CURRENT RESEARCH IN TACTUAL CARTOGRAPHY

Charles E. Ogrosky
Rutgers University

INTRODUCTION

Estimates of the importance to humans of vision as a source of information about their surroundings vary, but there is little doubt that visual imagery often dominates inputs from the other senses. Geographers have relied heavily on visual imagery for data collection and for the communication of information about spatial relationships. However, much geographical information is not readily available to a significant minority of persons in the United States and worldwide, the visually handicapped. 1/ Persons who are severely handicapped -- the blind -- are very limited in the ease and efficiency with which they may perceive patterns and processes in their environments.

Compared to visual acuity, the other human senses are quite crude. For example, the visual two point threshold, an indication of the ability to correctly report one stimulus as one and two closely spaced stimuli presented simultaneously as two, is about .1 mm for a person with "normal" (20/20) vision at a reading distance of 30 cm. The tactual two point threshold for active exploration of a three dimensional surface is approximately 2.5 mm.2/ By this standard, the human visual sense is at least 25 times more acute than is the tactual sense. Furthermore, tactual information acquisition is strictly a linear process; multidimensional relationships must be reconstructed mentally from a series of serially acquired percepts. The blind can not "stand back" and view, tactually, the general relationships of a set of mapped phenomena without first becoming fully aware of the details of the distribution. Because the blind must rely primarily on touch for active acquisition of information, they must directly experience either their immediate surroundings or three-dimensional representations of their surroundings.3/ Therefore, most blind persons are slow to gather information about their environments and many have demonstrated generally poorly developed levels of understanding of basic geographic concepts.4/

MAPS AND THE EDUCATION OF THE BLIND

Tactually legible surrogates for many phenomena play an important role in the education of the blind. Tactually legible maps are known to be effective for transmitting information about the relationships of geographical phenomena.5/ Knowledge of such relationships is useful both for practical purposes such as unassisted mobility (travel) as well as for the development of an understanding of abstract relationships. Although alternative "map" forms, such as tape recorded directions are being explored,6/ most tactual maps are of the conventional, raised relief variety.

Of the three classes of tactual maps (mobility, orientation and thematic-reference), by far the greatest emphasis has been placed on the development and production of large-scale mobility maps. Maps such as neighborhood plans (Figure 1) are used to encourage independent mobility and exploration. These graphics are usually small, about 30 cm square, and lightweight to insure their portability. Image content must, therefore, be restricted to only the most essential phenomena. Relatively less attention has been devoted to the production of maps of the second type -- regional orientation maps. Particularly lacking are medium-scale map resources for urban areas, even though many blind persons live in cities. The map of central London (Figure 2) is typical of the limited number of such maps which are available.7/ The distribution of major points of interest and of primary transportation routes such as roads, bus lines and railroads is stressed. Regional orientation maps are not usually designed for portability, but are intended to be used for regional mobility planning. Moreover, such products are useful for helping the blind to develop an understanding of the complex spatial relationships of urban environments. Finally, only a very few small-scale thematic and general reference maps are available in tactual form. The general reference map of the United States (Figure 3) is part of a braille reference atlas. Because of the greater tactual two point threshold, data density has been drastically limited and a nonuniform degree of image generalization has been applied to various parts of the map. Production of more meaningful tactual reference and thematic maps is particularly important. Increasing numbers of blind persons are being educated with their sighted counterparts and growing numbers of State and Federal regulations mandate equal access to information for all persons.8/

RESEARCH IN TACTUAL CARTOGRAPHY

Opportunities for both graphic design research and the actual production of more effective tactual maps have been restricted by the relative lack of knowledge of tactual perceptual processes and by the inability to produce high quality, original, three-dimensional images at reasonable costs. Because of the relatively low demand for, and decentralized production of most tactual maps, images most often have been created manually by embossing figures in aluminum sheets or similar materials.9/ The result is often an image which lacks the uniformity necessary for optimal legibility. Better images have been produced by standard photoengraving methods, but costs have been prohibitive. Very recently, research involving the use of existing computer hardware and adaptable software has shown promise for helping to cut the costs of image preparation while simultaneously helping to increase the objectivity of tactual graphic design.10/ Programs are being developed to aid in the conversion of geographic data sets to graphic data structures and in the analysis of these structures for tactual legibility, based on objectively defined symbology and design criteria. Numerically controlled routing machines have been used to prepare three-dimensional map images directly. Laser systems may also be adapted to the production of three-dimensional surfaces with variable relief. Plotted output has been converted to raised form using recently developed, low cost photomechanical materials.11/ Full use of these technological advances will result in the availability of more maps of the types now produced and in the production of maps not currently available, including more thematic maps. In addition, by making possible the production of numerous alternative map displays, automation of some or all of the tactual cartographic process will increase the possibilities for experimentation aimed at expanding our understanding of tactual graphic design principles.

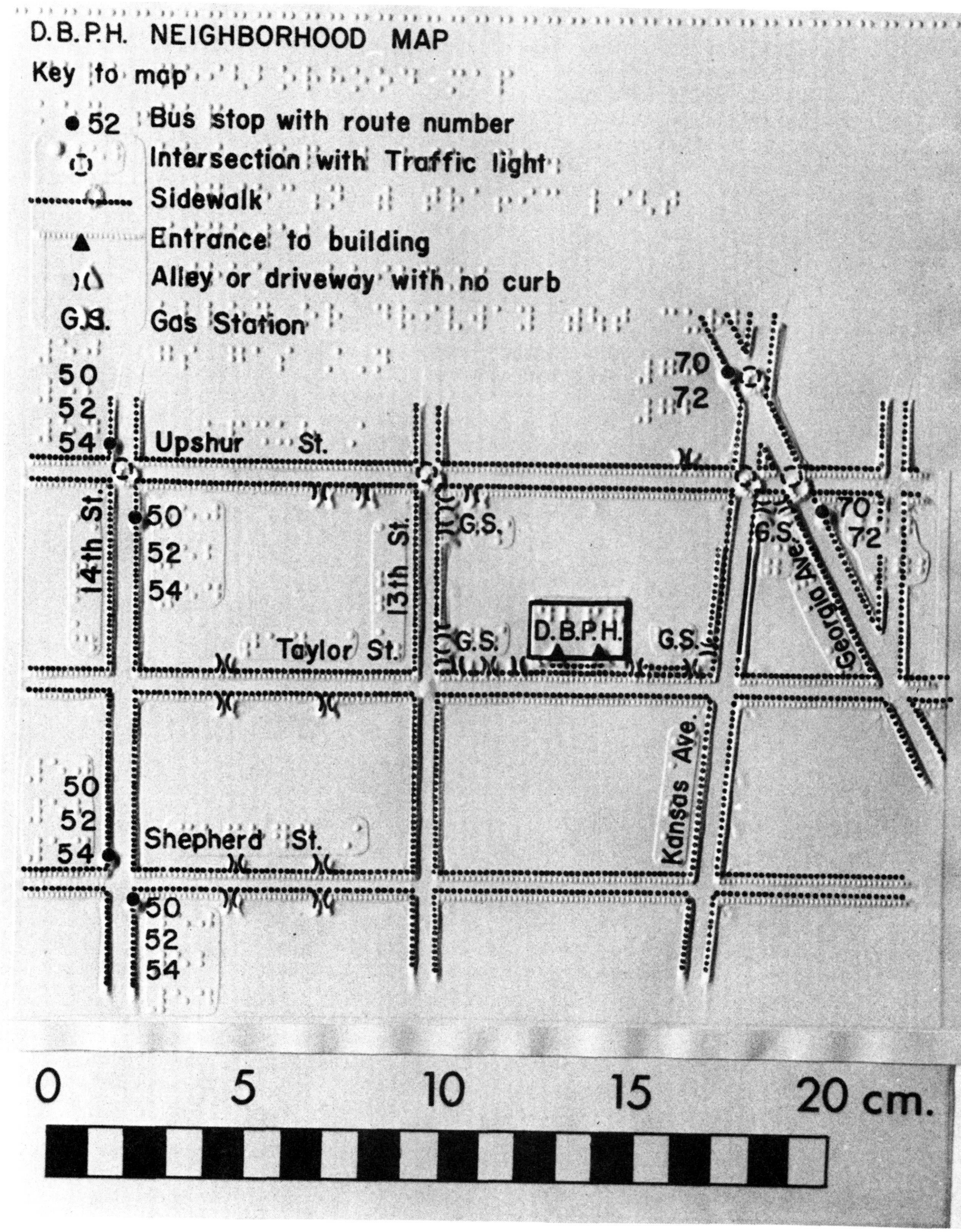


Figure 1. MOBILITY MAP OF WASHINGTON, D.C. NEIGHBORHOOD. *Prepared by Professor J.W. Wiedel, Department of Geography, University of Maryland, College Park, Maryland. The plastic was preprinted and the three dimensional image was reproduced by vacuum forming. The dimensions of the original image are about 25 by 25 cm.*

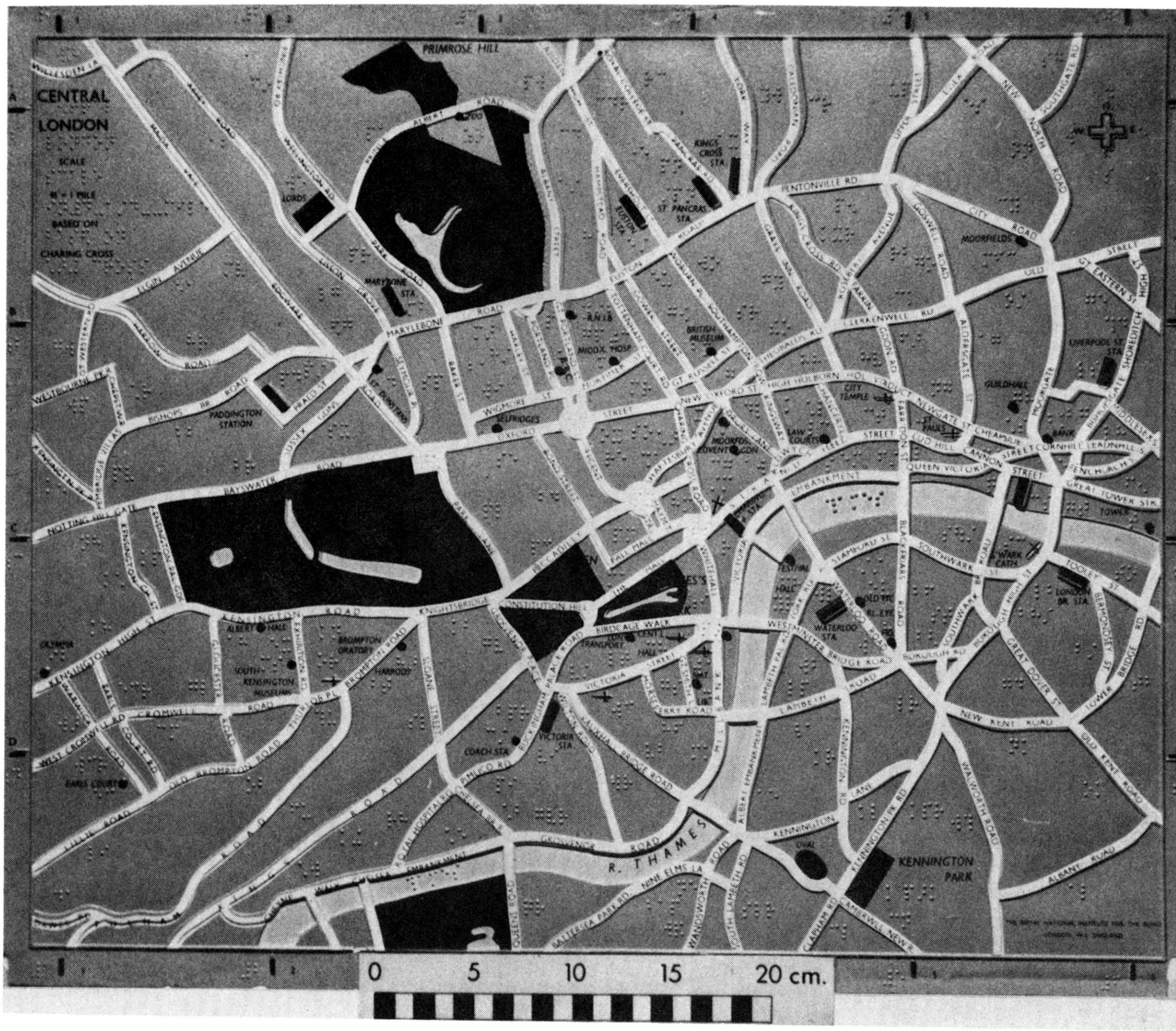


Figure 2. ORIENTATION MAP OF CENTRAL LONDON. Scale of original about 1:14,000. Prepared by the Royal National Institute for the Blind, the map is reproduced in plastic with a preprinted, multicolor image. The map is too large to be easily transported and used during travel, but it is well suited to mobility planning and general orientation. A braille legend is reproduced separately.

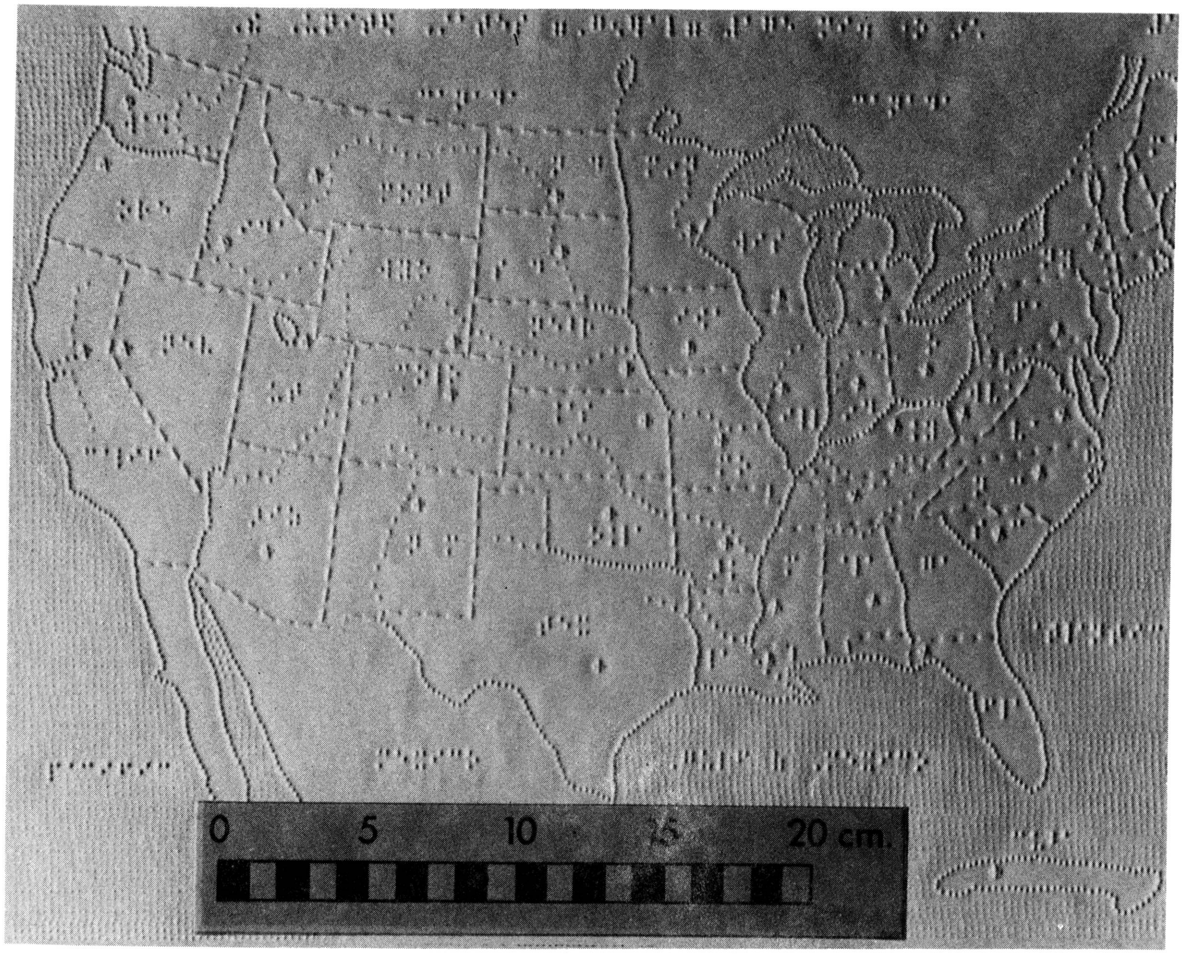
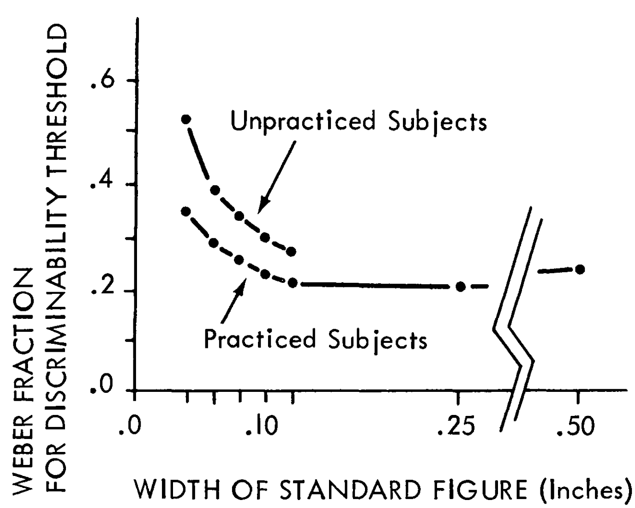


Figure 3. GENERAL REFERENCE MAP OF THE UNITED STATES. Size of original about 13 by 40 cm. The map is embossed in paper. The relative insensitivity of the human tactual sense dictates a high degree of generalization. In particular, note the lack of State identifiers in the northeast portion of the Nation.

Much of the existing research in tactual graphic communication has been directed toward the identification of tactual design variables and the isolation of sets of legible symbols.12/ As opposed to conventional cartography, in which differences in shape, size, color, tone, pattern, etc., may be used to create maps, tactual variables are less numerous and differences must be more coarse. Changes of shape -- for point symbols -- and texture -- for linear symbols -- have been shown to be important design parameters. 13/ Other tactual variables include size, orientation and height of the figure above the map base. The symbol sets which have been shown to be discriminable have meaning primarily in situations requiring nominal differentiation of map elements. Thus, mobility maps have been produced on which squares or rectangles represent buildings, triangles show the location of building entrances, single lines represent streets and dotted lines represent sidewalks. Although mobility maps serve a useful and well-defined purpose, production of maps showing higher level relationships, including all quantitative thematic maps, has not been possible. Production of such maps must be based on an improved understanding of certain aspects of active tactual perception including discrimination of changes in symbol characteristics which imply a change in the rank or value of phenomena (ordinal, interval or ratio relationships) rather than a change in the class of phenomena (nominal differentiation).

ORDINAL SCALING OF THREE-DIMENSIONAL FIGURES

Little attention has been given to the study of ordinal, interval and ratio scaling of tactually discriminable figures. Of the studies which have been completed, most have involved either passive touch, in which stimuli are applied to the skin of a subject, or forms of active touch, such as thumb-finger span, which are not directly applicable to the dynamic perception of three dimensional maps. In a recent study, Berla and Murr14/ investigated the tactual perception of single line widths by active touch to find discriminability thresholds for judging differences of line width. The discriminability threshold was defined as the minimum difference in the width of two linear stimuli necessary for a group of observers to correctly pick the wider stimulus in 90 percent of a series of trials. The Weber fraction, the ratio of the change in the dimension of a stimulus to the comparable dimension of the original figure, was computed for the 90 percent threshold for the range of stimuli used (Figure 4). High frac-



Source: E. P. Berlá and M. J. Murr, "Psychophysical Functions for Active Tactual Discrimination of Line Width by Blind Children," Typed manuscript submitted for publication, 1974, Table 7.

Figure 4. WEBER FRACTIONS FOR SIMPLE LINEAR FIGURES

tions were noted for both practiced and unpracticed subjects, although those persons who were tested repeatedly over a period of eight weeks showed improved discriminatory abilities. Although Berla and Murr's research provides deeper insights into certain aspects of dynamic touch, immediate implementation of the results in the design of ordinally scalled figures for maps may not be possible. The study was executed using milled steel lines mounted on wooden blocks and the tactual scan pattern of the subjects was restricted.15/

	POINT SYMBOLS		LINE SYMBOLS	
FIGURE	●	■	—	═
VARIABLE DIMENSION	Diameter	Side	Width	Interline Spacing
SIZES OF STANDARD FIGURES	5 to 25 mm in increments of 5 mm		2.5 to 12.5 mm in increments of 2.5 mm	

Figure 5. POINT AND LINE SYMBOLS CHOSEN FOR PAIR COMPARISON TESTING

To extend the understanding of ordinal tactual symbol scaling to other commonly used figures and to investigate active tactual exploration in a more realistic graphic reading situation, two linear and two point symbols were chosen for pair comparison testing (Figure 5). A variety of line widths, interline spacings and point symbol sizes are being evaluated to find discriminability thresholds for the standard figures. The raised standard and variable stimuli were created by (1) using a Calcomp plotter to plot two-dimensional figures on paper, (2) converting the figures to .7 mm high raised images using photomechanical methods 16/ and, (3) reproducing the raised symbols in vacuum-formed plastic, a medium in common use for the production of three-dimensional maps. Subjects are being allowed to scan the figures using any finger (usually the index or middle finger) of the preferred hand in a manner similar to that which would be used for reading an actual graphic. At this time, September 1975, the testing program is about 60 percent completed and certain well-defined trends are evident. In general, few persons seem to be extremely accurate in judging size differences, but subjects have made very large errors.

FIGURE	●	■		—	═
STD. SIZE			STD. SIZE		
5 mm	.15	.10	2.5 mm	.20	.10
10 mm	.08	.10	5.0 mm	.15	.10
15 mm	.12	.10	7.5 mm	.07	.07
20 mm	.08	.10	10.0 mm	.15	.10
25 mm	.08	.10	12.5 mm	.12	.12

Figure 6. PRELIMINARY WEBER FRACTIONS FOR THE DISCRIMINABILITY THRESHOLD

Weber fractions (Figure 6) have been computed for the standard figures being used in the current testing program. (It must be emphasized that these fractions are based only on partial results.) Comparison of the fractions for the single line stimuli with those obtained by Berla and Murr (Figure 7) show that, under more typical graphic reading conditions, smaller differences in line widths have been recognized more consistently in the present testing program. In no case is the Weber fraction more than .20 and, for the mid-range of the line widths, the fraction is only about .15. The group of unpracticed subjects in Berla

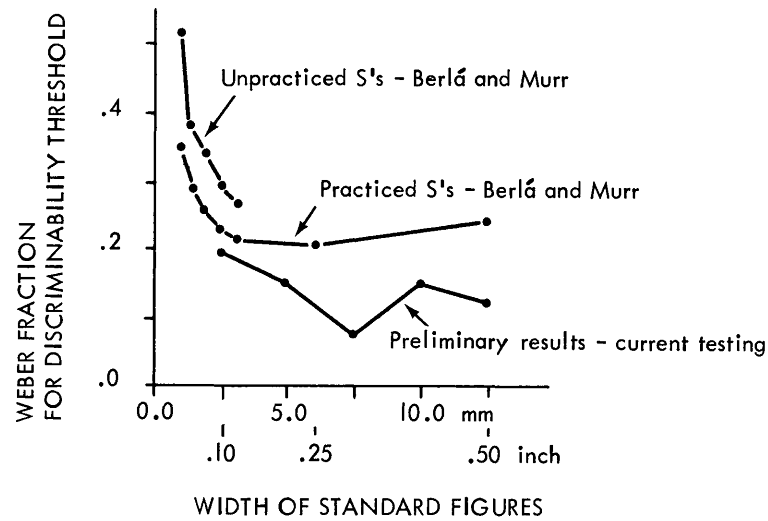


Figure 7. COMPARISON OF WEBER FRACTIONS FOR THE DISCRIMINABILITY THRESHOLD FOR SINGLE LINES

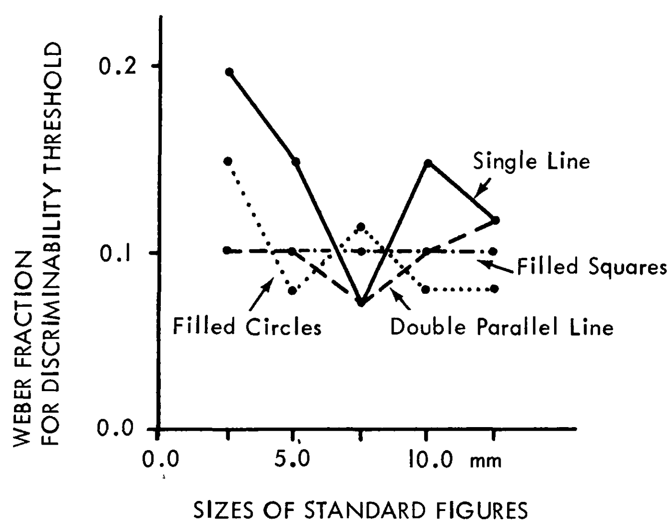


Figure 8. COMPARISON OF PRELIMINARY WEBER FRACTIONS FOR THE DISCRIMINABILITY THRESHOLD - CURRENT TESTING PROGRAM

and Murr's study achieved higher fractions, ranging from a low of .27 to a high of .52 for very fine lines. Even the group of subjects who were tested repeatedly for a period of eight weeks attained fractions ranging from a low of .21 to a high of .35. A similar function is evident in the Weber fractions for the double line symbol (Figure 8), but the 90 percent threshold is somewhat lower and more stable than for the single lines, ranging from about .07 to .12. Finally, preliminary indications are that subjects are able to perceive relatively fine differences in the dimensions of filled circles and squares. For these stimuli, Weber fractions for the 90 percent threshold range from .08 to .15. No previous results are available for comparison.

CONCLUSION

Although the foregoing preliminary results must be confirmed by more extensive testing, it seems unlikely that any significant deviations from the apparent trends will be found. Following the completion of the pair comparison testing stage of the project, the symbols will be tested in a map context. It is anticipated that the Weber fractions established on the basis of pair comparison testing in isolation will increase when the symbols are imbedded in a more complex graphic environment. However, the preliminary results are encouraging. The results for the single line symbols confirm previous work -- subjects are able to differentiate consistently between lines on the basis of size differences. Confirmation of the existence of this ability makes possible the design of more meaningful tactual maps. Simple line symbols scaled on an ordinal basis may be used to represent relatively complex linear geographic relationships. Furthermore, subjects engaged in tactual reading in a more realistic map reading situation, using commonly available materials, seem to be more adept at perceiving size differences for squares, circles and double linear symbols than had been assumed.

If the ability to judge size differences is confirmed in additional testing, it will mean that ordinally scaled symbols can be used on tactual maps with assurance that they may be read accurately. By basing design decisions on the results of this and related research, cartographers will be able to create uniform symbols which will occupy less of the very limited map image area than previously was thought possible. More information, within limits, may be placed on three-dimensional, quantitative thematic maps without a loss of image legibility. The ultimate increase in the availability of high quality, more easily read tactual maps will play an important part in extending the influence of map form to the visually handicapped, helping them to understand spatial patterns and processes in their unseen environment.

REFERENCES

1. Definitive statistics are not available. It has been estimated that there are about 443,000 legally blind individuals in the United States. Rodgers, C.T., "Understanding Braille," (New York: American Foundation for the Blind, no date), p. 10. One estimate of international rates of blindness places the ratio of blind to sighted persons at 1:225. Thus, there are probably more than 14 million blind persons worldwide. Wilson, J., "The Blind in a Changing World - New Trends Seen," New Outlook for the Blind, Vol. 59 (1965), p. 138.

2. Weber, E. "Ueber den Raumsinn und die Empfindungskreise in der Haut und im Auge," Ber. saechs, Ges. Wiss. Leipzig, Math.-Phys., C1. (1852), pp. 85 - 164. See also Boring, E.G., Sensation and Perception in the History of Experimental Psychology, (New York: Century-Appleton-Crufts, 1942).

3. Foulke, E., "The Perceptual Basis for Mobility," Research Bulletin No. 23, American Foundation for the Blind, 1971, pp. 1-8.

4. Franks, F.L. and Nolan, C.Y., "Development of Geographical Concepts in Blind Children," Education of the Visually Handicapped, Vol. 2 (1970), pp. 1-8.

5. Maglione, F.D., "An Experimental Study of the Use of Tactual Maps as Orientation and Mobility Aids for Adult Blind Subjects," Ph.D. dissertation, University of Illinois, 1969. See also Leonard, J.A. and Newman, R.C., "Three Types of 'Maps' for Blind Travel," Ergonomics, Vol. 13 (1970), pp. 165-179.

6. Leonard and Newman, "Three Types of 'Maps'."

7. Only a few other urban area maps have been produced. Work, under the supervision of Dr. John Sherman, is currently in progress on preparation of a metropolitan area orientation map for Washington, D.C. This project is being sponsored by the U.S. Geological Survey and also involves preparation of a large-scale mobility map of the Mall in central Washington.

8. Typical of laws which mandate equal opportunities for the blind, as well as for other handicapped persons, are Sections 28A.13.005 and 28A.13.010 of the 1974 Revised Code of Washington (State). Included in the sections is the provision that "each school district . . . (must) ensure an appropriate educational opportunity for all handicapped children of common school age."

9. Craven, R.W., "The Use of Aluminum Sheets in Producing Tactual Maps for Blind Persons," New Outlook for the Blind, Vol. 66 (1972), pp. 323-330.

10. Douce, J.L. and Gill, J.M., "The Computer-Assisted Production of Tactual Maps and Diagrams for the Blind," Electronics and Power, Vol. 19 (1973), pp.331-332.

11. Ogrosky, C., "New Approaches to the Preparation and Reproduction of Tactual and Enhanced Image Graphics for the Visually Handicapped," M.A. thesis, University of Washington, 1973.

12. See, for example, Nolan, C.Y. and Morris, J.E., "Improvement of Tactual Symbols for Blind Children," Final Report, Grant OEG-32-27-0000-1012, (Louisville: American Printing House for the Blind, 1971); James, G. A. and Gill, J.M., "'Mobility Maps' for the Visually Handicapped: A Study of Learning and Retention of Raised Symbols," Research Bulletin No. 27, American Foundation for the Blind, 1974; or Wiedel, J.W. and Groves, P.A., "Tactual Mapping: Design, Reproduction, Reading and Interpretation," Final Report, Grant RD-2557-S, (College Park: University of Maryland, 1972).

13. Nolan and Morris, "Improvement of Tactual Symbols," p.9.

14. Berla, E.P. and Murr, M.J., "Psychophysical Functions for Active Tactual Discrimination of Line Widths by Blind Children," Typed manuscript submitted for publication, 1974.

15. "The stimuli were...oriented perpendicularly to the body so that when the subject moved his fingertip across the length of the line he had to judge the width of the line. Consequently, the extent of arm or finger movement provided little if any information about the size of the line." Berla and Murr, "Psychophysical Functions," p. 2.

16. For a full description of the process, see footnote 11.