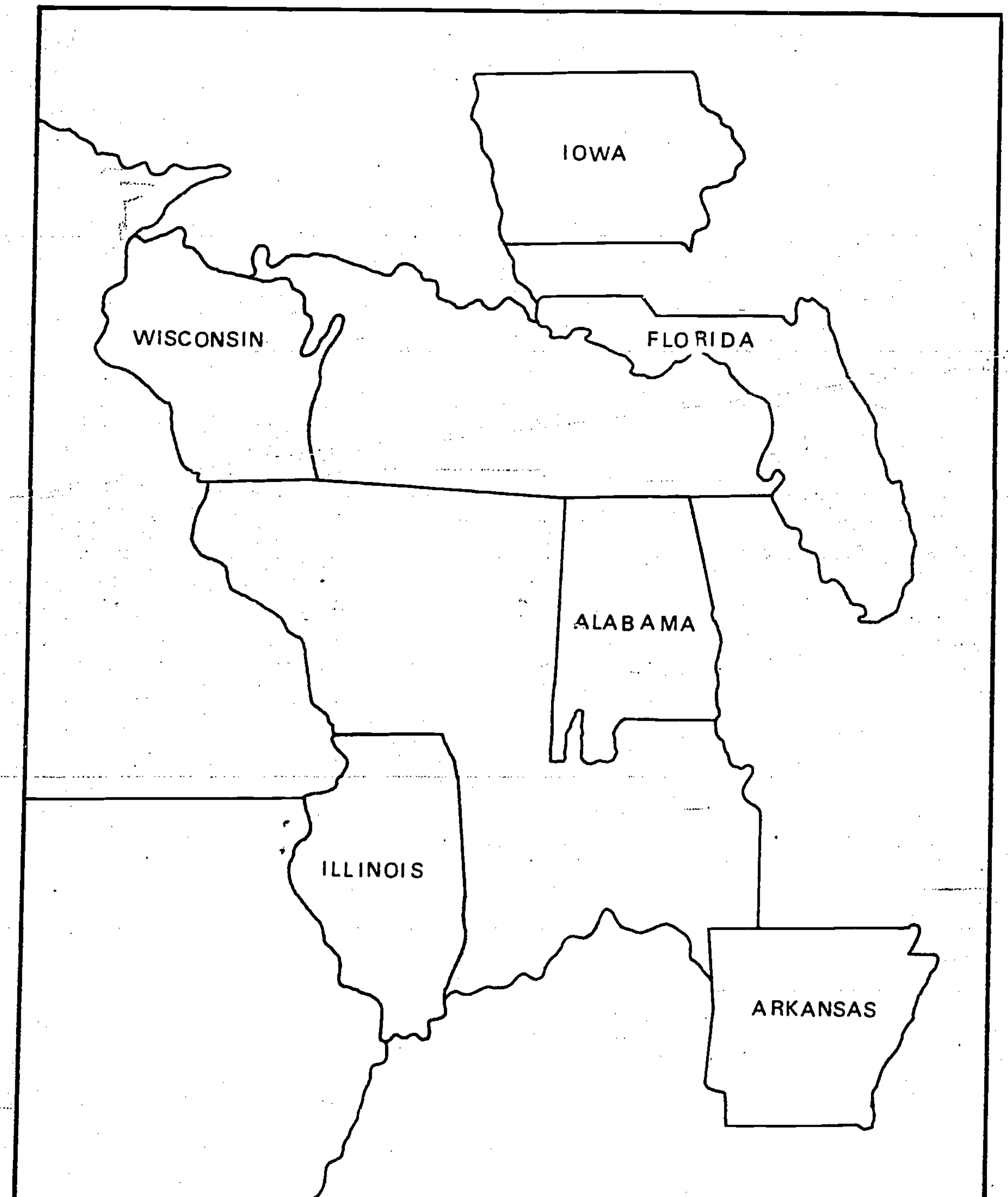


Figure 1. Tactile political pseudomap used for the test. The size of the map was 10 X 12 inches (25.40 X 30.48 cm). The lines were .02 inch wide (.051 cm) and raised .025 inch (.064 cm) above the surface. The six target states are indicated by name.

2. No frame of reference with vertical trained search: Subjects were asked to locate shapes on the pseudomap after having been trained to search a display with a vertical search technique. The subjects were told the nature of the task (locating shapes on a map) and then told to search the map using a vertical search technique. They were trained to use the technique on a flat piece of cardboard the same size as the pseudomaps. Following training they were presented with the first practice shape and asked to locate the shape on the map by searching the map with the vertical technique. During the practice period, deviations from the accepted pattern were corrected. For example, typical mistakes were failure to completely cover a column or moving over too far, or not far enough, when beginning to search a new column. Following the practice period the subjects were presented with the first test shape and reminded to search the pseudomap using the vertical technique.

3. Vertical frame of reference with vertical trained search: Subjects were told the nature of the task and then told to search the display using a vertical search technique. The subjects were trained in the use of a vertical technique on a flat piece of cardboard the same size as the pseudomaps. Following training they were presented with the practice pseudomap and told to inspect it using the vertical technique and to notice the shapes and trace the lines with their fingertips. The subjects were given 3 minutes to search the map. They were then shown the first practice shape and asked to locate it on the pseudomap using the vertical search technique. During the search period, deviations from the accepted pattern were corrected. Following the practice period, subjects were presented with the test map, reminded to inspect it with a vertical technique, told to notice the shapes, and to trace the lines. The subjects were given 3 minutes to search the map and then were presented with the first cue card and reminded to search for the shape using a vertical technique. No feedback, corrections, or instructions were given during the preliminary scan of the test map except to remind the subjects to continue searching the display in case they stopped scanning before the 3 minutes were up.

All subjects in all conditions were required to inspect each cue card for 45 seconds prior to attempting to search the map for each shape. A maximum of 5 minutes was allowed for each shape during the practice and test periods. A subject was timed from the time the experimenter said "begin" to the time the subject completed the tracing of the correct target shape. When a subject located the wrong shape, he was told it was the wrong shape and to look for the correct one.

## Results

The data consisted of four dependent measures: mean number of shape recognition errors (a subject located one or more shapes that were not the correct shape), percentage of shapes correctly located without a recognition error, percentage of shapes correctly located regardless of the number of recognition errors, and mean task time to locate the correct shape.

Since IQ (WAIS and WISC) scores were available, a multivariate analysis of covariance was performed on all four dependent measures using the IQ measure as a covariate. A multivariate test of significance was performed using Wilks Lambda Criterion to determine if IQ scores were significantly related to any of the dependent measures. The overall test of significance showed a highly significant effect for IQ ($F$ [4,66] = 5.70, $p < .001$). Separate univariate tests of significance showed that IQ was significantly related to two of the dependent measures; namely, IQ was positively correlated with the percentage of shapes correctly located regardless of the number of recognition errors ($F$ [1, 69] = 9.64, $p < .002$) and negatively correlated with mean task time ($F$ [1, 69] = 13.43, $p < .001$). There were no significant relationships between IQ and recognition errors ($F$ [1, 69] = 2.38, $p > .05$), or between IQ and the percentage of shapes correctly located without recognition errors ($F$ [1, 69] = 2.88, $p > .05$). The within groups regression coefficients for IQ and the number of shapes located without recognition errors; the number of shapes located with and without recognition errors; the number of recognition errors; and task time were respectively: .30, .44, .03, and -1.63.

Univariate tests of significance using Wilks Lambda Criterion were performed and showed no significant effect associated with conditions or the interaction of grades x conditions for any of the dependent measures (all $p$'s > .05). A summary of the adjusted means, unadjusted means, and standard deviations for grade groupings and conditions for each dependent measure is shown in Table 2. A significiant effect was found for grade groupings on each of three dependent measures, namely; recognition errors, ($F$ [2, 69] = 4.18, $p < .019$), the percentage of shapes located without recognition errors ($F$ [2, 69] = 5.37, $p < .006$), and task time ($F$ [2, 69] = 4.18, $p < .019$). The adjusted means, the unadjusted means, and the standard deviations for each significant dependent measure are shown in Table 3. Inspection of the means shows that recognition errors and task time decreased with increases in grade level and the percentage of shapes located increased with grade level.

At the completion of the map task the subjects were asked four questions, namely;

1. This map was hard to read. Why?
2. What do you think was wrong with the map?
3. How could we make it better?
4. When I showed you a shape what did you look for on the map?

Table 2

Adjusted Means (for IQ), Unadjusted Means, and Standard Deviations for Grade Groupings (4-6, 7-9, 10-12) and Conditions on Several Dependent Measures

| Conditions | Grade grouping | Number of recognition errors | | | Percentage of shapes located without recognition errors | | | Percentage of shapes correctly located with or without recognition errors | | | Mean task time (sec.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M' | M | SD | M' | M | SD | M' | M | SD | M' | M | SD |
| No frame of reference and no training | 4-6 | 2.62 | 2.56 | 2.46 | 56.21 | 55.56 | 36.32 | 71.33 | 70.37 | 38.89 | 166.24 | 169.81 | 83.91 |
| | 7-9 | 1.89 | 2.00 | 2.40 | 78.45 | 79.63 | 20.03 | 92.74 | 94.44 | 11.78 | 83.33 | 76.96 | 53.29 |
| | 10-12 | 1.22 | 1.33 | 1.94 | 76.60 | 77.78 | 22.05 | 90.88 | 92.59 | 8.79 | 115.55 | 109.19 | 52.40 |
| No frame of reference and vertical training | 4-6 | 4.32 | 4.00 | 2.67 | 51.38 | 47.92 | 20.77 | 90.44 | 85.42 | 18.77 | 135.50 | 154.25 | 67.90 |
| | 7-9 | 1.00 | 1.00 | 1.66 | 81.44 | 81.48 | 25.61 | 88.83 | 88.89 | 16.67 | 121.57 | 121.35 | 63.91 |
| | 10-12 | .82 | 1.00 | 1.58 | 81.39 | 83.33 | 20.41 | 87.92 | 90.74 | 12.11 | 93.89 | 83.37 | 55.15 |
| Vertical frame of reference and vertical training | 4-6 | 2.16 | 2.11 | 2.42 | 65.30 | 64.81 | 24.22 | 76.64 | 75.92 | 22.22 | 169.92 | 172.59 | 68.99 |
| | 7-9 | 2.60 | 2.67 | 4.74 | 73.33 | 74.07 | 18.84 | 82.26 | 83.33 | 11.78 | 140.35 | 136.33 | 64.78 |
| | 10-12 | .71 | .63 | 1.41 | 71.78 | 70.83 | 26.35 | 82.63 | 81.25 | 24.30 | 133.60 | 138.73 | 74.97 |

Table 3

Adjusted Means (for IQ), Unadjusted Means, and Standard Deviations for the Number of Recognition Errors, Percentage of Shapes Located without Recognition Errors, and Mean Task Time to Locate a Shape for Each of Three Grade Groupings

| Grade grouping | Number of recognition errors | | | Percentage of shapes located without recognition errors | | | Mean task time | | |
|---|---|---|---|---|---|---|---|---|---|
| | *M'* | *M* | *SD* | *M'* | *M* | *SD* | *M'* | *M* | *SD* |
| 4-6 | 2.98 | 2.85 | 2.54 | 57.87 | 56.41 | 27.92 | 158.06 | 165.99 | 71.64 |
| 7-9 | 1.83 | 1.89 | 3.17 | 77.74 | 78.39 | 21.09 | 115.08 | 111.55 | 63.89 |
| 10-12 | .93 | 1.00 | 1.62 | 76.78 | 77.56 | 22.58 | 113.60 | 109.34 | 62.81 |

Of the 79 subjects, 78% (62) responded to one or more of the first three questions. Of the 62 subjects, 73% (45) indicated that the map was difficult to read because the shapes and/or lines were too close together and should be separated. Fifty-nine subjects responded to the fourth question on locating shapes. Twenty-eight (47%) said they located a shape by searching for a distinctive feature (e.g., "a part that stuck out"), 19 (32%) subjects indicated they searched for a whole shape, and 11 (19%) subjects indicated they located the shape by a combination of distinctive features and the whole shape. These responses constituted the only consistent answers to the questions. The remaining subjects responded with a wide variety of problems and suggestions: too many shapes (2 subjects), shapes were too similar (4 subjects), shapes were too complicated (1 subject), raise the distinctive features higher than the rest of the shape (1 subject), and use different textures (1 subject).

## Discussion

A frame of reference, in the form of a preliminary scan, had absolutely no effect on students' ability to locate shapes on a political pseudomap. Videoanalysis of students working with tactile political maps in previous research and on-site observations in this study suggest that during a preliminary scan the students do not perceive a political map as a series of juxtaposed shapes. Students typically scan the map as if it were a series of interconnected lines; they tend to follow lines rather than delineate shapes. Poor shape concepts coupled with a lack of experience in using political maps appeared to be the main factors contributing to poor performance. Line tracing, the tracing of the whole shape, the analysis and recognition of a shape by distinctive features, and disembedding a shape from surrounding shapes appear to be important skills and concepts that are prerequisites to tactile political map reading. While some students demonstrated these skills to a high degree and were able to benefit from a preliminary scan, the overwhelming majority gained little or no information from the preliminary scan.

While there was evidence of significantly better performance at the higher grade levels, there was no indication that a frame of reference aided performance in the upper grade levels any more than in the lower grade levels.

Performance on this map reading task was significantly correlated with intelligence; the higher the IQ score the better the performance. While this suggests that the more intelligent students use maps more effectively than students with lower intelligence, it is not suggested that maps and map reading be confined to the more intelligent students. The fact that performance improved over grade levels, adjusted for differences in intelligence test scores, is evidence for the efficacy of experiential factors in contributing to the use of maps by blind students.

The answers to the questions suggest that political maps could be redesigned so as to physically separate the shapes which would make each political entity perceptually distinct. Since the majority of the subjects indicated that they use distinctive features in locating and identifying shapes, this could be emphasized in using maps with blind students. Finally, the suggestion by one student to raise some distinctive features of a shape higher than the rest of a shape would appear to be an important observation. This would make the distinctive features more salient and facilitate the location and identification process.

STUDY IV

# TACTUAL SCANNING AND MEMORY FOR A SPATIAL DISPLAY BY BLIND STUDENTS

Edward P. Berla' and Marvin J. Murr

Abstract

One of the primary purposes of maps is to convey information about space and spatial relationships. This study was an attempt to determine whether specific training in scanning a tactile display would enable blind students to organize the spatial relationships presented more effectively than students not so trained. In this study, 36 braille students in grades 4-12 were asked to inspect a tactile display consisting of nine removable symbols. After inspecting the display the nine symbols were removed and the students were asked to replace the parts in their correct location. There were two groups: A control group which received no training and an experimental group which was trained to systematically search the display using a vertical search technique. The results show that the students in the lower grade levels benefited most from the training and were superior to the control group in the same grades. However, training interfered with the performance of the students in the upper grade levels (10-12) with the control group performing better than the experimental group. Apparently, training is effective before strong habits have been established.

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# STUDY IV

# TACTILE SCANNING AND MEMORY FOR A SPATIAL DISPLAY BY BLIND STUDENTS

One of the primary purposes of diagrams and maps is to convey information about space and spatial relationships. For the blind student the major modality for obtaining information about spatial relationships is the tactual-kinesthetic sense. Consequently, tactile diagrams and maps potentially serve as important educational tools in educating blind students about the nature of their environment. However, the tactual-kinesthetic sense is not as adequate as vision in acquiring information from displays, primarily because of the piecemeal, fragmentary, and serial nature of acquiring information via tactual inspection. This, in part, could account for the difficulty many blind students have in reading and using tactile diagrams and maps effectively.

The present study focused on the scanning behavior of blind students and the effect this scanning behavior had on their memory of a tactile display. Previous research (Berla', 1973; Berla' and Murr, 1974) has shown that scanning a tactile display with a vertical search pattern was an effective way of locating symbols on the display. The present study attempted to determine whether specific training in the use of a vertical search technique would enable blind students to remember the spatial relationships presented on a tactile display more effectively than students not so trained. Specifically, each student was asked to inspect a dissectable display for 5 minutes after which the pieces of the display were removed and the student was asked to replace the parts into their correct location. One group of students was not given any training while a second group was trained in the use of a vertical search technique. In order to determine the feasibility of the procedures, tasks, and materials of the study, a pilot study was conducted. In the pilot study each student was asked to perform the task first without any training and then to perform the task again after receiving training in the use of a vertical search technique.

## Pilot Study

### Method

Subjects. The subjects were three male and four female students who used braille as their primary reading medium and were enrolled at the Indiana School for the Blind. One student from each of grades 4 through 11 was chosen as a subject. The range, mean, and standard deviation of their ages were: range = 10.67 years-18.58 years, $\underline{M}$ = 14.10 years, $\underline{SD}$ = 2.67.

Materials. Two test displays were developed. One display contained nine tactile point symbols and a second display contained nine textured areal symbols. All the symbols in each display were highly discriminable for blind students (Nolan & Morris, 1971). The symbols were produced through a photoengraving process which produced male molds. Plastic copies were made by drape molding styrene plastic over the male molds. The symbols were randomly assigned to one of nine equal sized squares in a 14 X 14 inch (35.56 X 35.56 cm) grid. Each symbol was also randomly assigned to one of five positions in a given square (four corners or center). The symbols were mounted on 4 X 4 inch (10.16 X 10.16 cm) wooden blocks, and the set of nine blocks was fitted into a wooden grid frame that had nine separate compartments. Each block was raised .5 inch (1.27 cm) above the compartment walls and could be removed from the frame without disturbing any of the other blocks.

Each point symbol was drawn within a .5 inch (1.27 cm) square so that at least one dimension of each symbol was .5 inch (1.27 cm) in length. The nine textured areal symbols were reproduced in 2 inch (5.08 cm) squares.

One additional display was constructed and used in a preliminary familiarization task. The display consisted of two point and two areal symbols mounted on wooden blocks and fitted into a four-compartment wooden frame similar to the one used in the test task.

Procedure. The subjects were told that they would inspect a dissectable display and be asked to remember the position of each shape or texture in the display. Following the inspection they would be given the nine blocks of the display and asked to replace them into their correct positions within the frame.

All subjects were shown the practice display first and how the four blocks could be removed from the frame. The four blocks were then placed in the frame and the subjects were asked to inspect the display for 1 minute and to remember the positions of the figures within the display. Following the 1-minute search, the blocks were removed and two blocks were randomly placed on the left and right sides of the frame. Each subject was given 1 minute to replace the blocks into the frame in their correct positions. After the subject replaced the blocks, the experimenter took the subject's hand and showed him where any misplaced blocks should have been placed. If no errors were made, the subject was told that he was correct. Each subject was given two additional configurations of the practice display and the same correction procedure was followed. Following practice, each subject was given either the point symbol or areal symbol test display and told he would have 5 minutes to inspect the display. At the end of 5 minutes, the blocks were removed and randomly placed along the bottom, left, and right sides of the frame. In order to control for the time delay between placement of the blocks around the sides of the frame and the beginning of the replacement task by the subject, a fixed 2-minute interval was given between the end of the inspection period and the beginning of the replacement period. Each subject was given a maximum of 5 minutes to replace the blocks.

Following this task, each subject was shown how to search a display using a vertical search technique. The training was conducted on a plain 8 X 8 inch (20.32 X 20.32 cm) piece of cardboard. The training consisted of having the subject scan the display in columns from top to bottom. After reaching the bottom of the display, the subject returned his hands to the top of the display and scanned down the next column. The subject was then given two practice trials using the vertical inspection technique with the four-block practice display. Subsequently, the subject was given the nine-block display and allowed a full 5 minutes to inspect it using the vertical scanning technique. At the end of 5 minutes, the blocks were removed during the 2-minute fixed interval and placed along the bottom, left, and right sides. The subject was then asked to replace the blocks into their correct locations.

For both the free scan and the vertical scan, four subjects were given two different configurations of the point symbol display and three subjects were given two different configurations of the areal symbol display. Each subject's performance was videotaped and the amount of time, in seconds, required to complete the tasks, as well as the accuracy, was recorded.

## Results

Performance was very high under all conditions indicating a ceiling effect. Overall performance for the free scan was 89% correct replacement and for the vertical scan 87% correct replacements. Only two subjects of the seven failed to achieve 100% correct replacements on the free scan and only three of the seven subjects failed to achieve 100% accuracy using the vertical scan.

The videotapes were analyzed in terms of the type of scan and the number of complete scans of the display during both the "free" scan period and the vertical scan period. Six of the subjects used a horizontal or horizontal and vertical type scan during the free period. One subject used a perimeter type scan. The average number of complete scans during the 5-minute inspection period was 9.71 scans during the free period and 14.86 scans during the vertical scan period.

Additional analysis of the videotapes showed that all seven subjects picked up a block and then searched for the correct cell rather than picking a cell and then looking for the block that belonged in that cell. Observations of the videotapes plus questioning of the subjects revealed that the frame divided into nine cells contributed substantially to the ease of completing the tasks. The subjects appeared to remember the symbols in rows of three and tried to remember which of three rows a block belonged in (top, middle, or bottom) and whether it was the first, second, or third in the sequence.

## Discussion

The pilot study suggested that the task was too easy as indicated by the very high scores under all conditions. It appeared that the frame, into which the blocks were placed, contributed substantially to the ease of the task. The pilot study also indicated that allowing a full 5 minutes to inspect the display allowed the subjects to memorize the positions of the nine symbols. Consequently, in order to determine whether training in scanning would actually facilitate performance, it would be necessary to make the task more difficult by eliminating the frame and reducing the inspection time allowed. Therefore, a new set of materials and a refined design and procedure were developed for the formal testing with a larger number of subjects.

## Experiment

### Method

Subjects. The subjects were 36 students enrolled at the Overbrook School for the Blind who used braille as their primary reading medium. The means and standard deviations of their ages, according to grade grouping and sex, are presented in Table 1.

Table 1

Means and Standard Deviations of Ages (in years) of Subjects According to Grade Grouping and Sex

| Group | Male | Female | Total |
|---|---|---|---|
| Grade levels 4-5-6 | M = 11.07<br>SD = 1.79<br>n = 5 | M = 11.46<br>SD = 1.11<br>n = 7 | M = 11.30<br>SD = 1.37<br>n = 12 |
| Grade levels 7-8-9 | M = 15.25<br>SD = 2.94<br>n = 6 | M = 15.59<br>SD = 1.22<br>n = 6 | M = 15.42<br>SD = 2.15<br>n = 12 |
| Grade levels 10-11-12 | M = 19.35<br>SD = 1.45<br>n = 6 | M = 19.35<br>SD = 1.51<br>n = 6 | M = 19.35<br>SD = 1.41<br>n = 12 |
| Total | M = 15.47<br>SD = 3.98<br>n = 17 | M = 15.26<br>SD = 3.56<br>n = 19 | M = 15.35<br>SD = 3.71<br>n = 36 |

Materials. Two test displays were developed. One display contained nine tactile point symbols and a second display contained nine textured areal symbols. All the symbols in each display were highly discriminable (Nolan & Morris, 1971). Each symbol was produced through a photoengraving process which makes male molds. Plastic copies were made by drape molding styrene plastic over the male molds. Each of the nine symbols in each display was randomly assigned to one of nine equal-sized squares within a 15 X 15 inch (38.10 X 38.10 cm) grid. Each symbol was also randomly assigned to one of five positions in a given square (four corners or center). Each symbol was mounted on a 2.5 X 2.5 inch (6.35 X 6.35 cm) piece of cardboard and backed with pieces of male velcro. Three test boards were made by gluing sheets of female velcro 15 X 15 inches (38.10 X 38.10 cm) to separate pieces of cardboard. In this way, when a symbol was placed on the test board the male velcro would attach itself to the female velcro and would remain in place until pulled off with firm pressure.

The set of nine point symbols was placed on one test board in their correct locations as indicated by the random assignment previously described. The set of nine areal symbols was placed on another test board using a different random order than was used for the point symbols. The maximum dimension of each point symbol was .5 inch (1.27 cm) and the size of the areal symbols was 2 X 2 inches (5.08 X 5.08 cm). A duplicate set of both sets of symbols was made and, after a subject inspected one of the test displays, he was given a plain 15 X 15 inch (38.10 X 38.10 cm) velcro board on which he was to place the nine duplicate test symbols.

A practice board was made by gluing female velcro to a 9.75 X 9.75 inch (24.77 X 24.77 cm) piece of cardboard. Four additional discriminable symbols were chosen (two point and two areal), mounted on cardboard, and backed with pieces of male velcro. The correct locations of the symbols on the test and practice boards were marked off with a white crayon in 2.5 X 2.5 inch (6.35 X 6.35 cm) squares on which each symbol was placed. Each white square had a letter written in the center and the same letter was written on the corners of the appropriate symbol.

A transparent scoring grid was made from thin plastic. The 15 X 15 inch (38.10 X 38.10 cm) scoring grid was ruled in .5 inch (1.27 cm) squares and placed over each test board. The exact center of each target symbol was determined, and a black dot placed in the center of each symbol. When the scoring grid was placed over each test board containing the symbols, the black dots showed through and indicated which of the .5 inch (1.27 cm) squares were target squares. Each target square was marked on the grid with the same letter as the symbol centered in it. Each .5 inch (1.27 cm) square was numbered from 1 to 900.

<u>Procedure</u>. The subjects were told that they were going to work with some "puzzles" that had nine different shapes or textures. The subject's task was to feel the "puzzle" and remember the place where each shape or texture was located. The puzzle was then removed and the subject was given a blank board and the parts of the puzzle and told to put the parts back into their correct location.

The control group was given three practice trials with three different configurations of the four-part puzzle. Each subject was presented with the four-part puzzle and given 1 minute for inspection. At the end of 1 minute, the parts were removed from the board and placed in random order around the left and right sides (two parts to a side). The subject was then given 1 minute to put the pieces back into their correct location. The experimenter then corrected the subject by placing his hand on each part that was not correctly placed and moving the subject's hand with the part in it to the correct location. The same four parts were used for two additional trials consisting of different configurations of the four parts.

The training group received the same preliminary instructions as the control group and was given one presentation of the four-part puzzle. After correcting the subjects' responses, the subjects in the training group were given instructions on how to search a display using a vertical scanning technique. The subjects were told to use two hands and to start in one of the upper corners of the puzzle, keeping their hands next to each other, and to scan down the puzzle. When their hands reached the bottom of the puzzle they were told to return them to the top where they had begun and to move their hands over just far enough so they could search the next section of the puzzle. They were told to search the puzzle in this way until told to stop. The subjects were given approximately 4 minutes of instruction in this technique on a plain piece of cardboard. Following the training period, they were given two additional training trials using the vertical scan with the four-part puzzle and deviations from the accepted scanning pattern were corrected.

The subjects in the training and control groups were then presented with one of the nine-item test puzzles. They were told to inspect the puzzles and to remember the location of the parts. The training group was reminded to search the puzzle using the vertical search pattern. All subjects were given a full 4 minutes to search the puzzle and then told to stop. There was a 2-minute interval while the experimenter removed the puzzle and placed a blank board in front of the subject. The puzzle parts were placed along the bottom, left, and right sides (three to each side) in a predetermined random sequence. At the end of 2 minutes the subjects' hands were moved along the sides and bottom of the puzzle to indicate where the parts were, and then they were given 5 minutes to replace the parts in their correct location.

Each subject in each condition was given both the point symbol and areal symbol puzzles in sequence. Half the subjects in each condition started with the point symbol puzzle followed by the areal symbol puzzle and half in the reverse order. No feedback was given during the test phase. After the subjects had replaced the symbols on the board, the transparent grid was placed on top of the board and the number of the square in which the subject placed each symbol was recorded.

## Results

The data consisted of the linear distance each subject misplaced each of the nine target symbols from its correct target square. Each subject's placement was indicated by two numbers representing the coordinates of this placement with respect to the target square. Coordinate measurements were taken from the centers of the placement and target squares. To obtain the distance each subject misplaced each symbol, the coordinates were used in Pythagoras' Theorem. Consequently, each subject had one score for each symbol he had placed on the board. The average of the nine scores constituted the average absolute error for the nine target symbols. The scores thus obtained were used in a three-way analysis of variance in which grade groupings (4-6, 7-9, and 10-12) and conditions (control vs. training) constituted the between subjects' variables and symbols (areal vs. point) constituted the within subjects' variable. The analysis showed there was a significant difference in absolute error between symbols ($F$ = 21.78; $df$ = 1, 30; $p$ < .01) with subjects making less average error with the point symbols than with the areal symbols (point $M$ = 1.70 inches [4.32 cm], $SD$ = 1.08 inches [2.74 cm]; areal = $M$ = 2.38 inches [6.04 cm], $SD$ = 1.22 inches [3.10 cm]).

Of more importance was the significant interaction of grades x conditions ($F$ = 3.65; $df$ = 2, 30; $p$ < .05). The means and standard deviations of the absolute error for each condition for each grade grouping is shown in Table 2. The interaction shows that the control group improved in performance over the grade groupings while the training group decreased in performance over grade groupings. However, inspection of the mean error performance shows that training facilitated performance in the lowest grade grouping to the extent that the absolute error scores for the trained group were only about half those for the untrained group in grades 4-6. In addition, performance of the trained group in grades 4-6 was equivalent to the performance of subjects in the untrained group in grades 10-12. A summary of the analysis of variance is shown in Table 3.

Table 2

Organization of Space

Means and Standard Deviations for Absolute Errors in Inches (cm) in Grades 4-6, 7-9, 10-12 for Trained and Untrained Subjects

| Group | Trained | Untrained |
|---|---|---|
| Grade levels 4-5-6 | $M$ = 1.50 (3.81)<br>$SD$ = .75 (1.91)<br>$n$ = 6 | $M$ = 2.50 (6.35)<br>$SD$ = .95 (2.41)<br>$n$ = 6 |
| Grade levels 7-8-9 | $M$ = 1.93 (4.90)<br>$SD$ = 1.12 (2.84)<br>$n$ = 6 | $M$ = 1.80 (4.57)<br>$SD$ = 1.41 (3.58)<br>$n$ = 6 |
| Grade levels 10-11-12 | $M$ = 2.89 (7.34)<br>$SD$ = 1.07 (2.72)<br>$n$ = 6 | $M$ = 1.64 (4.17)<br>$SD$ = .66 (1.68)<br>$n$ = 6 |

Table 3

Analysis of Variance on Mean Absolute Error Scores for Grade Groupings, Training Conditions, and Area vs. Point Symbols

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 403.81 | 71 | | |
| Between subjects | 319.53 | 35 | | |
| Grade groupings | 7.96 | 2 | 3.98 | .48 |
| Conditions (trained vs. untrained) | 1.18 | 1 | 1.18 | .14 |
| Grade groupings x conditions | 60.71 | 2 | 30.35 | 3.65* |
| Error | 249.69 | 30 | 8.32 | |
| Within subjects | 84.28 | 36 | | |
| Area vs. point (symbols) | 32.90 | 1 | 32.90 | 21.78** |
| Grades x symbols | 1.45 | 2 | .73 | .48 |
| Conditions x symbols | .27 | 1 | .27 | .18 |
| Grades x conditions x symbols | 4.35 | 2 | 2.17 | 1.44 |
| Error | 45.32 | 30 | 1.51 | |

*$p < .05$
**$p < .01$

Differences between the trained and untrained groups in the different grade groupings could be attributable to increases or decreases in performance on either the x-axis, y-axis, or both. In order to determine where the differences existed, separate analyses of variance were performed on the mean absolute error scores on each axis. A three-way analysis of variance was performed with the conditions and grade groupings (4-6, 7-9, 10-12) constituting between subjects variables and symbols constituting a within-subjects variable.

For the y-axis, there were significantly less errors made with the point symbols than with the areal symbols ($F = 12.02$; $df = 1, 30$; $p < .01$). There was no significant difference between the trained and untrained groups. For the x-axis, there were also significantly less errors made with the point symbols than with the areal symbols ($F = 10.78$; $df = 1, 30$; $p < .01$). Also, a significant interaction between grade groupings x conditions ($F = 3.95$; $df = 2, 30$; $p < .05$) was found. The means and standard deviations of the absolute errors for the trained and untrained groups on the x-axis are shown in Table 4. Inspection of Table 4 shows that training facilitated performance in grades 4-6 and 7-9 as compared to the untrained group and decreased performance in grades 10-12 as compared to the untrained group. However, performance by the trained subjects in grades 4-6 was slightly better than performance of the untrained subjects in grades 10-12. A summary of the analyses of variance are shown in Tables 5 and 6.

Table 4

Organization of Space

Means and Standard Deviations for Absolute Error in Inches (cm) on the x- and y-Axes for Trained and Untrained Subjects in Grades 4-6, 7-9, and 10-12

| | Trained | | Untrained | |
|---|---|---|---|---|
| | x-axis | y-axis | x-axis | y-axis |
| Grade levels 4-5-6 | M = 1.75 (4.45)<br>SD = .58 (1.47)<br>n = 6 | 1.99 (5.05)<br>1.35 (3.43)<br>6 | M = 3.21 (8.15)<br>SD = 1.16 (2.95)<br>n = 6 | 3.16 (8.03)<br>1.41 (3.58)<br>6 |
| Grade levels 7-8-9 | M = 2.34 (5.94)<br>SD = 1.31 (3.33)<br>n = 6 | 2.49 (6.32)<br>1.51 (3.84)<br>6 | M = 2.61 (6.63)<br>SD = 2.01 (5.11)<br>n = 6 | 1.89 (4.80)<br>1.82 (4.62)<br>6 |
| Grade levels 10-11-12 | M = 3.34 (8.48)<br>SD = 1.22 (3.10)<br>n = 6 | 3.85 (9.78)<br>1.69 (4.29)<br>6 | M = 1.93 (4.90)<br>SD = .75 (1.91)<br>n = 6 | 2.03 (5.16)<br>1.08 (2.74)<br>6 |
| Total | M = 2.48 (6.30)<br>SD = 1.23 (3.12)<br>n = 18 | 2.78 (7.06)<br>1.64 (4.17)<br>18 | M = 2.58 (6.55)<br>SD = 1.43 (3.63)<br>n = 18 | 2.36 (5.99)<br>1.50 (3.81)<br>18 |

Table 5

Analysis of Variance on Mean Absolute Errors on the x-axis for Grade Groupings, Training Conditions, and Area vs. Point Symbols

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 706.187799 | 71 | | |
| Between subjects | 479.406549 | 35 | | |
| Grade groupings | 1.675969 | 2 | .837985 | .07 |
| Conditions (trained vs. untrained) | .847168 | 1 | .847168 | .07 |
| Grades x conditions | 99.458419 | 2 | 49.729210 | 3.95* |
| Error | 377.424992 | 30 | 12.580833 | |
| Within subjects | 226.781250 | 36 | | |
| Area vs. point (symbols) | 53.785735 | 1 | 53.785735 | 10.78** |
| Grades x symbols | 15.650836 | 2 | 7.825418 | 1.57 |
| Conditions x symbols | .044501 | 1 | .044501 | .01 |
| Grades x conditions x symbols | 7.650253 | 2 | 3.825126 | .77 |
| Error | 149.649925 | 30 | 4.988331 | |

*$p < .05$
**$p < .01$

Table 6

Analysis of Variance on Mean Absolute Errors on the y-axis for Grade Groupings, Training Conditions, and Area vs. Point Symbols

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 860.472488 | 71 | | |
| Between subjects | 682.655375 | 35 | | |
| Grade groupings | 26.721008 | 2 | 13.360504 | .75 |
| Conditions (trained vs. untrained) | 12.508335 | 1 | 12.508335 | .70 |
| Grades x conditions | 108.068269 | 2 | 54.034135 | 3.03 |
| Error | 535.357925 | 30 | 17.845264 | |
| Within subjects | 177.816950 | 36 | | |
| Area vs. point (symbols) | 47.450035 | 1 | 47.450035 | 12.02** |
| Grades x symbols | .944119 | 2 | .472060 | .12 |
| Conditions x symbols | 1.386113 | 1 | 1.386113 | .35 |
| Grades x conditions x symbols | 9.583758 | 2 | 4.791879 | 1.21 |
| Error | 118.452925 | 30 | 3.948431 | |

*$p < .05$
**$p < .01$

Another focal point of interest is whether there was a constant error in replacing the elements of the display. Table 7 shows the mean relative replacement errors in inches on both the x- and y-axes for grade groupings 4-6, 7-9, and 10-12. On the x-axis, there was a very small negative bias overall for the trained subjects. These subjects, as a group, replaced the symbols slightly to the left of where they belonged. On the other hand, the untrained subjects showed a small positive error and placed the symbols slightly to the right of where they belonged. For the trained group, 9 subjects showed a negative constant error, 8 subjects showed a positive constant error, and 1 subject showed no constant error. For the untrained group, 6 subjects showed a negative constant error and 12 subjects showed a positive constant error. Apparently, training shifted the direction of the constant error; however, the differences within groups or between groups were not statistically significant as indicated by separate chi square tests (All $x^2$'s $< .68$; $p > .10$).

On the y-axis both the trained and untrained groups showed a small negative constant error. For the trained group, 15 subjects showed a negative constant error and 3 subjects showed a positive error. For the untrained group, 11 subjects showed a negative constant error and 7 a positive constant error. There were no significant differences between trained and untrained subjects in the direction of their constant error ($x^2 = 1.24$; $df = 1$; $p > .10$). However, the trained subjects showed a much higher negative constant error than would be expected by chance ($x^2 = 8$, $df = 1$; $p < .01$), but this directional difference was significant only for grade grouping 10-12 ($x^2 = 6.00$; $df = 1$; $p < .01$) and not for the other grade groupings.

Table 7

Mean Relative Replacement Errors in Inches (cm) on x- and y-Axes for Grade Groupings 4-6, 7-9, and 10-12

| Grade groupings | x-axis Trained | x-axis Untrained | y-axis Trained | y-axis Untrained |
|---|---|---|---|---|
| 4-5 | -.089 (.226) | .305 (.775) | -.402 (1.021) | -.320 (.813) |
| 7-9 | -.093 (.236) | .458 (1.16) | -.634 (1.610) | .0188 (.048) |
| 10-12 | .042 (.107) | .004 (.010) | -.620 (1.57) | -.514 (1.306) |
| *M* Total | -.046 (.117) | .256 (.650) | -.552 (1.402) | -.272 (.691) |

Discussion

The pilot study showed that when a tactile display is systematically organized into a 3 column x 3 row grid, braille readers remember the location of symbols within the cells of the grid at a very high level. The fact that they scanned the display most frequently in rows and reported remembering the symbols in rows suggests that the grid pattern was compatible with their perceptual-cognitive strategies for organizing and storing information in memory. The nearly errorless performance suggests that a removable grid could be used on maps to aid subjects in inspecting, organizing, and retaining information. Training subjects to scan the display in columns had no effect on performance because of the ease of the task.

When the task was made more difficult and a more precise scoring method used, training to scan a display in columns resulted in a significantly higher level of performance in the lowest grade level tested (4-6). The interesting result was that the trained students in grades 4-6 performed as well as untrained students in grades 10-12. Considering the total extent of training was less than 5 minutes, this indicates that substantial improvement in tactile skills can be achieved in a short period of time.

The superiority of the trained subjects was confined to the reduction of placement errors on the x-axis (left-right axis). Since the subjects were trained to scan up and down the display, the distance their hands were from the right or left edges of the board apparently became more salient and they apparently became more aware of the distance a symbol was from the left or right edge of the board. Training had no effect on performance with respect to the y-axis (toward and away from the body).

Training students to scan a display definitely interfered with performance at the upper grade levels and resulted in greater error scores in grade grouping 10-12. While there were no significant constant errors for the untrained students, nor for the trained students up through grade 9, there was a significant constant error in replacing the symbols on the board by the trained subjects in grades 10-12. The trained students had a consistent bias of replacing the symbols lower on the board (closer to the body) than did the untrained subjects.

The results of this study indicate that students should be introduced to tactual-spatial concepts and skills early in the educational process. Delaying the introduction of these concepts and skills until the upper grade levels may not have any advantage whatsoever and, in fact, may interfere with performance.

The implementation of scanning techniques in order to systematically locate, organize, and remember information on tactile displays teaches important concepts and abilities for using diagrams, maps, graphs, and even in arranging one's work space. Spatial concepts and relationships pervade our daily life and the formal introduction of these concepts early in the educational process is important for sensitizing blind students to the salient spatial aspects of their immediate environment.

STUDY V

# THE EFFECTS OF TRAINING BLIND STUDENTS IN DISTINCTIVE FEATURES ANALYSIS AND LINE TRACING ON TACTILE SHAPE RECOGNITION AND THE LOCATION OF SHAPES ON A TACTILE MAP

Edward P. Berla', Lawrence H. Butterfield, Jr., and Marvin J. Murr

## Abstract

Two experiments were conducted to determine the effects of training blind students in using a distinctive features analysis strategy and line tracing on shape recognition accuracy and speed and accuracy of locating shapes on a tactile map. In Experiment I, training improved the shape recognition performance of a group of 25 trained braille readers by 32% as compared to a matched group of 25 untrained braille readers. In Experiment II, training resulted in a 25% increase in the number of shapes located and a 41% decrease in the average time to locate a shape on a tactile map by 21 trained students as compared to a matched group of 21 untrained students. The results are discussed in terms of the critical importance of training blind students to be analytical, systematic, and complete in exploring tactile materials to ensure adequate development of perceptual-conceptual abilities.

STUDY V

# THE EFFECTS OF TRAINING BLIND STUDENTS IN DISTINCTIVE FEATURES ANALYSIS AND LINE TRACING ON TACTILE SHAPE RECOGNITION AND THE LOCATION OF SHAPES ON A TACTILE MAP

In a series of studies investigating the effects of stimulus parameters and methods of exploring shapes on maps (Berla', 1972, 1974; Berla' & Murr, 1972) it was found that tactual shape discrimination performance was quite poor by children in grades 1-6. There were three striking observations concerning the blind child's inspection of tactile shapes. First, it was observed that many of the children failed to completely explore the entire tactile shape and many inspected only a small portion of a shape. Secondly, the overwhelming majority of the students had no systematic method for exploring shapes. Third, some subjects did trace the entire shape, but did not appear to realize at what point on the shape they had begun tracing and at what point on the shape they had completed their tracing. In other words, they failed to determine a point of origin and a point of ending.

In other studies (Berla', 1973; Berla' & Murr, 1974; Nolan & Morris, 1971; Study I and Study VI) on tactile map reading by blind students in grades 4-12, it was found that students are unsystematic in their exploration of maps. In a videomatic study (Study I) of blind students reading tactile political maps it was found that poor map readers have substantial difficulty in tracing lines. They have a tendency to fall off the line they are tracing and/or are disrupted by other intersecting lines. Good map readers have no difficulty in tracing the outlines of bounded areas on maps. Furthermore, a major characteristic of the performance of good map readers is the degree to which they appear to perform a distinctive features analysis of shapes either in inspecting a shape in isolation or locating it on a map. Poor map readers engage in a distinctive features analysis less frequently and less skillfully than good map readers.

In summary, three perceptual-cognitive deficits have permeated the tactual-motor performance of blind students:

1. Lack of a systematic method of exploring tactual materials; students not only perform in an unsystematic manner, but also appear to have no knowledge of what a system is or the importance of being systematic in their exploration of their tactile environment.
2. Poor line tracing skills.
3. Lack of an analytic cognitive strategy in exploring tactile materials, such as a distinctive features analysis of shapes which Gibson (1969) has shown to be of critical importance in the development of various perceptual abilities.

The present studies focused on training in two basic skills: distinctive features analysis of shapes and line tracing. In concentrating on these two skills a third derived skill is implicitly being taught, and that is a systematic exploration of the tactile environment.

In the first experiment, students were trained in line tracing and distinctive features analysis to determine if it would improve their shape recognition accuracy. In the second experiment the same type of training was used to determine if it would improve the speed and accuracy with which shapes were located and traced on maps.

## Experiment I

### Method

Subjects. The subjects were 50 students enrolled in residential schools for the blind who used braille as their primary reading medium. The number of students participating from grade classifications of beginners, primary, and grades 1-5 were respectively: 3, 18, 6, 10, 6, 6, 1. There were 31 males and 19 female students. The mean, *SD*, and range of their ages in years were as follows: *M* = 9.69, *SD* = 2.14, range = 5.92-16.92. The schools participating in the research were the Alabama Institute for the Deaf and the Blind, the Louisiana State School for the Blind, and the Overbrook School for the Blind.

Materials. The pretest and posttest materials were exactly the same and consisted of a series of 36 shape recognition cards. On one side of a card there was a single standard shape and on the flip side there were four shapes which consisted of the standard and three choices. The shapes consisted of two sets of outline figures drawn from 18 United States' states and 18 European countries. Each shape appeared once as the standard, and the choice figures were chosen from the same set from which the standard was chosen. The states and countries were traced on paper from maps which appeared in: Goode's World Atlas (Espenshade & Morrison, 1974), National Geographic Atlas of the World (National Geographic Society, 1970), and Reader's Digest Great World Atlas (Reader's Digest Association, 1963). All the shapes were photographically reduced or enlarged to fit within the confines of a 3-inch (7.62 cm) circle. Photographs of the shapes were used in a photo-etching process to make raised line figures on metal plates. Vacuum-formed plastic copies were made of each of the shapes and the plastic copies were mounted on rectangular sheets of cardboard measuring 19.05 X 41.91 cm. The height of the raised lines was .076 cm and the width was .12 cm. The shapes were centered and equally spaced on the cards.

The choice figures for each standard were chosen on the basis of similarity in shape. Each shape appeared an equal number of times as choice figures on the pre- and posttests with the standard (correct alternative) appearing in each of the four choice positions an equal number of times. A different random order of presentation of the 36 cards was used for the pre- and posttests. The pretest consisted of the 36 shapes presented in their correct orientation. The posttest consisted of the same standards and choice figures but rotated 180° from their orientation on the pretest. The United States' states and European countries used on these tests were: Alabama, Idaho, Indiana, Kentucky, Maine, Minnesota, Missouri, Nevada, New Mexico, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee, Utah, West Virginia, Wisconsin, Wyoming; Albania, Austria, Belgium, Bulgaria, Czechoslovakia, East Germany, Finland, France, Ireland, Italy, Netherlands, Poland, Portugal, Romania, Spain, Sweden, Switzerland, West Germany.

The training materials consisted of 27 shape recognition cards using countries in Africa, Asia, and South America. The countries chosen were: Botswania, Central African Republic, Chad, Ethiopia, Guinea, Libya, Mali, Somalia, Southwest Africa, Sudan; Afghanistan, Cambodia, Iran, Iraq, Laos, Mongolia, Nepal, North Korea, Pakistan, Syria, Yemen; Brazil, Colombia, Ecuador, Paraguay, Venezuela. Outline figures of each of these countries were taken from maps which appeared in the atlases previously cited. The tactile shapes were constructed in the same manner as the materials used on the pre- and posttests.

Design and procedure. The students were told that they were going to play a game in which they would be shown a card which had a shape on it. They were told to feel the shape for 30 seconds after which they would be shown four shapes from which they were to identify the shape they had felt before. All students were then shown a card which had a triangle on one side and a circle, square, rectangle, and triangle on the flip side. The students felt the triangle and then the card was flipped over and the students were asked to choose the correct shape. All the students were then given the pretest. Those who got 8 (78% correct) or more wrong were designated as the target population. Once the target population had been identified the subjects were matched in pairs on their pretest scores first and then their grade level. One member of each pair was randomly assigned to the trained group and the remaining student was assigned to the untrained group. The students in the trained group were instructed to trace a shape by using the index finger of their preferred hand while using the index finger of the nonpreferred hand as a reference. Tracing was to begin and end at the reference finger.

After tracing the contour, subjects were instructed to trace the shape again and pick out three distinctive features. Distinctive features were defined as "parts that stick out, parts that are pointed, parts that go in, parts that are curved." Each subject was asked to tap the parts chosen and tell the experimenter. The subject was then asked to trace the shape again to "make sure you know what the shape is like." The card was then flipped over and the subject was told to find the same shape by finding the shape that had the same parts as the shape he had traced before. If the student located the correct shape he was asked to trace it and show the experimenter the parts he had picked out before. If the student picked the wrong shape he was shown the standard shape again and the entire instructional process was repeated. If the student failed to recognize the target shape again the experimenter placed the student's finger on one of the distinctive features the student had picked out and the student was told to trace the shape and show the three parts he had picked out before. If the student forgot what parts he had chosen or picked parts that were different from the original set of three, the experimenter placed the student's finger on each of the chosen parts. The student was then asked to trace the shape again and show the experimenter the three parts. Throughout a training session the student was given assistance in line tracing and reminded on each trial to trace the shape, pick out three parts that were different, and trace the shape again.

Each student was trained in three sessions over 3 consecutive days. Each subject was given 30 minutes for the entire training session. A session consisted of nine shape recognition trials. If a subject completed the nine trials in less than 30 minutes, the cards were rotated 180° and the subject was given up to nine additional trials. At the completion of training, both the trained and untrained subjects were posttested. Both the pretest and posttest required approximately 35 minutes to administer.

## Results

The data consisted of the percentage of correct responses. Since subjects were matched on their pretest scores and then randomly assigned to either the trained or untrained groups, the group's factor was considered as a within subjects variable. A two-factor repeated measures analysis of variance was performed on the data with the factors being pre- vs. posttest and trained vs. untrained. The analysis showed significant main effects for the trained vs. untrained groups ($F = 21.20$; $df = 1, 24$; $p < .01$) and pre- vs. posttest ($F = 6.54$; $df = 1, 24$; $p < .05$). The interaction of the trained vs. untrained groups x pre- vs. posttest was also significant ($F = 27.66$; $df = 1, 24$; $p < .01$). A summary of the analysis of variance is shown in Table 1.

Table 1

Analysis of Variance of Percentage of Correct Shape Recognitions for Trained vs. Untrained Subjects on the Pre- and Posttest

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 39,309.36 | 99 | | |
| Trained vs. untrained (groups) | 1,369.00 | 1 | 1,369.00 | 21.20** |
| Pre- vs. posttest (tests) | 772.84 | 1 | 772.84 | 6.54* |
| Groups x tests | 1,128.96 | 1 | 1,128.96 | 27.66** |
| Subjects | 30,672.86 | 24 | | |
| Groups x subjects | 1,549.50 | 24 | 64.56 | |
| Tests x subjects | 2,836.66 | 24 | 118.19 | |
| Groups x tests x subjects | 979.54 | 24 | 40.81 | |

*$p < .05$
**$p < .01$

A summary of the means and standard deviations of the percentage of correct recognitions for the trained and untrained groups on the pretest and posttest is shown in Table 2. Inspection of Table 2 shows that the matching of the subjects on the pretest resulted in nearly identical means and standard deviations. On the posttest the untrained group showed a very small decrease in performance while the trained group showed a relative increase in the percentage of correct recognitions of 27% from pretest to posttest. The trained group scored 32% higher relative to the untrained group on the posttest. Of the 25 subjects in the untrained group; 8 (32%) showed an increase from pre- to posttest, 12 (48%) showed a decrease, and 5 (20%) remained the same. Of the 25 subjects in the trained group; 21 (84%) showed an increase from pre- to posttest, one (4%) showed a decrease, and three (12%) remained the same. As is usually observed in most training programs, some students benefited more from training than other students. One trained student, for example, went from 31% correct on the pretest to 78% correct on the posttest.

Table 2

Means and Standard Deviations for Percentage of Correct Shape Recognitions of Trained and Untrained Subjects

| | Pretest | Posttest |
|---|---|---|
| Trained | $M$ = 45.64<br>$SD$ = 17.23<br>$n$ = 25 | $M$ = 57.92<br>$SD$ = 21.16<br>$n$ = 25 |
| Untrained | $M$ = 44.96<br>$SD$ = 17.79<br>$n$ = 25 | $M$ = 43.80<br>$SD$ = 20.98<br>$n$ = 25 |

## Summary and Discussion

A short period of instruction in line tracing and distinctive features analysis significantly improved the shape recognition performance of blind students. On an absolute basis, however, performance on the posttest by the trained subjects was far below an acceptable level from an educational achievement standpoint. However, the shapes were very similar and quite complex and the total amount of training time was of relatively short duration. In essence it was a difficult task for young blind students. At the very least, this study demonstrates that training and emphasis on just these skills and concepts is an effective way of improving the tactual perceptual performance of young blind students.

It was observed during the posttest that a few of the trained students abandoned in part or entirely the techniques taught during the training period. This, of course, attenuated improvements in performance. Presumably with longer training periods and practice the students would begin to develop more skill and adopt and use these skills spontaneously in engaging in various tactual tasks. Consequently, performance should improve substantially with longer training periods.

## Experiment II

This experiment focused on training in line tracing and distinctive features analysis to determine whether it would improve blind students speed and accuracy of locating and tracing shapes on a tactile political map. In this study all the students were pretested on their accuracy and speed of locating each of eight different bounded areas (shapes) on a map. On the basis of their pretest scores the subjects were matched in pairs. One member of each pair was randomly selected and trained in three 1/2-hour sessions over 3 consecutive days in line tracing and distinctive features analysis and then was given practice in locating shapes on maps. Following training both the trained and untrained groups were posttested.

### Method

Subjects. The subjects were 42 students from the W. Ross Macdonald School in Ontario, Canada, who used braille as their primary reading medium. There were an equal number of males and females randomly selected from grades 2-7. The number of students selected from each of grades 2-7 were respectively: 1, 6, 7, 8, 15, 4, and 1 student from an ungraded class. The mean, standard deviation, and range of ages of the students in years were; $M$ = 11.88, $SD$ = 1.84, range = 8.42-15.08.

Test materials. Pre- and posttest map: A pseudomap was constructed using a thin raised line. The content of the map consisted of eight states of the United States and were as follows: Alabama, Idaho, Indiana, Maine, Missouri, Oklahoma, Pennsylvania, Wisconsin. Each state was photographically reduced or enlarged to fit within the confines of a 3-inch circle.

A 22.86 X 33.02 cm page was divided into a grid having five rows and four columns. Each of the eight states was randomly chosen and randomly assigned to one of the cells with the restriction that no two states could occupy adjacent cells in the same column or row. In order to increase the complexity of the map, 20 additional boundary lines were added to the map to connect the states and divide up the remaining space. The additional connecting lines and the states were taken from a base map in Reader's Digest Great World Atlas (1963, p. 47). Raised line copies of the map were made using a photoetching process to produce a master plate. Plastic vacuum-formed copies were made from the plates. A photograph of the map is shown in Figure 1.

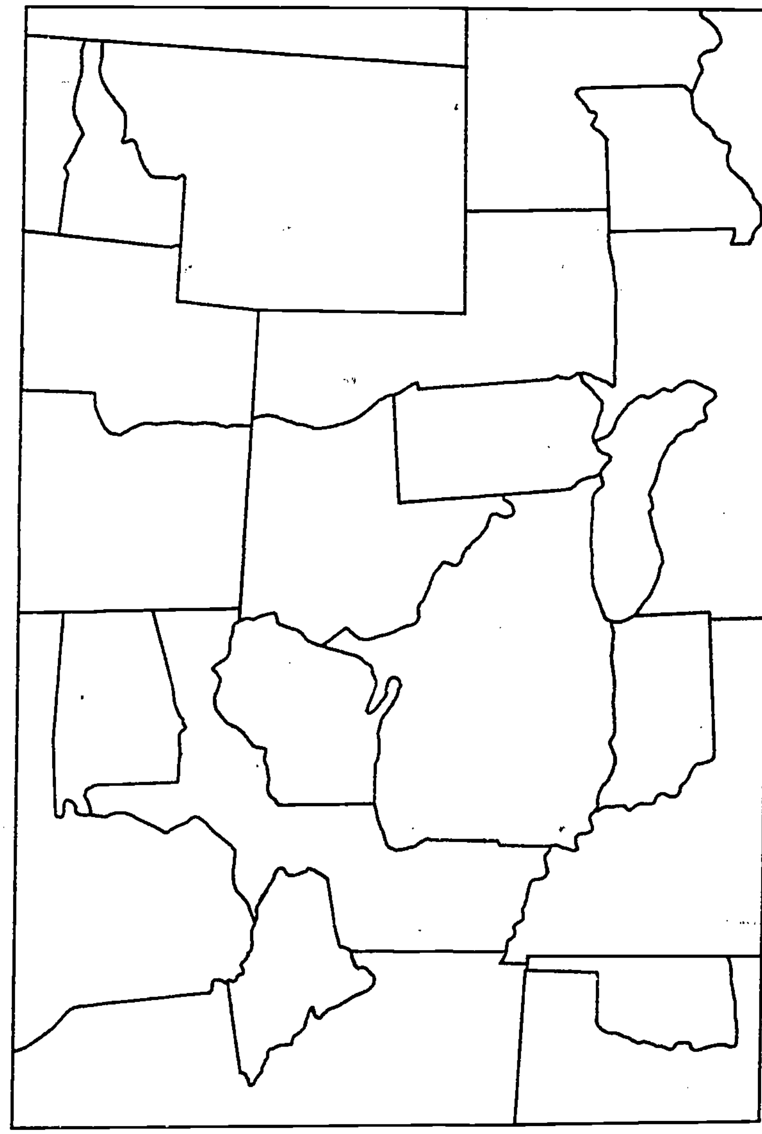

Figure 1. The pre- and posttest map consisted of eight states of the United States randomly placed on the map. Twenty additional lines were added to connect the states and divide up the remaining space. The size of the map was 22.86 X 33.02 cm. The lines were raised .051 cm above the surface and were .12 cm wide. The shapes were numbered for identification purposes with ink.

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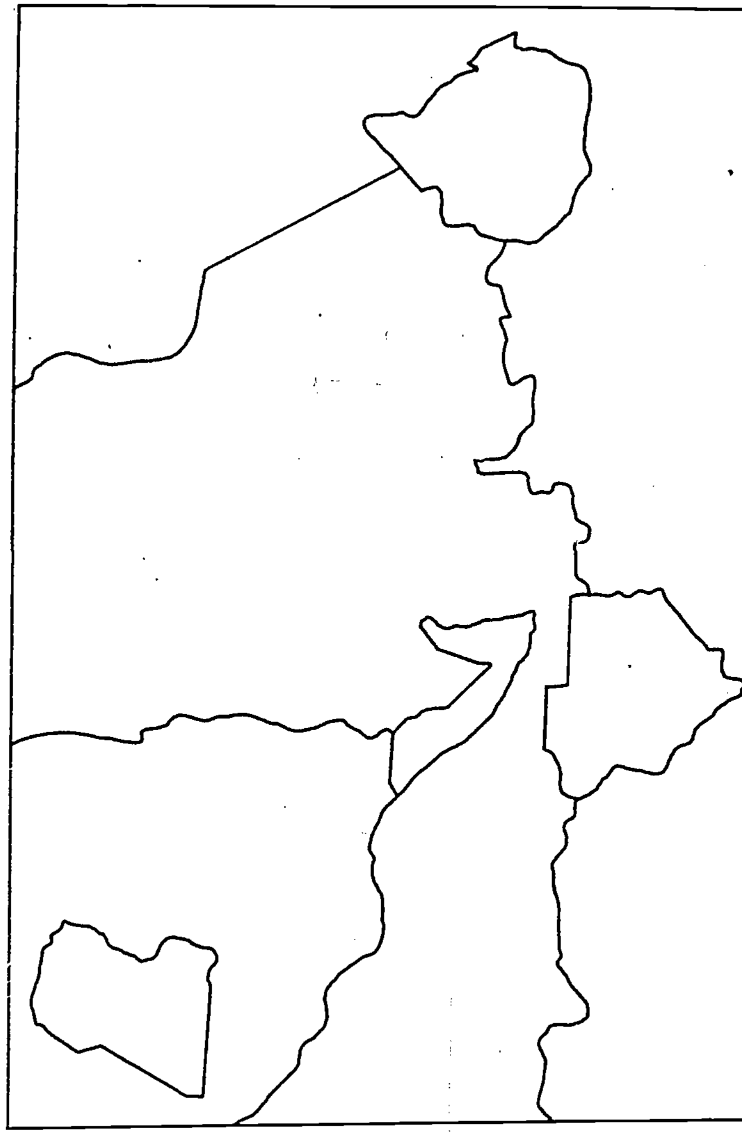

Figure 2. Training Map #1 consisted of four African countries randomly placed on the map. Five additional lines were added to connect the countries and divide up the remaining space. The size of the map was 22.86 X 33.02 cm. The lines were raised .051 cm above the surface and were .12 cm wide. The shapes were numbered for identification purposes with ink.

77

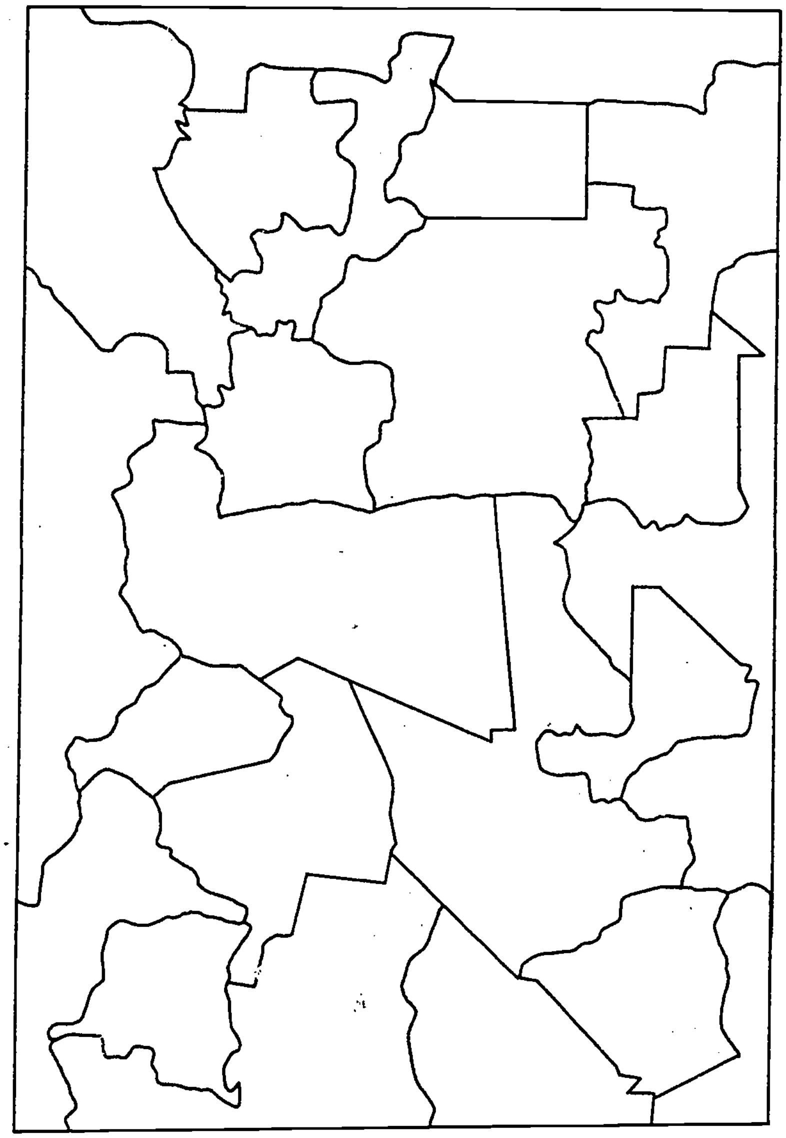

Figure 3. Training Map #2 consisted of eight African countries randomly placed on the map. Twenty additional lines were added to connect the countries and divide up the remaining space. The size of the map was 22.86 X 33.02 cm. The lines were raised .051 cm above the surface and were .12 cm wide. The shapes were numbered for identification purposes with ink.

Training materials. The training materials consisted of three different pseudomaps. Each map was constructed by having different African countries represented on it and were traced from base maps appearing in Goode's World Atlas (Espenshade & Morrison, 1974). Each of the countries was photographically reduced or enlarged to fit within the confines of a 3-inch (7.62 cm) circle. A 22.86 X 33.02 cm page was divided into a grid having five rows of four columns. African countries were randomly placed in one of the cells with the restriction that no two countries could occupy adjacent cells on the map. Additional boundary lines were added to each map to connect the countries and divide up the remaining space.

Training Map #1 consisted of four African countries which were: Botswania, Libya, Rhodesia, and Somali Republic. Five additional boundary lines taken from the base maps were added to the pseudomap to connect the countries and divide up the remaining space. A photograph of the map is shown in Figure 2.

Training Map #2 consisted of eight African countries which were: Angola, Chad, Ethiopia, Ghana, Kenya, Southwest Africa, Spanish Sahara, and upper Volta. Twenty additional lines taken from the base map were added to the pseudomap to connect the countries and divide up the remaining space. A photograph of the map is shown in Figure 3.

Training Map #3 consisted of eight African countries which were: Algeria, Equatorial Guinea, Gabon, Ivory Coast, Mali, Mauritania, Nigeria, and Zaire. Twenty additional boundary lines taken from the base map were added to the pseudomap to connect the countries and divide up the remaining space.

Metal plates of the maps were made using a photoetching process to produce male molds. Vacuum-formed plastic copies were made of each map using the molds.

All the maps used in the study measured 22.86 X 33.02 cm, their lines were raised .051 cm above the surface and were .12 cm in width. All the maps were mounted on cardboard with a nonskid backing. For each of the maps, separate cue cards were made showing each of the states or countries. The states or countries were cut from plastic copies of the maps and each shape was mounted on 8.9 X 8.9 cm cardboard squares with a nonskid backing.

Two shape recognition cards used in Experiment I were also used as training materials.

Design and procedure. All the students were tested with the pretest map. Each student was shown the pretest map for a 1-minute period of free exploration. A subject was then shown a cue card for 30 seconds and asked to locate the shape on the map. The subject was given up to 4 minutes to locate and trace each shape. The cue card remained alongside the map for reference while the subject searched the map. The eight shapes were presented to each subject using the same random order.

At the completion of the pretest, the students were matched in pairs as closely as possible on their accuracy and time scores, respectively. One member of each pair was randomly chosen and assigned to the trained group while the remaining member of the pair was assigned to the control group.

The students in the training condition were trained over a 3-day period in tracing shapes, distinctive features analysis of shapes, and locating shapes on the pseudomaps by locating distinctive features.

Day I: Each student was shown how to trace, pick out distinctive features, and recognize shapes via distinctive features, using two shape recognition cards. Each subject was presented with a standard shape and was shown how to trace by tracing the inside edge of the shape and to pick out three distinctive features on the shape. The card was then flipped over and the subject was asked to locate the correct shape by choosing the shape which had the same parts. If the subject chose the wrong shape, the standard was presented again and the subject repeated the same procedure. If the subject chose the wrong shape again he was shown the correct choice and told to trace it and pick out the same distinctive features he chose originally. Both cards were presented in the same manner.

After the two cards had been presented the subject was told that he was to locate shapes on a map. The subject was presented with the map which had the four target shapes and given 1 minute to explore the map. He was then shown a cue card and told to trace the inside edge, pick out three distinctive features, trace the shape a second time, and to locate the shape on the map by looking for distinctive features. A subject was given 4 minutes to locate the shape. At the end of 4 minutes the subject was shown the location of the target figure by being shown one of the distinctive features he chose on the cue card and then asked to trace the shape. Assistance was given in tracing if needed. The cue card remained alongside the map during the search period.

Each subject was given 30 minutes for the entire training session. If a subject located all four shapes in less than 30 minutes the map was rotated 180° and he was allowed to locate up to four more shapes or until the 30 minutes was exhausted.

Day II: The subject was reminded about tracing and picking out distinctive features and then given 1 minute to explore one of the pseudomaps having eight shapes. He was then presented with the first cue card and told to trace the inside edge, pick out three distinctive features, trace the shape a second time, and locate the shape on the map. Each subject was given 30 seconds to inspect the cue card and 4 minutes to locate the shape. At the end of 4 minutes the subject was shown the location of the shape if he had not found it. The cue card remained alongside the map during the search period. If time remained, the map was rotated 180° and the subject was permitted to locate up to eight more shapes within the 30 minute time limit.

Day III: Training was the same as Day II except a different map was used.

Beginning on the day after training was completed, the subjects in the trained and control groups were tested with the pretest map which was rotated 180° from its original orientation. The subject was presented with a cue card and told to inspect it for 30 seconds and to locate and trace the same shape on the map. Each subject was given 4 minutes to locate each shape.

## Results

The data consisted of the number of shapes located and the mean time required to locate a shape. Separate analyses of variance were computed for each dependent measure. Since subjects in the trained and untrained groups were matched in pairs, this factor was considered as a within subjects factor for purposes of the analysis. Each analysis consisted of a two-factor repeated measures analysis of variance with the factors being pre- vs. posttest and groups (trained vs. untrained). The analysis on the number of shapes located showed that the pre- vs. posttest ($F = 7.33$; $df = 1, 20$; $p < .05$), groups ($F = 11.72$, $df = 1, 20$; $p < .01$) and the interaction of pre- vs. posttest x groups ($F = 11.72$; $df = 1, 20$; $p < .01$) were significant. A summary of the analysis is shown in Table 3. Table 4 shows the means and standard deviations of the number of shapes located on the pre- and posttest for the trained and untrained groups. Because the subjects were matched, the means of the trained and untrained groups were identical ($M = 5.29$) with nearly identical $SD$'s. Inspection of Table 4 shows that significantly more shapes were located on the posttest by the trained group ($M = 6.95$) than the untrained group ($M = 5.52$). This represents a 25.90% improvement by the trained group over the untrained group on the basis of their posttest scores.

Table 3

Analysis of Variance on Number of Target Areas Located as a Function of Training vs. No Training and Pre- vs. Posttest

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 483.24 | 83 | | |
| Trained vs. untrained (groups) | 10.71 | 1 | 10.71 | 11.72** |
| Pre- vs. posttest (tests) | 19.05 | 1 | 19.05 | 7.33* |
| Groups x tests | 10.71 | 1 | 10.71 | 11.72** |
| Subjects | 354.24 | 20 | | |
| Groups x subjects | 18.29 | 20 | .91 | |
| Tests x subjects | 51.95 | 20 | 2.60 | |
| Groups x tests x subjects | 18.29 | 20 | .91 | |

*$p < .05$
**$p < .01$

Table 4

Means and Standard Deviations of Number of Target Areas Located as a Function of Training vs. No Training and Pre- vs. Posttest

| Group | Pretest | Posttest | Total |
|---|---|---|---|
| Trained | M = 5.29<br>SD = 2.55<br>n = 21 | M = 6.95<br>SD = 1.72<br>n = 21 | M = 6.12<br>SD = 2.31<br>n = 21 |
| Untrained | M = 5.29<br>SD = 2.55<br>n = 21 | M = 5.52<br>SD = 2.48<br>n = 21 | M = 5.40<br>SD = 2.49<br>n = 21 |
| Total | M = 5.29<br>SD = 2.52<br>n = 42 | M = 6.24<br>SD = 2.23<br>n = 42 | |

The analysis of variance on the mean time to locate a shape on the map showed that the pre- vs. posttest ($F = 14$; $df = 1, 20$; $p < .01$), groups ($F = 8.55$; $df = 1, 20$; $p < .01$) and the interaction of pre- vs. posttest x groups ($F = 9.70$; $df = 1, 20$; $p < .01$) were significant. A summary of the analysis is shown in Table 5. Table 6 shows the means and standard deviations of the time, in seconds, to locate shapes on the pre- and posttest by the trained and untrained groups. Inspection of Table 6 shows the means and standard deviations of the time scores, in seconds, for the trained and untrained groups were nearly identical on the pretest (trained, $M = 135.07$, $SD = 59.85$; untrained, $M = 136.36$, $SD = 60.38$). A comparison of the posttest means shows that the trained group significantly reduced the mean time to locate a shape ($M = 89.31$ sec., $SD = 55.05$) as compared to the untrained group ($M = 125.97$ sec., $SD = 67.30$). This represents a 41% decrease in time by the trained group as compared to the untrained group on the basis of the posttest scores.

Table 5

Analysis of Variance on Mean Task Time to Locate Target Areas as a Function of Training vs. No Training and Pre- vs. Posttest

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 326,414.18 | 83 | | |
| Trained vs. untrained (groups) | 7,562.77 | 1 | 7,562.77 | 8.55* |
| Pre- vs. posttest (tests) | 16,554.84 | 1 | 16,554.84 | 14.00* |
| Groups x tests | 6,568.12 | 1 | 6,568.12 | 9.70* |
| Subjects | 240,834.60 | 20 | | |
| Groups x subjects | 17,696.78 | 20 | 884.84 | |
| Tests x subjects | 23,651.75 | 20 | 1,182.59 | |
| Groups x tests x subjects | 13,545.32 | 20 | 677.27 | |

*$p < .01$.

Table 6

Means and Standard Deviations of Mean Task Times to Locate Target Areas as a Function of Training vs. No Training and Pre- vs. Posttest

| Group | Pretest | Posttest | Total |
|---|---|---|---|
| Trained | M = 135.07<br>SD = 59.85<br>n = 21 | M = 89.31<br>SD = 55.05<br>n = 21 | M = 112.19<br>SD = 61.33<br>n = 21 |
| Untrained | M = 136.36<br>SD = 60.38<br>n = 21 | M = 125.97<br>SD = 67.30<br>n = 21 | M = 131.16<br>SD = 63.37<br>n = 21 |
| Total | M = 135.71<br>SD = 59.38<br>n = 42 | M = 107.64<br>SD = 63.50<br>n = 42 | |

Discussion

Training blind students in line tracing and in a strategy of distinctive features analysis of shapes significantly facilitated their ability and speed of locating and tracing shapes on a map. Coupled with the fact the same type of training facilitated shape recognition performance, it would appear that this method is effective in improving the tactual skills of blind students. However, these studies and their conclusions have their limitations. There is no way of determining which factor(s) of training contributed most to improving performance. These factors are difficult to isolate experimentally because a subject needs to trace an entire figure in order to detect and encode all the distinctive features. Training in tracing the contour line of a shape may implicitly teach the detection of distinctive features and conversely teaching distinctive features analysis may implicitly suggest the necessity for tracing a line. Furthermore, in training both of these skills a subject is learning the derived concept of being systematic. In these studies, the subjects were taught to trace the complete shape in a clockwise direction, taught to pick out a point of departure which was used as a reference point and to perceive the distinctive features in a fixed serial order. It would appear that all these factors are necessary conditions for improving performance in these and similar type tasks.

The training procedures used here are simply applications of Gibson's (1969) concept of distinctive features and Piaget's concept of decentration and perceptual activity (Piaget & Inhelder, 1967, Chap. 1). In addition, emphasis must be given to the principle of serial order which is of critical importance in tactual perception and has been elaborated on by Lashley (1967, pp. 112-136). The tactual perceptual system is the only system of the five major sense systems where the freely roaming hand or finger determines the serial order of perceiving the distinctive features of the stimulus. For visual perception there is a simultaneous perception of the distinctive features and their spatial relationships which are invariant. For auditory events the serial, temporal order of the distinctive features is fixed. In both systems there is relatively little or no room for variation in the serial perception of the distinctive features in comparison to the tactual system. Distinctive features may remain invariant, but in tactual perception the pattern or serial order is subject [illegible] variation depending on the inspection techniques employed. For example, if a shape had six distinctive features, a child co[illegible]l the distinctive features in any one of a possible 720 different sequences. Consequently, the manner in which a tactile stimulus is inspected will determine to a large extent the nature of one's perception. If the same stimulus is presented to the same child on two or more occasions, the inspection strategy could well contribute to whether the child perceives the two stimulus events as being identical or different.

This analysis suggests the importance of teaching blind children to be analytical, systematic, and complete in exploring their immediate tactile environment which would facilitate the development of other perceptual abilities and concepts which, of necessity, must be acquired through the tactual system.

# STUDY VI

# THE EFFECTS OF NOISE ON THE LOCATION OF POINT SYMBOLS AND TRACKING A LINE ON A TACTILE PSEUDOMAP

Edward P. Berla' and Marvin J. Murr

Abstract

Braille students in grades 4 through 12 were given the task of locating target point symbols and following a tactile track on a tactile pseudomap using a vertical search technique. Half of the 72 students were asked to perform the tasks on a map containing texture (noisy map), while half performed the tasks on an identical map without texture (noise-free map). The addition of texture to the map significantly decreased the accuracy of location of points by 20% and significantly increased location time by 36% as compared to the noise-free map. It also took the students 41% longer to follow the tactile track on the noisy map as compared to the noise-free map. The results are discussed in terms of how texture produces noise and the implications of the results in using texture on tactile maps.

## STUDY VI

## THE EFFECTS OF NOISE ON THE LOCATION OF POINT SYMBOLS AND TRACKING A LINE ON A TACTILE PSEUDOMAP

Reading a tactile map is an enormously difficult task for the blind student. Not only is he required to discriminate a substantial number of tactile symbols, but he is also required to scan the display with his fingertips (acquiring information serially) and to code this information to mentally form an organized cognitive map. The blind student's task is further complicated by the lack of a standardized tactile symbology and a dearth of information on tactile-map design. Research efforts to date have produced only a small set of discriminable symbols (Gill & James, 1973; Nolan & Morris, 1971; Wiedel & Groves, 1969), which has not been standardized. Furthermore, there has been almost no research on factors affecting map legibility, such as the figure-ground aspects of a display, the amount of information to be contained on the display, and the effects of combinations of symbols on the legibility of the display.

One way of conceptualizing the tactile-map legibility problem is within the context of communication theory. The information to be obtained from a display in the form of symbols or relationships between symbols can be considered the signals, while all additional information or symbols can be considered background noise. This conceptualization suggests that research should focus on maximizing the signal strength and/or minimizing tactile noise.

The present study investigated the effects of irrelevant information in the form of texture (noise) on the detectability and speed of finding point symbols on a tactile pseudomap, and on the accuracy and speed of tracking a line. Two groups of blind students were given a set of standardized instructions on how to scan a map using a vertical search technique (Berla', 1973). The students were then asked to locate as many of 16 target-point symbols on the map as they could during an 8-minute test period. In a second task the students were asked to follow a tactile track on the map as quickly as they could. One group of students was asked to perform these tasks on a map which contained background textures, while a second group performed the same tasks on a map without background textures.

### Method

#### Subjects

The subjects were 38 male and 34 female braille students in grades 4 through 12. Eight students from each of grades 4 through 12 participated in the study. The means and standard deviations of the ages of the students in years according to grade level are presented in Table 1. The schools that participated in the research were the Ontario School for the Blind, Canada; Overbrook School for the Blind, Pennsylvania; and the West Virginia School for the Blind.

Table 1

Means and Standard Deviations of

Ages in Years According to Grade Level

| Statistic | Grade level 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|
| *M* | 11.21 | 11.83 | 12.87 | 14.82 | 15.34 | 17.12 | 18.61 | 19.39 | 20.00 |
| *SD* | 1.11 | 1.25 | 1.18 | 1.65 | 0.69 | 1.27 | 1.15 | 1.32 | 0.72 |

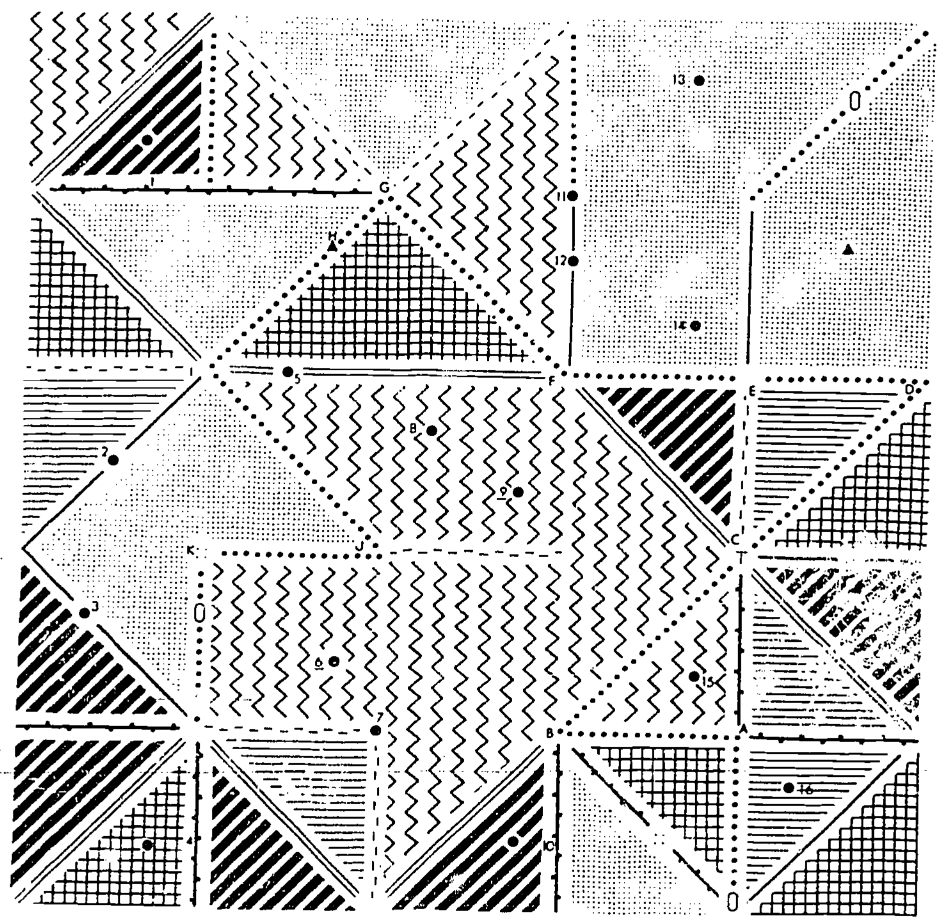

Figure 1. Noisy Pseudomap Havine Texture, Line, and Point Symbols

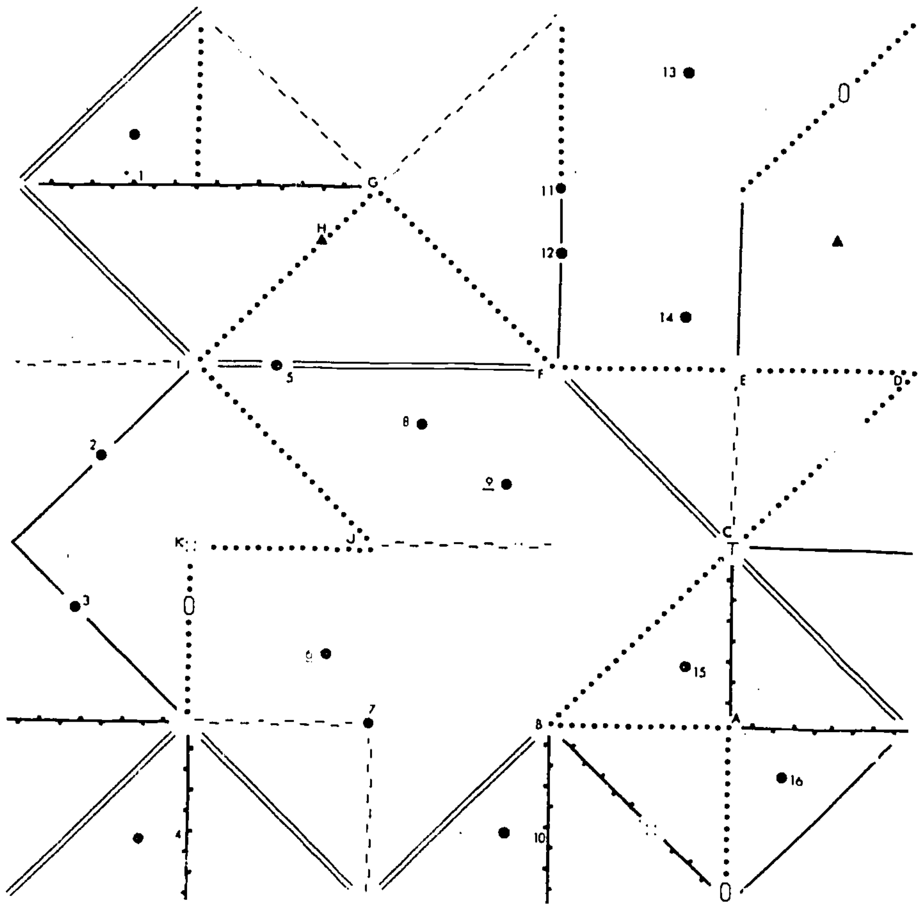


Figure 2. Noise-Free Pseudomap Having Line and Point Symbols

## Materials

The study used two tactile pseudomaps which were constructed through a photoengraving process. Male molds were made from this process, and copies were made by drape-molding styrene plastic over the male molds. Photographic reproductions of the maps are shown in Figures 1 and 2. One map, designated "noisy," had textured areal symbols, line symbols, and point symbols. A second map, designated "noise-free," had only line and point symbols but no textured areal symbols. The height of the symbols was as follows: textured areal symbols = 0.015 inch (.038 cm), line symbols = 0.025 inch (.064 cm), and point symbols = 0.035 inch (.089 cm). The separation between symbols was 0.150 inch (.381 cm). The outer dimensions of the maps were 15 X 15 inches (38.10 X 38.10 cm). Each map contained 16 target-point symbols, (i.e., raised circles having a diameter of 0.188 inch [.478 cm]). On each map there was a tactile track consisting of a dotted line which began in the lower right-hand corner. The beginning of the track was designated by an oval point symbol which terminated on the left side at another oval point symbol. As shown in Figures 1 and 2, a different number was placed next to each target symbol on the original plastic maps so that the experimenters could record the target symbols as the subjects located them. Letters were used to indicate terminal points of track sections. The numbers and letters were not detectable by touch. Additionally, two keys were made: The first key showed one of the round raised target symbols, and the second key showed a section of the tactile track which was in the shape of a right angle.

Design and procedure

There were two map conditions (noise versus no noise) and two tasks (Locating target symbols and tracking). Conditions were randomly assigned to subjects within grades. Half of the subjects within each grade were given the location task first, followed by the tracking task; the other half of the subjects performed the tasks in reverse order. For the location task, each subject was trained to use a vertical scanning technique (Berla', 1973) and given 4 minutes of practice in implementing the strategy. Each subject was presented with a key showing the target symbol that was to be found during the practice and test periods. During the practice period, the subject was given feedback to reinforce correct responses and to correct deviations from the accepted pattern. The feedback consisted of reminding the subject to scan straight down the map keeping fingers and hands together and to keep his hands flat on the map. Following the 4-minute practice period the map was removed. The subject was then told that he was to search another map on which he was to locate as many of the target symbols as he could in the time permitted. The same map was presented to the subject again; however, the map was rotated 180° from the original position. The subject was told to place his hands on one of the upper corners of the map and to begin searching for the target symbols. Task time was measured from the time the experimenter said "Begin" until the subject indicated he had searched the entire map. The subject was given a maximum of 8 minutes to complete the task.

For the tracking task, the subject was provided with a key having a tactile track in the form of a right angle. The subject was told to use two hands in following the track, one hand behind the other, using one or two fingers of each hand. One hand was used to follow the track, and the other hand trailed behind and served as a reference. Each subject was then presented with the tactile map and told that he was to follow the track on this map for practice. The subject was shown the starting point of the track and told to follow it to the end. Each subject was given up to 5 minutes to follow the track. At the end of 5 minutes or when the subject completed the tracking task, the map was removed, rotated 180°, and given back to the subject as a "different" map. The subject was shown the starting point of the track (th[illegible] point during the practice period), which was now located on the lower right side, and told to follow the track to the end. The experimenter said "Begin," and the subject was timed until he followed the track and touched the last section of track designated by the terminal point K (Figures 1 and 2). The subject received a point for each section of track completed, with the maximum number of points a subject could receive being 11. A subject's finger had to trace a section of track from beginning to end in order to receive a point. No feedback or instructions were given during the test period.

## Results

### Scanning

For the scanning task, a two-way analysis of variance for independent groups was performed on the percentage of target symbols located, using an arcsin transformation of the data. Grade levels (4 to 12) and texture versus no texture constituted the two factors. The analysis showed that only texture versus no texture had a significant effect ($F = 13.23$, $df = 1, 54$; $p < 0.01$). A summary of the analysis is shown in Table 2. The mean percentage of target symbols located in the no-texture condition was 88.19 ($SD = 12.57$), while the mean percentage of target symbols located in the texture condition was 73.78 ($SD = 19.81$). This represents an absolute increase of approximately 15% more target symbols located when the map contained no texture as compared with when the map contained texture, and a relative difference in performance of 20%. In addition, the standard deviations indicated that there was substantially greater variability in performance when texture was used on the map than when there was no texture. An $F$ ratio of the variances showed that the texture condition was significantly more variable than the no-texture condition ($F = 2.48$; $df = 30, 30$; $p < 0.01$).

Table 2

Analysis of Variance on Percentage of Target Symbols Located, Using an Arcsin Transformation

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 71 | 13.73070 | | |
| Grades | 8 | 0.901974 | 0.112747 | 0.66 |
| Texture vs. no texture | 1 | 2.276516 | 2.276516 | 13.23* |
| Grades x texture vs. no-texture | 8 | 1.262327 | 0.157791 | 0.92 |
| Error | 54 | 9.289883 | 0.172035 | |

*$p < 0.01$

A separate two-way analysis of variance was performed on the task times in seconds, using a reciprocal transformation. The only significant effect was for texture versus no texture ($F = 8.36$; $df = 1, 54$; $p < 0.01$), with the no-texture condition being significantly faster than the texture condition. The mean time in seconds for the no-texture condition was 124.06 ($SD = 41.38$), and the mean task time for the texture condition was 168.86 seconds ($SD = 74.92$). The standard deviations indicated that there was substantially greater variability in search time with texture as compared with the no-texture condition. An $F$ ratio of the variances showed that there was significantly greater variability in search time on the textured map as compared with the no-texture map ($F = 3.28$; $df = 30, 30$; $p < 0.01$). A summary of the analysis is shown in Table 3.

Table 3

Analysis of Variance on Total Task Time in Seconds for Scanning Task, Using a Reciprocal Transformation

| Source | $df$ | $SS$ | $MS$ | $F$ |
|---|---|---|---|---|
| Total | 71 | 0.00082601 | | |
| Grades | 8 | 0.0001506 | 0.00001882 | 2.05 |
| Texture vs. no texture | 1 | 0.00007672 | 0.00007672 | 8.36* |
| Grades x texture vs. no texture | 8 | 0.00010313 | 0.00001289 | 1.40 |
| Error | 54 | 0.00049557 | 0.00000918 | |

*$p < 0.01$

Separate nonparametric analyses were carried out on the errors of duplication, since the error scores were not normally distributed. In order to assess the effects of texture versus no texture on the errors of duplication, a Kolmogorov-Smirnov two-sample test was performed using the small-sample formula for a one-tailed test. There was no significant difference between the two conditions ($D = 7$; $N = 36$; $p$ 0.05). In order to determine whether reliable differences existed between grade levels, a Kruskal-Wallis one-way analysis of variance by ranks was performed on the rank-order scores of the errors of duplication. There were no significant differences between grade levels ($H = 3.93$, $df = 8$, $p > 0.05$ corrected for ties).

Tracking tasks

Only 1 of the 36 subjects in the no-texture condition, and only 5 of the 36 subjects in the texture condition, failed to complete the tracking task perfectly (i.e., followed all sections of the track from beginning to end). In addition, the maximum number of track sections missed by any subject was two. Consequently, Fisher's exact probability test was used to determine whether the proportion of the subjects who missed sections of track in the no-texture condition was significantly different than the proportion of subjects who missed sections of track in the texture condition. There was no significant difference between the two conditions ($p = 0.099$, one-tail test).

A two-way analysis of variance for independent groups was performed on the total time scores in seconds for the tracking task, using a reciprocal transformation of the data. Grade levels (4 to 12) and texture versus no texture constituted the two variables. The only significant effect was attributable to texture versus no texture ($F = 4.69$; $df = 1, 54$; $p < 0.05$). Following a tactile track on a textured map took significantly longer ($M$ = 77.33 seconds, $SD$ = 66.72) than on a no-texture map ($M$ = 54.89 seconds; $SD$ = 48.54). An $F$ ratio of the variances showed that following a line on a textured map resulted in significantly greater variability in tracking time than on the no-texture map ($F$ = 1.89; $df$ = 30, 30; $p < 0.05$). A summary of the analysis is presented in Table 4.

Table 4

Analysis of Variance on Total Task Time in Seconds for Tracking Task, Using a Reciprocal Transformation

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 71 | 0.010270 | | |
| Grades | 8 | 0.001229 | 0.000154 | 1.10 |
| Texture vs. no texture | 1 | 0.000654 | 0.000654 | 4.69* |
| Grades x texture vs. no texture | 8 | 0.000862 | 0.000108 | 0.77 |
| Error | 54 | 0.007525 | 0.000139 | |

*$p < 0.05$

## Discussion

The addition of textured areal symbols to a tactile map decreased blind students' accuracy of locating target-point symbols by 20% and increased location time by 36%. For the line-tracking task, the addition of textured areal symbols had no effect on accuracy but substantially increased the tracking time by 41%.

The addition of texture to a tactile map acted as noise in the tactual communication channel. As is well-documented in visual and auditory research as well as vibrotactile research (Geldard, 1972), noise masks a target signal and decreases its detectability. When the fingertips scanned across the display containing texture, a certain degree of superfluous stimulation resulted, possibly in the form of vibration. The additional vibration made it less likely for the student to detect a change in stimulation which signaled the presence of a target symbol, and thus fewer detections were made. Furthermore, the intensity and frequency of the vibration were in part dependent upon the speed of the fingertips as they moved across the map. Students evidently attempted to attenuate the effects of the added noise by reducing the speed of their scanning hand, thus increasing the total task time.

For the tracking task, students traced the tactile track with their fingertips. Since the tactile track was raised higher than the textured areal symbols, the textured areal symbols could have no effect on tracing performance as long as the fingertips remained on the track. However, when a subject's fingers fell off the track or when the track was interrupted by a break or an additional symbol, it necessitated a search for the continuation of the track. As the subject searched for the continuation of the track, his fingertips came into contact with a prominent element of one of the textures. Each time this occurred, the subject had to make a decision as to whether the element was part of the track (the signal) or irrelevant information (noise). Consequently, each decision required a small, but decided, increment in task time and resulted in substantially longer task times to follow the complete track. Thus, for both tasks, texture had a disruptive effect on performance.

It has been assumed that texture on tactile maps is analagous to the use of color on print maps and would thus facilitate map-reading for the blind. However, on print maps, color is used in part to enhance the differences between figure and ground as well as to differentiate one adjacent area from another. While texture can be used to differentiate one adjacent area from another, the results of this study showed that it had the opposite effect, making it more difficult to detect figure (point symbols) from ground. Although most producers of tactile displays would agree to limit the amount of irrelevant information on a tactile display, there is a tendency to represent expansive areas (e.g., grass) by a given type of texture, thus increasing the general noisiness of the map. Both teachers and producers of tactile maps may want to exhibit caution in the use of texture, particularly when it does not differentiate adjacent areas. They may also want to consider differentiating adjacent areas by bounding an area with a line symbol or by using braille labels instead of textures. Also, it would seem unwise to use texture on areas where other symbols are needed to represent significant information (e.g., political maps where capital cities or industrial centers are of major importance).

Another implication of the results is that where line-following is the major component of an educational task, such as in reading graphs, the display should be devoid of any prominent texture so that the subject can more efficiently follow the line. The addition of texture would probably increase task time and make tracking more difficult, particularly in the case of interrupted, broken, or criss-crossing lines.

The textured map in the present study contained five different textures. Presumably, not all five textures were equally noisy, even though this set of five were highly discriminable. The degree of noise is probably dependent upon the physical dimensions of the elements that made up a texture as well as the spacing and density of its elements. For example, Lederman and Taylor (1972) showed that the wider the elements and the smaller the spacing between elements in a texture, the greater the subjective estimate of roughness. Consequently, there are probably large differences in degrees of noisiness among any set of discriminable textures. Studies are needed to compare the noisiness of different textures with a variety of map-reading tasks. With this information the designers of maps could not only choose textures that are discriminable but also provide a minimum of noise.

# STUDY VII

# TACTILE POLITICAL MAP DESIGNS FOR BLIND STUDENTS

Edward P. Berla', Lawrence H. Butterfield, Jr., and Marvin J. Murr

Abstract

The design of tactile political maps for blind students was investigated by constructing two experimental maps using either a broad raised line or a broad incised line. Performance on these two maps was compared with performance on a thin raised line map (control) which is typically found in braille books. The subjects were 72 braille readers in grades 4-12. Performance on the broad raised line map was superior to performance on the control map in terms of a significantly greater number of shapes being located in significantly less time. Performance on the broad incised line map was no different than performance on the control map. The results are discussed in terms of line tracing behavior and the detectability of distinctive features.

## STUDY VII

## TACTILE POLITICAL MAP DESIGNS FOR BLIND STUDENTS

Tactile political maps represent one of the largest categories of embossed displays in braille textbooks (Arampatta, 1970), yet visually impaired students (ages 10-21 years) receive little or no training in map reading (Wiedel & Groves, 1969). Typically, tactile maps are reported to be difficult to read, and students are found to lack the necessary skills to read them (Berla', 1973; Berla' & Murr, 1974, 1975; Nolan & Morris, 1971; Study I; Wiedel & Groves, 1969).

A fundamental problem the blind student faces in reading tactile political maps is locating and differentiating the shape of an area (county, state, or country) within the larger complex of bounded areas. Study I showed that two of the major differences between good and poor map readers in locating and recognizing shapes on maps was difficulty in tracing lines and locating distinctive features of shapes. Poor readers typically had difficulty following the contour line of a shape, typically fell off the line they were tracing, erroneously followed intersecting lines, and became disoriented by lines that intersected the line they were tracing. Poor map readers also had substantial difficulty in picking out and locating distinctive features of shapes regardless of whether the shapes were in isolation or embedded within a larger display containing a number of juxtaposed shapes.

There are two approaches toward a solution to these problems. One approach is to train students in those skills in which they are deficient, and a second approach is to investigate different map designs which would ameliorate the problems students have in reading maps. This study focuses on the design of tactile maps. One map design principle which could ameliorate line tracing problems and make distinctive features more prominent would be to physically separate the shapes on a map. Physically separating shapes should facilitate line tracing because it should eliminate or at least reduce the probability of following an intersecting line and falling off a line and not being able to locate it again. It should also enhance the saliency of the distinctive features of a shape because the distinctive features of one shape would be separated from the distinctive features of adjacent shapes and there would be no intersecting lines to reduce the saliency of a distinctive feature.

Two experimental map designs were developed based on the principle of physical/perceptual separation. One design used a broad incised line and resulted in the shapes being separated and raised above the surface of the map. A second design used a broad raised line and resulted in the shapes of the map being separated and recessed.

## Method

### Subjects

The subjects were 72 students, enrolled in residential schools for the blind, who used braille as their primary reading medium. The schools participating in this research were the Lavelle School for the Blind, the Michigan School for the Blind, and the Wisconsin School for the Visually Handicapped. There were 24 subjects in each of the following grade groupings: 4-6, 7-9, 10-12. The means and standard deviations of the students ages within each grade grouping were, respectively: $M$ = 11.27, $SD$ = .86; $M$ = 15.15, $SD$ = 1.75; $M$ = 18.13, $SD$ = 1.63. There were 45 males and 27 females.

### Materials

Three different designs for the same map were developed. Map A represented the political divisions (shapes) with a continuous thin raised line separating the different areas and is shown as Figure 1 in Study III. The width of the line was .12 cm. This map was an analogue of a print outline map and is the typical design for political maps now used in braille atlases and textbooks. Map B was constructed by using a broad raised line (.635 cm) to separate the different areas and is shown in the drawing in Figure 1. Map C was reverse of Map B and was constructed by having a broad incised line (.635 cm) around each state resulting in the shapes being raised above the surface. All the maps had their lines or shapes raised .0635 cm above the surface of the map. The outer dimensions of the maps were 20.32 X 25.40 cm. The content of each map consisted of six states of the United States chosen on the basis of approximately equal area. The states with their areas in square kilometers were as follows:

| State | Area in square kilometers |
|---|---|
| Alabama | 132,292 |
| Arkansas | 136,558 |
| Florida | 140,539 |
| Illinois | 144,903 |
| Iowa | 145,003 |
| Wisconsin | 141,711 |

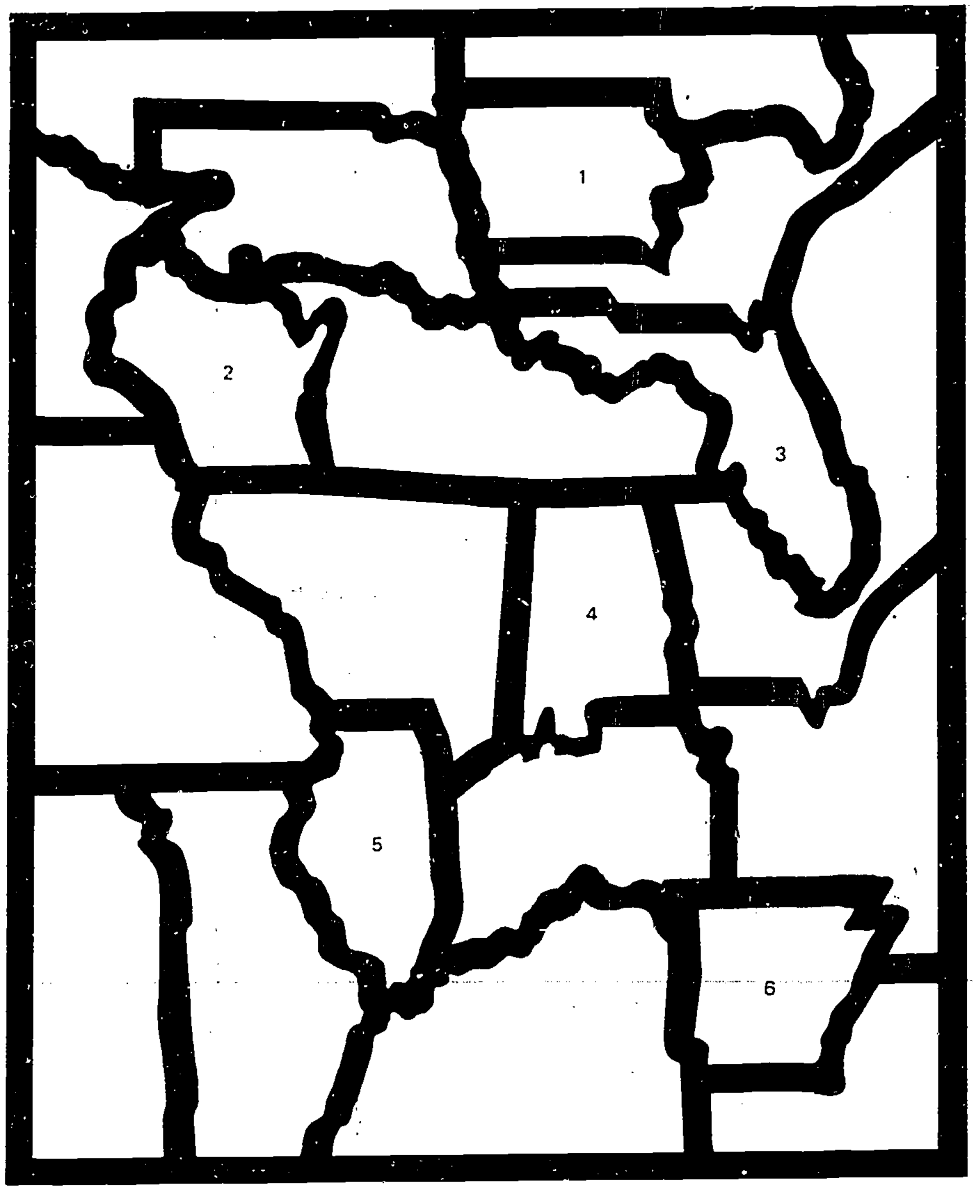


Figure 1. Map B was designed with a broad (.635 cm) line, raised .0635 cm above the surface. The overall size of the map was 20.32 X 25.40 cm.

The six states' boundaries were drawn from a base map in Reader's Digest Great World Atlas (1963, p. 47). The map scale was 1 cm to 89.97 km or 1 = 9,000,000. A 20.32 X 25.40 cm page was divided into a grid having five rows and four columns. Each of the six states was randomly chosen and randomly assigned to one of the cells with the restriction that no two states could occupy adjacent cells in the same column or row. In order to increase the complexity of the map, 20 additional boundary lines were added to each map to connect the states and divide up the remaining space. The additional intersecting lines were actual boundary lines taken from the United States base map and shortened where necessary to fit within the size of the paper. The base pseudomap constructed in this fashion was used as the base map for developing the three different designs described above. Three-dimensional molds of each of the formats were made using a photoetching process to produce master plates. Plastic, vacuum-formed copies were made from the plates.

A second set of maps was made and used during a familiarization period. The content of the familiarization map consisted of three states as follows:

| State | Area in Square Kilometers |
|---|---|
| New York | 124,136 |
| North Carolina | 127,278 |
| Georgia | 151,562 |

Each of these states was arbitrarily placed on a 20.32 X 25.40 cm page and 10 additional boundary lines were added to connect the states and divide up the remaining space. The familiarization map was produced in the three different designs described above. Both the test and the familiarization maps were mounted on cardboard with a nonskid backing. For each of the maps separate cue cards were made showing each one of the states separately. The states were cut from plastic copies of the maps and each state was mounted on an 8.9 X 8.9 cm cardboard square with a nonskid backing.

## Design and Procedure

Each of the subjects was given the task of locating and tracing the target shapes on both the practice and test maps. A subject was shown a cue card and told to feel it for 30 seconds and then told to locate the same shape on the map. The cue card was placed alongside the map to serve as a reference while the subject searched the map for the target shape. Each subject was given a familiarization map corresponding to the same type of map design as the test map in order to familiarize the subject with the nature of the map design prior to being introduced to the test map. Each subject served as his or her own control with each receiving the control map and one of the experimental maps. Half the subjects were tested on the control map and the broad raised line map. The other half were tested on the control map and the broad incised line map. Each subject was presented with a different orientation of the two test maps (0° or 180°) in order to minimize the subject remembering the location of a shape from one map to the next. The order of presenting the test maps was counterbalanced so that half the subjects received the control map first and the experimental map second. The other half of the subjects received the reverse order. Subjects were randomly chosen from grade lists and randomly assigned to conditions. Subjects with residual vision were blindfolded.

## Results

The dependent measures were time to locate each of the six shapes and the number of shapes correctly located. Separate analyses of variance were computed for both time and number of shapes located. Two analyses of variance were performed on the broad raised line map vs. the control map and two analyses of variance were performed on the broad incised line map vs. the control map. Each analysis performed was a two between-one within analysis of variance. Grade groupings (4-6, 7-9, 10-12) and order of presenting the maps were between subjects variables and map design was the within subjects variable.

There were no significant differences in performance on the broad incised line map as compared to the control map in time ($F$ = 2.06; $df$ = 1, 30; $p > .05$) or the number of shapes located ($F$ = 1.92; $df$ = 1, 30; $p > .05$). All other main effects and interactions also were not significant (all $p$'s > .05). A summary of the analyses are shown in Tables 1 and 2.

Table 1

Analysis of Variance on Mean Task Time to Locate Shapes as a Function of Map Designs (Broad Incised Line vs. Control), Grade Groupings (4-6, 7-9, 10-12), and Order of Presentation

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 289,658.18 | 71 | | |
| Between subjects | 260,672.29 | 35 | | |
| Grade groupings | 16,668.64 | 2 | 8,334.32 | 1.09 |
| Order | 2,154.09 | 1 | 2,154.09 | .28 |
| Grades x order | 12,757.24 | 2 | 6,378.62 | .84 |
| Error | 229,092.32 | 30 | 7,636.41 | |
| Within subjects | 28,985.89 | 36 | | |
| Map designs | 1,585.22 | 1 | 1,585.22 | 2.06 |
| Grades x maps | 1,854.76 | 2 | 927.38 | 1.20 |
| Order x maps | 36.87 | 1 | 36.87 | .05 |
| Grades x order x maps | 2,387.01 | 2 | 1,193.50 | 1.55 |
| Error | 23,122.04 | 30 | 770.73 | |

Performance on the broad raised line map was significantly faster than on the control map ($F$ = 7.94; $df$ = 1, 30; $p < .01$) and significantly more shapes were located on the broad line map than on the control map ($F$ = 4.66; $df$ = 1, 30; $p < .05$). The average time to locate a shape on the broad raised line map and control map were, respectively: $M$ = 110.87 seconds, $SD$ = 44.39 and $M$ = 131.85, $SD$ = 62.52. The mean number of shapes correctly located on the broad raised line map and control map were, respectively: $M$ = 4.97, $SD$ = 1.16 and $M$ = 4.26, $SD$ = 1.74.

Table 2

Analysis of Variance on Number of Shapes Located as a Function of Map Designs (Broad Incised Line vs. Control), Grade Groupings (4-6, 7-9, 10-12), and Order of Presentation

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 220.875 | 71 | | |
| Between subjects | 191.375 | 35 | | |
| Grade groupings | 7.583 | 2 | 3.792 | .63 |
| Order | .681 | 1 | .681 | .11 |
| Grades x order | 2.861 | 2 | 1.431 | .24 |
| Error | 180.250 | 30 | 6.008 | |
| Within subjects | 29.500 | 36 | | |
| Map designs | 1.681 | 1 | 1.681 | 1.92 |
| Grades x maps | .361 | 2 | .181 | .21 |
| Order x maps | .125 | 1 | .125 | .14 |
| Grades x order x maps | 1.083 | 2 | .542 | .62 |
| Error | 26.250 | 30 | .875 | |

There was also a significant difference between grade groupings in the mean time required to locate a shape on these maps ($F = 3.99$; $df = 2, 30$; $p < .05$) with students in the lowest grade grouping taking more time than students in the other two grade groupings. Performance in the upper two grade groupings was approximately equivalent. The mean times in seconds to locate a shape in grade groupings 4-6, 7-9, and 10-12, were, respectively: $M = 144.11$, $SD = 59.89$; $M = 111.13$, $SD = 58.45$; $M = 116.04$, $SD = 52.07$. A summary of the analyses are shown in Tables 3 and 4.

Table 3

Analysis of Variance on Mean Task Time to Locate Shapes as a Function of Map Design (Broad Raised Line vs. Control), Grade Groupings (4-6, 7-9, 10-12), and Order of Presentation

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 197,033.55 | 71 | | |
| Between subjects | 146,290.45 | 35 | | |
| Grade groupings | 29,947.08 | 2 | 14,973.54 | 3.99* |
| Order | 450.85 | 1 | 450.85 | .12 |
| Grades x order | 3,260.59 | 2 | 1,630.30 | .43 |
| Error | 112,631.93 | 30 | 3,754.40 | |
| Within subjects | 50,743.10 | 36 | | |
| Map designs | 9,503.38 | 1 | 9,503.38 | 7.94** |
| Grades x maps | 1,196.42 | 2 | 598.21 | .50 |
| Order x maps | 2,522.75 | 1 | 2,522.75 | 2.11 |
| Grades x order x maps | 1,618.87 | 2 | 809.44 | .68 |
| Error | 35,901.68 | 30 | 1,196.72 | |

* $p < .05$
** $p < .01$

Table 4

Analysis of Variance on Number of Shapes Located as a Function of Map Design (Broad Raised Line vs. Control), Grade Groupings (4-6, 7-9, 10-12), and Order of Presentation

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Total | 135.653 | 71 | | |
| Between subjects | 85.153 | 35 | | |
| Grade groupings | 6.861 | 2 | 3.431 | 1.33 |
| Order | .125 | 1 | .125 | .05 |
| Grades x order | .750 | 2 | .375 | .15 |
| Error | 77.417 | 30 | 2.581 | |
| Within subjects | 50.500 | 36 | | |
| Map designs | 6.125 | 1 | 6.125 | 4.66* |
| Grades x maps | 3.250 | 2 | 1.625 | 1.24 |
| Order x maps | 1.125 | 1 | 1.125 | .86 |
| Grades x order x maps | .583 | 2 | .292 | .22 |
| Error | 39.417 | 30 | 1.314 | |

* $p < .05$

## Discussion

Designing a tactile map by using a broad raised line to represent political boundaries facilitated the task of locating and tracing shapes on a map. The question is why should a broad line facilitate performance as compared to the typical thin line map? Any line can be conceived of having three parts, a top surface and two edges. On a thin line map subjects characteristically trace the top surface probably because they do not perceive the line as having two distinct edges, just one surface. In so doing their line tracing behavior is more likely to be disrupted by intersecting lines. They may erroneously follow an intersecting line or the intersecting line may interrupt their tracing and increase the time it takes to trace a shape. With a broad line the two edges are clearly discernible and subjects characteristically trace an edge rather than the top surface. By tracing an edge of a line, the fingertip never comes in contact with any intersecting line; thus the possibility of tracing an intersecting line or having tracing disrupted temporarily by the intersecting line is reduced. Consequently, once the target shape was located on the broad raised line, the edge could be traced in one continuous motion without being hindered by intersecting lines. Another factor which may have contributed to better performance on the broad raised line map was the fact that the shapes were more widely separated; thus the distinctive features of shapes were separated. This may have made the distinctive features more prominent and thereby more detectable.

Tracing problems similar to those encountered on the thin line map were also observed on the part of the students using the broad incised line map. The students frequently traced the recessed line rather than the edge of a shape. Consequently, there was a greater probability of following an erroneous intersecting line. In addition, it has been documented in previous research (Nolan, 1971) that following an incised line takes more time than following a raised line, and that students in the lower grades require significantly more time to trace a recessed line than students in the upper grades.

If the important aspect of the broad line map is perceiving and tracing the edge of a line rather than the top surface, then it might be possible to train this particular behavior and use narrower lines than the .635 cm line used in this study. It would appear safe to conclude that a line should be at least wide enough so that a student could easily detect two distinct edges. Each edge would define the existence of a shape. Tracing either of the two edges would define a different shape. Designing tactile maps in such a manner should contribute to the amelioration of the problems confronting the tactile map reader.

## SUMMARY AND CONCLUSIONS

## SUMMARY AND CONCLUSIONS

The purpose of this section is to delineate the major map reading behaviors and map design principles found to be effective or ineffective and to suggest further areas for research and development. Although the research reported herein was conducted in the context of maps, it should be recognized that the principles of behavior and design which were identified are probably generalizable to other types of embossed displays such as graphs and charts.

### Frames of Reference

The research by Nolan and Morris (1971), as well as a rational analysis of map reading, suggested very strongly that a blind student's map reading performance would be facilitated if the student gave a map a preliminary scan prior to initiating specific tasks. It was assumed that a preliminary scan would give the student a frame of reference which would include such information as the size of the map, the nature of the symbology on the map, and the location of some of the distinctive features of the map to serve as reference points. The studies reported herein showed that a frame of reference, in the form of a preliminary scan, had little or no positive effect. These studies showed that little information is gained during a preliminary scan that is useful during a subsequent detailed search.

However, one incidental finding in these studies is worthy of more attention. Training appeared to facilitate the map reading performance of the younger students in the lower grades (4-6) while it had no effect or a deleterious effect on the map reading performance of the older students in the upper grades (7-12). This fact suggests the importance of beginning training in reading embossed tactile displays in the lower grade levels or at least training in those kinds of skills needed for reading embossed displays.

### Basic Map Reading Skills

The videomatic study of good and poor map readers and the subsequent training studies pointed to a number of basic skills that are not only important in map reading, but that can be significantly improved with just short periods of training. Line tracking was one of the most basic skills needed in reading a map, yet it appeared to be a skill that students were deficient in from grade levels 4-12. However, a short period of training (1.5 hours or less) significantly facilitated line tracking performance.

Another important concept and skill needed in reading maps is the distinctive features analysis of shapes. Training students to analyze and remember a few distinctive features of a specific shape was very effective in improving their ability of locating and recognizing shapes both in isolation and when presented in a series of juxtaposed shapes on a political map. The results of the studies in this area demonstrated the importance for blind students to be analytical, systematic, and complete in their inspection of tactile materials.

## Map Design

The studies in this category showed the deleterious effect of complexity of design on map reading performance. The addition of texture to a map composed only of point and line symbols reduced accuracy of locating of points by 20% and increased the time to locate point symbols by 36%. In addition it took 41% longer to follow a line on a map with different textures on the background as compared to a map having a smooth background.

Using relatively broad raised lines (.25 inch [.635 cm]) on political maps also facilitated the location, recognition, and tracing of shapes as compared to the very narrow lines which are typically found in embossed paper braille atlases and textbooks. The broader lines appeared to facilitate line tracing because the students were able to follow an edge of a line and because it perceptually separated two adjacent shapes sharing the same boundary line. On the other hand, designing a political map by using raised shapes separated by broad (.25 inch [.635 cm]) incised lines was not as effective as using broad raised lines and no better than the thin raised lines which are typically found in braille atlases.

## Further Research and Development

The most important research and development activity suggested for the immediate future is the development of an embossed displays reading program. This program should incorporate tangible displays that contain the discriminable symbology previously identified and a series of activities designed to promote the perceptual-motor skills needed for reading embossed displays. The embossed displays and activities should contain information and tasks that are relevant to the grade levels in which they are being used. It is suggested that the creation of such a program begin at the first or second grade level.

Serious consideration should also be given to the redesign or creation of new braille atlases and individual maps that incorporate the discriminable symbology and principles of design that are now known. Furthermore, kits of materials also should be developed to enable classroom teachers to make their own maps that would use the discriminable symbology identified previously. The kit should include a manual on the perceptual-motor skills needed to read embossed displays and suggested criterion tests and activities for determining the level of skill of individual students.

Further research should be conducted combining map design principles with short periods of training. The studies reported herein investigated the design of tactile displays and reading skills as separate problems. A good place to begin would be to use the broad line map design in combination with training in distinctive feature analysis. Additional studies should be undertaken to investigate the reading of other types of embossed displays such as graphs and charts. A research program in this area might begin with a videomatic study of the problems students currently have in reading these types of displays. Results could suggest skills and embossed displays principles in addition to those already identified.

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