Use of Tactile Maps by Blind and Visually Impaired People

Simon Ungar, Angeles Espinosa Bayal**, Mark Blades*, Espernaza Ochaíta**, and Christopher Spencer**

**Department of Psychology, University of Sheffield, Western Bank, Sheffield S10 2TP, U.K. s.ungar@sheffield.ac.uk*

***Departamento de Psicología Evolutiva y de la Educacíon, Facultad de Psicología, Universidad Autonoma de Madrid, Madrid 28049, Spain espinosa@ccuam3.sdi.uam.es*

Most research on tactile maps has focused on aspects of map design and methods of construction. Relatively little attention has been paid to the way in which blind and visually impaired people actually use tactile maps for everyday way finding tasks. This paper reports on studies carried out in Madrid and Sheffield which consider how people gain spatial knowledge from tactile maps. In the Madrid study, participants were introduced to an urban area by one of three instructional methods: direct experience, tactile map or verbal description. Those who learned the area with the map were considerably more proficient in following the route unguided than were participants who received the other two instructional methods. However the different methods had little effect on the participants' overall representation of the space. It is possible that the map reading strategies used by the participants were effective for gaining practical route-based knowledge but did not give the participants an overall spatial representation of the area. To explore this possibility further, the Sheffield study considered the effect of individual differences in map reading strategies on the type of mental representation which visually impaired people acquire from a tactile map. It was found that those participants who acquired an accurate and full representation of the map used different map learning strategies from those who performed less well. We suggest implications of these studies for the education and rehabilitation of blind and visually impaired people.

INTRODUCTION

Most research on tactile maps has focused on design aspects, such as discriminability of symbols and relative suitability of various tactile media (e.g. Thermoform vs. Microcapsule). Comparatively little attention has been paid to how tactile maps are used by blind and visually impaired people. Psychologists have long been interested in the way in which people form and manipulate mental representations of the spatial environment. Within this research area, a small number of studies has considered the way in which blind and visually impaired people form mental representations of space from direct experience and from tactile maps (Carreiras and Codina, 1992; Dodds, Howarth and Carter, 1982; Herman, Herman and Chatman, 1983; Ungar, Blades, Spencer and Morsley, 1994).

"Comparatively little attention has been paid to how tactile maps are used by blind and visually impaired people."

It has been shown in a number of studies that blind and visually impaired people have difficulty in constructing an accurate and spatially integrated mental representation of their environment from direct locomotion alone (Rosa and Ochaíta, 1993; Spencer, Blades and Morsley, 1989). Maps, which provide the spatial structure of the environment at a scale accessible to touch and without the disorienting effects associated with travel in the real world, can overcome this difficulty (Ungar, Blades and Spencer, 1996; Espinosa and Ochaíta, in press). Unfortunately tactile maps are still not widely used, and we feel that this is partly due to a lack of understanding of tactile map use.

"It has been shown in a number of studies that blind and visually impaired people have difficulty in constructing an accurate and spatially integrated mental representation of their environment from direct locomotion alone. . ."

This paper reports on two studies, each of which focuses on a different aspect of using tactile maps. The Madrid study compared the effectiveness of different instructional methods to provide visually impaired adults with the practical spatial knowledge necessary to navigate in a complex urban environment, and with configurational knowledge of the spatial structure of the environment. The Sheffield study looks at the strategies used by blind and visually impaired children to learn a tactile map, focusing on the acquisition of an overall representation of an urban layout.

LEARNING A COMPLEX URBAN AREA BY THREE INSTRUCTIONAL METHODS

Researchers working with sighted adults have found that learning about space is highly related to the instructional method used (Espinosa and Ochaíta, 1997; Hirtle and Hudson, 1991; Lindberg and Gärling, 1983). For example, when people learn a space using a map or a panoramic verbal description, the resulting spatial schemas are better co-ordinated than when the space is learned through direct interaction with the environment or from a sequential verbal description (Thorndyke and Hayes-Roth, 1982). The Madrid study examined the effects of different instructional methods on way finding performance and mental representations of space in blind and visually impaired adults.

Participants

The participants were 30[1] visually impaired adults who were blind from birth or before six years of age. The participants ages ranged from 22 to 40 years (mean = 29 years, 3 months). All the participants were employed by ONCE (Spanish Organization for the Blind) in a variety of posts. All had the equivalent of secondary school (high school) education. None of the participants had any residual vision which could be effectively used during the experiment. None of the participants had received any formal training in the use of tactile maps for navigation. Participants were randomly assigned to one of the three methods of instruction designed for this study.

Procedure

Participants were required to walk and learn a complex route of 2,050 meters in an unknown environment over four sessions (see Figure 1). The route consisted of eight landmarks, all of which could be recognized by kinesthetic, auditory and tactile cues. There were three different methods of instruction during the first session:

Direct Experience: the participants, accompanied by the instructor, walked freely along the route. The experimenter guided the participant but did not provide any descriptive information about the route.

Tactile Map: the participants carried a tactile map of the area with the route marked on it while they walked the route accompanied by the experimenter. Again, the experimenter did not provide any details of the route.

Verbal Description: as the participants walked the route the instructor provided a detailed verbal description of the route.

"The route consisted of eight landmarks, all of which could be recognized by kinesthetic, auditory and tactile cues."

In the subsequent three sessions, the participant was asked to walk the route unguided. When the participant got lost, the experimenter allowed him/her to walk to the next intersection between streets. Then, we asked him or her the right way to reach the next landmark. If the participant knew the correct direction, he/she was allowed to continue along the route, otherwise he/she was guided by the instructor to the next point of the route.

"...the participants carried a tactile map of the area with the route marked on it while they walked the route accompanied by the experimenter."

[1]Although relatively small, the sample size is necessitated by the relatively low incidence of visual impairments in the general population.

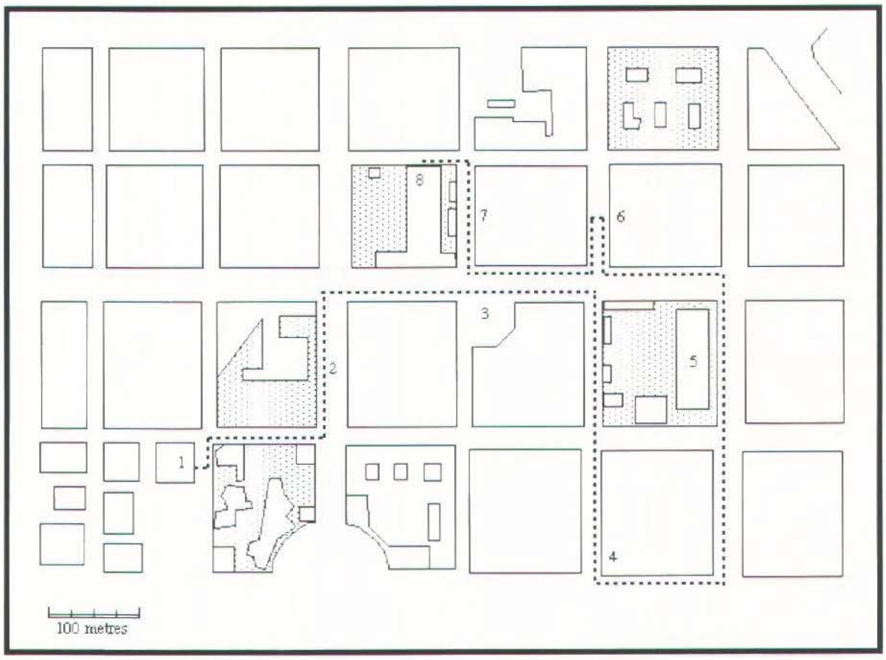

Figure 1.

"The participant's behavior was video-recorded on all sessions. The information from these recordings was combined with behavioral maps. . ."

The participants' behavior was video-recorded on all sessions. The information from these recordings was combined with behavioral maps (which were drawn by the instructor as she accompanied the participants) and were analyzed using a number of different measures of practical spatial knowledge, some of which had proved effective in previous studies by the Madrid research team (Ochaíta, Huertas and Espinosa, 1991). During the second and fourth sessions, the participants were also asked to make direction and distance estimates between all the landmarks, which yielded three measures of configurational knowledge. Thus the following six measures were used in the analysis:

Measures of Practical Spatial Knowledge

Meters: the number of meters by which the participant deviated from the specified route, measured as the difference between the total number of meters walked by a participant and the total length of the specified route, or 2,050 meters.

Stops: the number of times the participant paused while navigating the route for any reason.

Lost: the number of times the participant lost his/her way. A participant was considered to be lost when he or she did not know the way to the next landmark. In this situation, the experimenter allowed the participant to walk to the next intersection, and then asked him or her the way to the next landmark. If the participant was not able to give the correct directions, he or she was led by the experimenter to the next point on the route.

"A participant was considered to be lost when he or she did not know the way to the next landmark."

Measures of Configurational Knowledge

Direction Error: the deviation in degrees between the participant's estimate of direction and the actual direction.

Euclidean Distance Error: difference between the participant's estimate and the true Euclidean (i.e. Crow-flight) distance.

Functional Distance Error: difference between the participant's estimate and the true functional (i.e. City-block) distance.

Results

Analyses of variance (ANOVA) were carried out for each of the six measures on the data from the fourth session to determine the effect of the instructional conditions on the practical and representational spatial knowledge of the participants.

Practical Spatial Knowledge: The results showed a significant effect of the different conditions on practical spatial knowledge in two of the measurements (see Table 1): meters ($F = 5.987$, $p < 0.05$) and lost ($F = 7.324$, $p < 0.05$). The participants who learned the route with a tactile map lost their way less often and walked fewer meters off the specified route than the other two groups. Performance was poorest when participants received a verbal description of the route while walking, resulting in higher scores on 'meters' and 'lost'. The number of stops was not significantly affected by the type of information which the participants received.

"The participants who learned the route with a tactile map lost their way less often and walked fewer meters off the specified route than the other two groups."

Condition	Meters	Stops	Lost
DE	275	5.00	2.00
DE+Map	50	1.60	0.00
DE+Verbal	462.5	2.00	2.25

Table 1. Effect of instructional condition on practical spatial knowledge average values

Spatial Representation: The results showed a significant effect of instructional condition on functional distance errors ($F= 3.716$, $p< 0.05$). The subjects who learned the route with direct experience + tactile map have higher error scores on functional distances estimation than the participants who learned the route with by direct experience alone (see Table 2).

Condition	Direction Error	Euclidean Distance Error	Functional Distance Error
DE	35°	61.56	40.74
DE+Map	38°	61.44	60.00
DE+Verbal	34°	56.11	57.70

Table 2. Effect of instructional condition on spatial representation

Discussion

These results suggest that the combination of direct experience and a tactile map is a very good method for giving visually impaired people practical knowledge of the environment; although participants in this condition did walk some distance off the taught route, they never became completely lost. However, the map seemed not to provide them with a coordinated spatial representation of the area. In this respect, it should be noted that blind and visually impaired people are generally taught to orient themselves on the basis of route knowledge of the environment (i.e., Knowledge based on landmarks linked in sequence), and thus may not have had experience of forming overall representations of their environ-

"However, the map seemed not to provide them with a coordinated spatial representation of the area."

ment. So they may require training in the use of effective strategies for coding the spatial information contained in tactile maps.

The results clearly differ between practical and the representational measures. While the use of a tactile map in conjunction with a direct experience is a good method for giving visually impaired people practical knowledge of the environment, it is not clear that the map allowed them to acquire a coordinated spatial representation of the area. It should be noted that the participants had several years of experience of route-based way finding, and may not have had experience in forming overall representations of their environment. This suggests that visually impaired people would benefit with training in the use of effective strategies for coding the spatial information contained in tactile maps.

"This suggests that visually impaired people would benefit with training in the use of effective strategies for coding the spatial information contained in tactile maps."

STRATEGIES FOR ACQUIRING INFORMATION FROM TACTILE MAPS

The Madrid study showed that, while maps are clearly effective for introducing visually impaired people to a route, they were found to be no more effective than the other instructional methods for providing a global representation of the mapped space. However, as the Madrid study focused on group differences in way-finding ability, the Sheffield study was carried out to consider the possibility that the group scores may have concealed individual differences in strategies used by visually impaired people to acquire information from a tactile map. It has previously been found with sighted people that differences in strategies can account for differences in the resulting mental representation of the map (Thorndyke and Stasz, 1980).

When a print map is viewed by a sighted person, a great deal of information such as the relative and absolute positions of locations, the relative orientations of roads and the divisions between regions is instantly available. But the visually impaired map reader must discover this information by constructing it from sequential scanning of the map, forming reference frameworks and gradually establishing an overall, integrated impression of the map. For this reason it is important that a visually impaired map user has effective strategies for learning information from a tactile map. In previous studies we found a close relationship between the tactile scanning strategies spontaneously used by visually impaired children and their performance in spatial tasks (Ungar, Blades and Spencer, 1995; Ungar, Blades and Spencer, 1996a; Ungar, Blades and Spencer, 1996b). We examined the relationship between map reading strategies and the ability of map readers to acquire information from a tactile map.

"But the visually impaired map reader must discover this information by constructing it from sequential scanning of the map, forming reference frameworks and gradually establishing an overall, integrated impression of the map."

Participants

Nineteen children with visual impairments (VI group) took part in the study; of these children seven were totally blind and twelve had limited residual vision. All usually read Braille. Twenty-two sighted children also took part in the study so that comparisons could be made between the performance of the children with visual impairments and the performance of children with sight. The children were divided into three age groups: a young group (6 and 7 year olds), a middle group (8 and 9 year olds) and an older group (10 to 13 year olds).

Materials

A map of an imaginary town center (30cm x 42cm) was constructed in tactile and print forms (see Figure 2). It included thirteen named roads, nine labeled places and a river. The materials also included a metal board (30 cm x 42 cm) and a box of magnetic pieces used for map reconstruction.

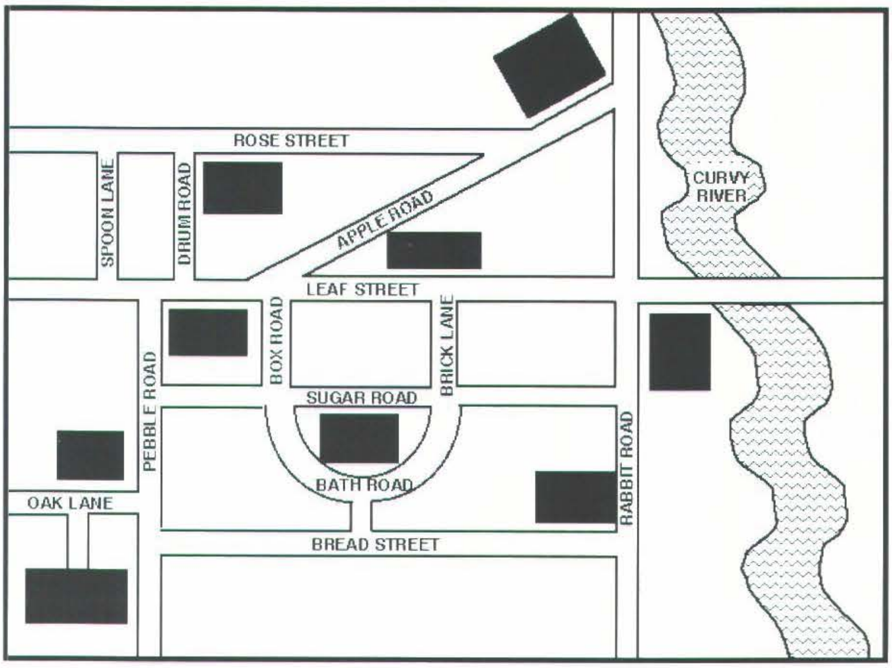

Figure 2.

Pieces were provided to represent roads, places and the river - there were more than three times the number of magnetic pieces required to reconstruct the map.

Procedure

The sighted children were given the print map and the visually impaired children were given tactile maps. All children were initially asked to learn the map for seven minutes. During this learning period they were asked to talk aloud about everything they noticed on the map and everything they thought about while they were trying to learn it (cf. Gilhooly, et.al., 1988; Thorndyke and Stasz, 1980). At the end of the learning period the map was removed, participants were given the metal board and magnetic pieces and were asked to reconstruct the map from memory. As the participant placed each piece on the board and named it, it was labeled by the experimenter with either a Braille or a print label. The reconstruction was photographed and the magnetic pieces were removed.

This procedure was repeated twice. Thus, in all, the participants learned the map three times and made three reconstructions. All three learning and reconstruction periods were videotaped to provide a complete record of the participants' commentaries and performance.

"The sighted children were given the print map and the visually impaired children were given tactile maps. All children were initially asked to learn the map for seven minutes."

"Thus, in all, the participants learned the map three times and made three reconstructions."

Analysis

The participants' commentaries were analyzed for statements which referred to: map objects; methods of learning the map; intentions to use particular techniques; and comments about their own performance. The strategy types were derived from previous pilot studies on learning tactile maps. For each child's transcript we calculated number of statements of each strategy type expressed as a proportion of the total number of statements by that child. Man Whitney U tests were used to test for any differences between the experimental groups in the mean proportion of use of each strategy type.

The children's reconstructed maps from the third trial were scored on two criteria - one objective and one subjective. For the objective criterion, the children scored one point for every map element placed within 4 cm of its original position on the map. Thus each child could score a maximum of 23 (13 roads + 9 locations + the river). For the subjective criterion, each map was rated by one of the experimenters and an independent rater. The children's maps were ranked blind according to how well they resembled the original map, in particular, how well they preserved the spatial relationships between locations and the interconnections between roads of the original. There was 95% agreement between two independent judges who rated the maps.

"The children's reconstructed maps from the third trial were scored on two criteria - one objective and one subjective."

Results

In this section, we will report only those results which were significant at the 0.05 level.

An analysis of the accuracy of the maps revealed no differences between totally blind and residual vision groups. However, both these groups were significantly less accurate in reconstructing the map than the children with sight (by both criteria). There were no significant differences by age. There was great individual variation in performance within and across groups.

A comparison of the learning strategies used by the visually impaired children and the children with sight revealed that the children with visual impairments spent more time reading out names or tracing routes around the map, they also tended to describe features on the map without interpreting them as symbols, and they were more likely to bring in general knowledge which was not directly relevant (e.g. By making comments like "there should be a roundabout in the park"). In contrast, the children with sight more frequently mentioned the position of features on the map with reference to the frame of the map or relative to the position of other features, and they made more frequent comments about patterns formed by groups of roads or features on the map.

"...children with visual impairments spent more time reading out names or tracing routes around the map..."

A second analysis focused on the children with visual impairments. A comparison was made between the strategies used by the seven visually impaired children who produced the most accurate maps and the strategies of the seven visually impaired children who produced the poorest maps. There were two significant differences in the way that these two groups of children learned the map - the more accurate children more frequently related features to the frame of the maps and more frequently mentioned the relationships between features.

Discussion

In the Sheffield experiment, successful learning of the map was associated with the use of a specific set of strategies; children who focused on the relative and absolute locations of objects on the map as well as on patterns formed by groups of map objects, tended to perform better than other children. This accounts for the better performance of the sighted children who more often reported using such strategies than did the blind children and distinguishes between the good learners and the poor learners within both sight groups.

"...successful learning of the map was associated with the use of a specific set of strategies;"

Both of these studies show that people with visual impairments can use tactile maps effectively. In the Madrid study, a tactile map used in conjunction with direct experience was shown to be more effective than direct experience alone or than direct experience plus verbal description for familiarizing visually impaired adults with a long and complex route through an urban area. The fact that they did not gain a faithful global representation of the mapped area may be due to the strategies they used to acquire and organize the information from the map.

GENERAL DISCUSSION AND CONCLUSIONS

"Good map learners tended to focus on the spatial relationships between items on the map, local and global patterns formed by map elements and the locations of places and structures in relation to the external framework of the map."

The Sheffield study showed that individual differences in the ability to learn a tactile map of an urban area were closely related to the strategies which the young people used while learning the map. Good map learners tended to focus on the spatial relationships between items on the map, local and global patterns formed by map elements and the locations of places and structures in relation to the external framework of the map.

Future work will look at ways of introducing people with visual impairments to the overall layout of environments through tactile maps and at ways of training tactile map users to employ more effective strategies which may allow them to extract a richer representation of the environment from a tactile map.

ACKNOWLEDGMENTS

We are extremely indebted to all of our participants. We also thank the staff of Tapton Mount School in Sheffield and the Royal Blind School in Edinburgh. The research in Madrid was part of a larger project funded by the Dirección General de Investigación Cientifica y Técnica (DGCYT) of the Spanish Government. The research in Sheffield was part of a larger project funded by the Economic and Social Research Council.

REFERENCES

Carreiras, M. and B. Codina. 1992. Spatial cognition of the blind and sighted - visual and a modal hypotheses. Cahiers de Psychologie Cognitive - *European Bulletin of Cognitive Psychology*, 12: 51-78.

Dodds, A.G., C.I. Howarth and D.C. Carter. 1982. The mental maps of the blind: the role of previous experience. *Journal of Visual Impairment and Blindness*, 76: 5-12.

Espinosa, A. and E. Ochaíta. 1997. El desarollo del conocimiento espacial de un entorno urbano desconocido: un estidiomicrogenético (Development of spatial cognition of an unfamiliar environment: a microgenetic study). *Infancia y Aprendizaje*, 79: 5-22.

Espinosa, A. and E. Ochaíta. (in press). Tactual maps: a useful instructional method for improving the practical spatial knowledge of visually impaired people. *Journal of Visual Impairment and Blindness*.

Gilhooly, K.J., M. Wood, P.R. Kinnear and C. Green. 1988. Skill in map reading and memory for maps. *Quarterly Journal of Experimental Psychology*, 40A: 87-107.

Herman, J.F., T.G. Herman and S.P. Chatman. 1983. Constructing cognitive maps from partial information: a demonstration study with congenitally blind subjects. *Journal of Visual Impairment and Blindness*, 77: 195-198.

Hirtle, S.C. and J. Hudson. 1991. Acquisition of spatial knowledge for routes. *Journal of Experimental Psychology*, 11: 335-345.

Lindberg, E. and T. Gärling. 1983. Acquisition of locational information in cognitive maps: automatic or effortful processing? *Psychological Research*, 45: 19-38.

Ochaíta, E., J.A. Huertas and A. Espinosa. 1991. Representación espacial en los niños coegos: una investigación sobre las principales variables que la determinan y los procedimientos de objetivación más adecuados (Spatial representation in blind children: an investigation of the major variables and most effective methods of externalization). *Infancia y Aprendizaje*, 54: 53-79.

Rosa, A. and E. Ochaíta. 1993. *Psicología de la Ceguera* (The Psychology of Blindness). Madrid: Alianza Psicología.

Spencer, C., M. Blades and K. Morsley. 1989. *The Child in the Physical Environment: the Development of Spatial Knowledge and Cognition*. Chichester: John Wiley & Sons, Inc.

Thorndyke, P.W. and C. Stasz. 1980. Individual differences in procedures for knowledge acquisition from maps. *Cognitive Psychology*, 12: 137-175.

Ungar, S.J., M. Blades and C. Spencer. 1995. Mental rotation of a tactile layout by young visually impaired children. *Perception*, 24: 891-900.

Ungar, S., M. Blades and C. Spencer. 1996a. The construction of cognitive maps by children with visual impairments. In J. Portugali (ed) *The Construction of Cognitive Maps*. Dordrecht: Kluwer Academic.

Ungar, S., M. Blades and C. Spencer. 1996b. Can visually impaired children locate themselves on a tactile map? *Journal of Visual Impairment and Blindness*, 1996, 90: 526-535.

Ungar, S., M. Blades and C. Spencer. 1997. Teaching visually impaired children to make distance judgements from a tactile map. *Journal of Visual Impairment and Blindness*, 91: 221-233.

Ungar, S., M. Blades, C. Spencer and K. Morsley. 1994. Can visually impaired children use tactile maps to estimate directions? *Journal of Visual Impairment & Blindness*, 88: 221-233.