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Assessing the configurational knowledge of people with visual impairments or blindness

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Abstract

One of the fundamental human needs is the need to know the world around us. and to be able to freely navigate within this environment. Visually impaired and blind individuals experience a different world from those that are sighted, and yet their spatial understanding of this world remains relatively unknown. Assessing their comprehension of the everyday geographic environment can be undertaken using a variety of data collection and analysis techniques. from the simple (e.g. sketch mapping) to the complex (e.g. multidimensional scaling). This paper examines the various methods designed to collect and analyse the configurational knowledge of sighted individuals and assesses their applicability to collecting the configurational knowledge of people with visual impairments or blindness. A small study, utilizing quantitative and qualitative techniques, is used to investigate the utility of various tests in assessing the configurational knowledge of one blind person and two visually impaired people from Aberystwyth.

Introduction

Each individual possesses a unique comprehension of the world around them and the cognitive mapping abilities to organise and interpret their knowledge (Kitchin, 1994a). Cognitive mapping concerns the study of these abilities; how we consciously, or otherwise, acquire, learn, develop, think about and store data relating to our everyday geographic environment, and the actual knowledge we acquire (Downs and Stea, 1973). Cognitive mapping research has the potential to be of great benefit to the visually impaired and blind population (Pick, 1987), as the inability to travel independently is a significant handicap (Golledge, 1993). Planners, mobility educationalists and navigation aid designers can apply the results from cognitive mapping research to individuals with visual impairments or blindness in a number of ways that will enhance their independence and quality of life. How this group comprehend the world could lead to the planning of environments that are easier to remember, and facilitate greater and more pleasurable use. It could also provide information about what spatial information should be made available to blind pedestrians, in what form and which particular locations. Additionally, it could provide clues about how to further enhance the wayfinding and orientation skills of the group by supplying feedback on current knowledge and strategies of thought. Such feedback, could indicate to mobility educationalists how to teach more effective strategies of spatial thought and provide benchmarks to navigation aid designers, against which to gauge the impact and effectiveness of various training strategies and mobility aids. With the accelerating development of new technological aids for the blind such as NOMAD, an audio-tactile graphics processor (Parkes, 1989), personal guidance systems (Golledge et *al.*, 1991; Petrie, 1995; Balanchardan, 1995), talking signs (Brabyn, 1995), and Atlas Speaks, a talking A to Z (Fruchterman, 1995), the need for an effective and reliable assessment of cognitive map knowledge becomes ever apparent. At present, much reported work is difficult to draw conclusions from because there are contradictory findings (Spencer et *al.*, 1989).

Three theories exist which seek to classify the results of the growing literature concerning the mobility, orientation and navigation of people with visual impairments or blindness. The *deficiency theory* stares that congenitally blind individuals are

processes (i.e. vision) necessary to comprehend two

and transformations.

Blasch, *Inefficiency theory*

haptic nation is based upon auditory and this knowledge and comprehension is inferior to that based upon vision (see Spencer *et al.,* 1989). *Difference theory* states that visually impaired individuals possess the same abilities to process and understand spatial concepts, and that any differences, either in quantitative or qualitative terms, can be explained by intervening variables such as access to information, experience or stress (Passini and Proulx, 1988; Golledge, 1993).

This paper examines a number of techniques which can be used to measure the configurational knowledge of individuals with visual impairments and blindness. Configurational knowledge concerns the knowledge of the associations between, and relative position of, places (Golledge, 1992). The three theories outlined suggest that blind individuals have trouble building a comprehensive cognitive map knowledge to the level of configurational knowledge, with deficiency theory stating that such knowledge is impossible. Most researchers now acknowledge that blind individuals can process spatial data and complete tests designed to measure configurational knowledge, although their ability to complete these tasks is variable and generally poorer than sighted individuals.

Tests designed to measure the configurational knowledge of the blind individual

Traditionally,

journey

becomes a need to use accuracy to infer utility, with the implication being that the more inaccurate the knowledge the less utility it has. Tests to measure configurational knowledge can be divided into four categories and each is discussed in turn (Table 1).

'Graphic methods

Graphic methods are all variations upon sketch mapping. This method of data collection still remains one of the most popular techniques for gathering data relating to configurational knowledge despite well documented faults (Blades, 1990). There are five basic sketch map variations that all revolve around the central tenet that cognitive map knowledge can be sketched reliably, and easily represented graphically. The basic sketch map technique is designed to obtain from the sketch mapper a freely drawn and solicited sketch map that has been *minimally* defined by the researcher. The respondent is given a blank piece of paper and asked to map a given environment. The *normal* sketch mapping technique imposes more constraints on the respondent than the basic approach. The researcher is often interested in more specific features and will word the instructions appropriately to obtain the required data. In *cued* sketch mapping data collection, the respondent is given a portion of the map and asked to complete specific features. *The longitudinal* sketch map technique allows the researcher to study how the sketch' map evolves. The instruction set is similar to the normal

Table 1. Tests to measure configurational knowledge (using studies of the blind as examples where possible)

Category	Variations	Examples
Graphic tests	Basic	Jacobson (1992)
	Normal	Saarinen *et al.* (1988)
	Cued	Pearce (1981)
	Longitudinal	Humphreys (1990)
	Language	Wood and Beck (1976)
Partially graphic and reconstruction tests	Spatial cued response	Thorndyke and Hayes-Roth (1982)
	Cloze procedure	Robinson (1974)
	Reconstruction	Casey (1978)
Uni-to-multidimensional tests	Metric multidimensional scaling	Haber *et al.* (1993)
	Non-metric multidimensional scaling	Lockman *et al.* (1981)
	Projective convergence	Kirasic *et al.* (1984)
Recognition	Map/configuration recognition	Evans and Pedzek (1980)
	Aerial photograph recognition	Matthews (1984)

Source, Kitchin (1995)

procedure, but it requires the respondent to provide the sketch map on layers of carbon or tracing paper. After certain time periods the sheets of paper are turned over and the respondent continues to draw. Wood and Beck (1976) and Beck and Wood (1976a; 1977b) have argued that teaching respondents a sketch map *language* produces maps that are not compromised by lack of mappng knowledge. They developed a sketch map language called Environmental A for use by school children. It might be anticipated that blind individuals might experience trouble with graphically based tasks as they require the drawer to select, classify, simplify, and symbolize their knowledge to cartographic conventions, manipulating it into representation synonymous with a bird's-eye view; a view never experienced by blind individuals. Jacobson (1992) has however, successfully used the normal sketch map procedure to collect the knowledge of the blind individual of the University of Wales Swansea campus (Figure 1). In this study, respondents used a raised line drawing board to sketch the campus area prior to, and after, learning a tactile map of the area. Although, the initial reaction of the respondents was one of refusal, when encouraged each individual could not only draw the campus, but each were remarkably accurate when compared with the tactual map prepared (for example in Figure 2). Downs and Stea (1977) also report of a blind student who could accurately draw an outline map of the United States after learning a tactile map.

Partially graphic and reconstruction methods

Spatial cued response methodologies are essentially location testers. They differ from sketch mapping because they only require the placing of points. This reduces the motor skill component of drawing to a minimum and provides a structured framework for the responses of the respondents. There are various techniques, but the basic method is that of Thomdyke and Hayes-Roth (1982) who asked

Figure 1. Reproduced tactile map of the University of Wales Swansea campus

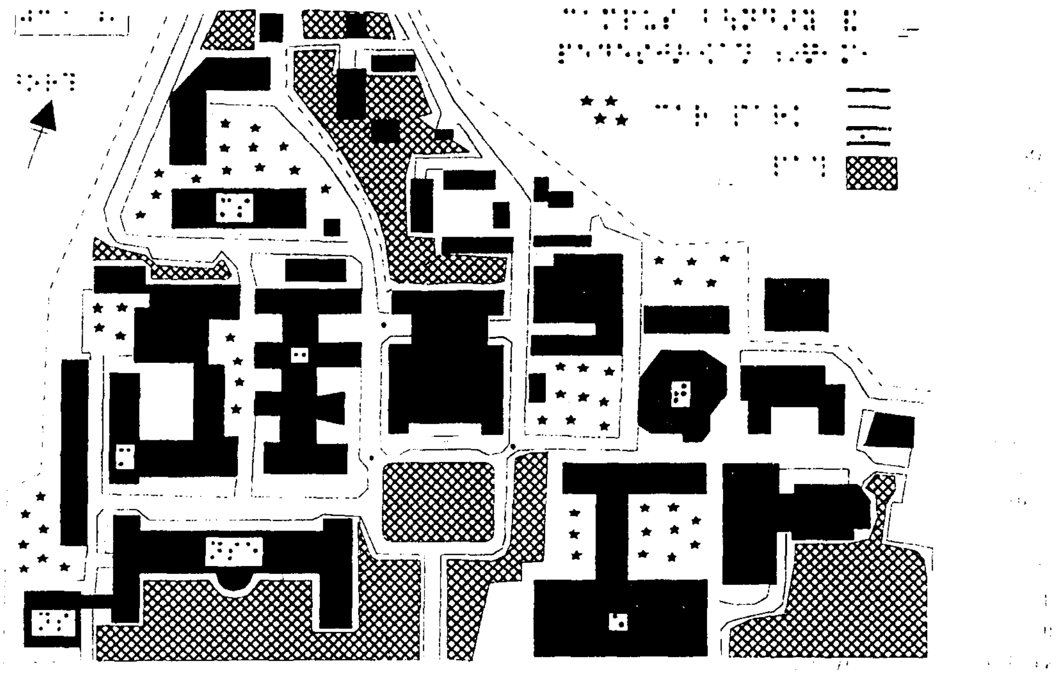
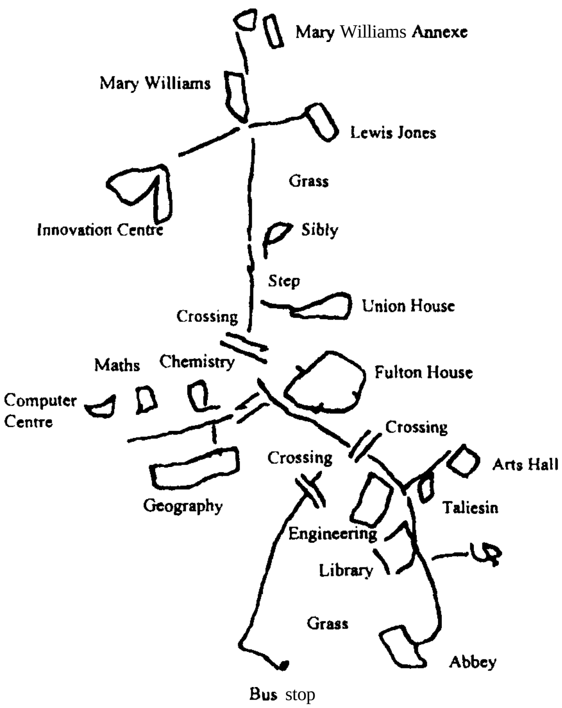


Figure 2. Sketch of the University of Wales Swansea campus by a congenitally blind student following tactile map familiarisation



respondents to place a location in relation to two points, one the starting point of a route and the other an arbitrary location. This method provides a scale and an orientation for the respondent. Kitchin (1990) altered the methodology so that instead of performing a series of triad tests, a whole series of locations were placed in relation to the original pairing, in this case, at a national and regional scale. Different researchers have added more information for the respondent to use. A similar method to that of Kitchin (1990) was used by Buttenfield (1986) but also provided a map outline as a cue. This test could easily be converted for use with blind individuals with the initial spatial cueing taking the form of a raised tactile surface or an enhanced graphic for' use by people with low vision. Because of the reduction in motor skills the spatial cued response test has more utility in measuring the knowledge of the blind individual than the sketch map technique. The data from the spatial cued response tests can be quantitatively analysed using bidimensional regression,, (see Kitchin, 1993), which is a two dimensional equivalent of ordinary least squares linear regression, and allows two sets of coordinates to be compared (Tobler, 1965). In this case, comparing the cognitive and real world locations.

The cloze procedure test is a spatial completion test. Traditionally the respondent 'fills in' the missing space, and an aspatial example would be, 'A dog barks but a cow ?', and this would be completed by the word 'moos'. Robinson (1974) and Boyle and Robinson (1978) have extended this exercise spatially. A base map is covered in a grid, and the information contained in some of the squares is deleted. Respondents are then asked to identify particular elements in these blank squares with the aid of contextual information retained in the remaining open squares. The results can be quantitatively analyzed by constructing an error score which represents how well an individual did in assigning places to the boxes. This score is simply the percentage of boxes with a place correctly assigned to it. This test could easily be converted for use with the blind, with respondents being given a tactile map with blank spaces and being asked to either match given places to spaces (cued) or decide what places might be in each square (uncued). Burroughs and Sadalla (1979) have used a similar technique called sentence frames. Respondents were required to complete a set of frames which took the typical format of: '_______ is close to ________' and '________ is essentially next to ________'. These sentence frames may have particular relevance to the blind as they involve no graphic extemalisation.

Reconstruction tasks allow the respondent to build a model of an environment. Casey (1978) asked ten congenitally blind students aged between 17 and 20, and ten partially sighted students aged between 16 and 21, to construct a map of their school using a modelling kit consisting of 22 wooden building blocks labelled in print and Braille, and adhesive strips to represent roadways and paths. Passini and Proulx (1988) used a similar modelling kit consisting of wooden blocks 2 cm in length, miniature stairs and circles to indicate entrances and exits. Each block had a magnetic strip so that it could be attached to a metal board. These models can be assessed both in terms of their contents and accuracy.

Uni-to-multidimensional methods

The third type of data that can be used to assess configurational knowledge is that of latent data. Techniques such as multidimensional scaling and projective convergence use route knowledge data to explore the latent, or inferred, structure of configurational knowledge. They do this by constructing a two-dimensional space from the one dimensional data which is provided, using a series of algorithms.

Multidimensional Scaling (MDS) is a technique that is designed to construct a 'map' showing the relationship between a number of objects, given only a matrix of 'distances' between them (Aitken et al., 1989). These 'distances' can be either all metric or all ordinal. The purpose of the technique is to discover the pattern or structure in a collection of empirical data and to represent that data visually (Golledge, 1977). The algorithm minimizes the difference, or stress, between the patterns of proximities in the matrix and the space created (Montello 1991a). Haber et al. (1993) have successfully used the MDS method to compare blind and the Euclidean distance estimates of sighted individuals and Lockman *et al.*, (1981) have implemented a non-metric equivalent. In the Lockman *et al.* (1981) study respondents were presented with the names of three locations and asked to determine which two places were furthest apart and which two were closest together. Respondents completed a series of these questions and the results were non-metrically multidimensionally scaled to produce a two dimensional map.

Whereas the MDS method constructs a configuration from a matrix of distances the projective convergence (or resection) method uses direction estimates to work out the coordinates of locations. Typically, respondents estimate the distance and direction to unseen places from three or more locations. The resulting vectors can be drawn and where the lines end a triangle of error can be drawn whose mean centre is taken as the cognitive location of a place. Hardwick *et al.* (1976) originally developed the method in a study where respondents first familiarised themselves with four locations within a library. Screens were then erected and respondents asked to estimate the direction by pointing a sighting tube in the direction of the four unseen locations. By calculating where the lines intersected the triangle of error could be found and a cognitive location could be calculated. Kirasic et al. (1981) first used the distance/direction method to study the memory of locations of 48 students on a university campus, using a direct magnitude method for eliciting distances. In a second experiment (Kirasic et al., 1984), they devised a method whereby distance and direction were recorded simultaneously with respondents drawing a line which represented both.

Recognition methods

Recognition methods collect configurational knowledge data by providing the respondents with a representation of an environment and asking them to correctly identify features and configurations. For example, Evans *et al.* (1980) asked respondents to identify four out of eight floor plans they had just walked through. Evans and Pedzek (1980) gave respondents a set of triad configurations, half of which had the correct configuration and half an incorrect configuration. These configurations were either non-rotated or rotated by 60, 120 or 180 degrees. Respondents were shown the triads one at a time and asked to say which configuration had the places correctly located relative to each other, despite the rotation, and the reaction times were noted. Recognition tests are likely to have great utility for measuring the configurational knowledge of individuals who are blind as the configurations can easily be displayed tactually and respondents only have to determine which configuration is correct. However, no Studies of the configurational knowledge of blind individuals have used such a data collection technique.

Issues of measurement validity

The conflict between utility and accuracy has already been discussed, but another important issue concerns which of the tests discussed is the 'best' at representing the knowledge of a blind individual? Liben (1988) has reported that no one test can extemalise the cognitive map knowledge of a respondent because tasks not only tap knowledge but also cognitive ability. Therefore, performance on isolated tasks may provide a distorted view of actual capabilities (Kirasic and Allen 1985). Goodchild (1974) suggested that the only way to understand the knowledge of an individual (including those that are blind) is to use a multi-task, multi-analysis strategy, where the same hypothesis is tested through a variety of data collection and analysis techniques. As Kirasic et al. (1984: 711) pointed out:

> 'Different task demands placed on the same knowledge base can yield significantly different results . . . This has far-reaching implications for cognitive mapping research. Configurational knowledge is a multifaceted, dynamic phenomenon that can be assessed either by multiple procedures or by a procedure that best reflects the facet of that knowledge that is of interest to the investigator. Clearly, the value of an empirical technique is not determined by whether it optimises the accuracy of a subject's performance, but rather by the light it sheds on the interface between an individual and his or her environment.'

Goodchild's (1974) recommendation seems logical, as studies such as Howard et al. (1973), Cadwallader (1979), Magana et *al.* (1981). Bryant (1984), Montello (1991a) and Kitchin (1995) have shown that different tests can lead to different conclusions, even though they are designed to measure the same knowledge. Differences are due to individual disparities in the ability to cope with cognitive task demands placed upon the respondents.

The Aberystwyth study

Such a multi-task, multi-analysis strategy was implemented in a small pilot study of the configurational knowledge of three blind individuals of Aberystwyth. The respondents, two of which were adventitiously visually impaired and one adventitiously blind, learnt a tactile map of the Aberystwyth area detailing the coastline and several towns. The respondents were then asked to undertake three tasks: complete a spatial cued response test; estimate relative distances for multidimensional scaling, and complete a recognition test. In addition, the respondents indicated how familiar (experience of visiting) they were with each place on the learnt tactile map using a scale that ranged between 1 (not familiar) to 10 (very familiar). Whilst each individual attempted the tasks a sighted companion (first author) observed the responses, and answered general queries, although no formal help was given concerning spatial relationships.

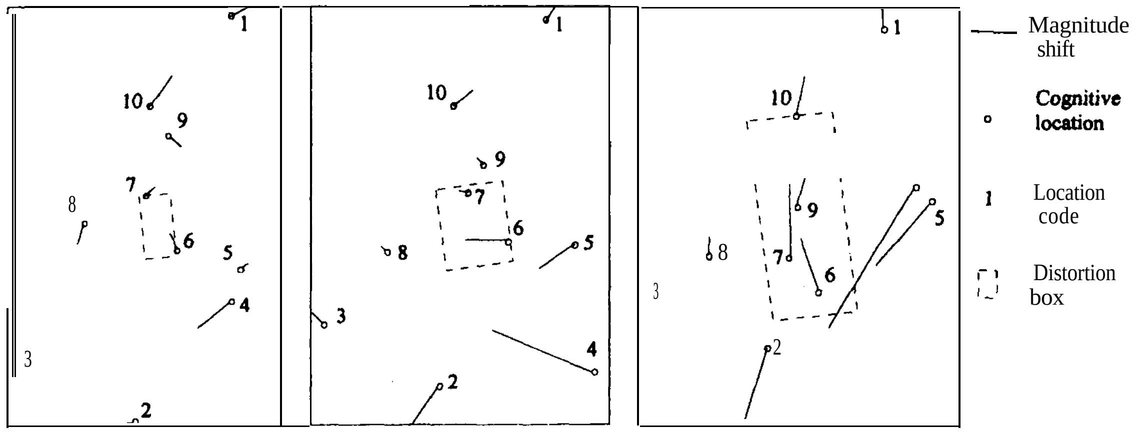
The spatial cued response test required the respondents to locate places upon a coloured and tactile map mounted upon a raised line drawing board. This detailed the coastline and the towns of Aberystwyth and Ponterwyd (the two locations that all three respondents were most familiar with). The spatial products were analyzed using CMAP (Kitchin 1994b). The cognized locations were bidimensionally regressed onto the real world locations. The individual results (Figure 3) show that two out of three of the respondents (A and B) located the ten places accurately. The third respondent (C) was not as accurate, but this may be expected as he was totally blind, rather than visually impaired. All three configurations by the respondents did, however, score well (r^2 values all above 50) and this demonstrates that the blind are capable of developing configurational knowledge. This provides evidence that the deficiency theory is incorrect, and suggests that the blind are capable of spatial understanding. Figure 4 shows the aggregated results for the three respondents. The ellipses represent the error in the placing of each location. For example, place 4 (Tregaron) has a large ellipse denoting that all three respondents placed it in a different location (the shape of the ellipse represents the dispersion pattern). In addition, each ellipse is displayed with its summed familiarity value. In contrast to other studies (Garling et al., 1991; Montello, 1991; Kitchin, 1994c), little relationship was found between familiarity and placement accuracy (linear regression r^2 = 30.5). This is not surprising as the respondents learnt the tactile map prior to the study. However, the particular low familiarity score and large ellipse for the location of Tregaron (place 4) does suggest that the learnt tactile map knowledge was used in conjunction with cognitive map knowledge constructed through experience,

All three respondents were unsuccessful in attempting to estimate relative distances for analysis using multidimensional scaling. All three respondents complained that they found the task of converting their knowledge into distances too abstract and cognitively demanding. The respondents could however, successfully complete' a recognition test that required them to determine which map, containing just the points, was correctly orientated from a set of three (the map was' rotated 120 and 240 degrees).

Conclusions

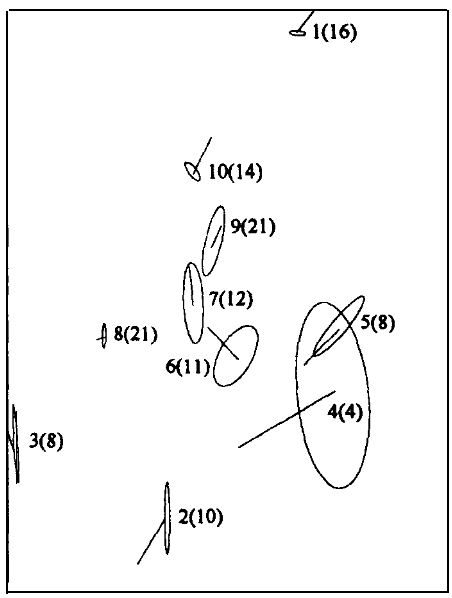
Two conclusions can be drawn from the discussion and study. First, blind individuals can understand, the spatial relationships between places as presented to them on a tactile map. This suggests that any differences found between sighted and blind individuals are due to problems of externalising their knowledge, rather than 'any fundamental difference in the ability to process spatial data. The deficiency is therefore rejected. Secondly, there are many ways in which to measure the configurational knowledge of a blind individual. However, a multi-task, multi-analysis strategy needs to be adopted to show the true extent of knowledge and abilities, because of individual differences in the ability to complete cognitive tasks. Unless such a strategy is adopted, any one test will only provide a 'snap-shot' of an individual and may represent their ability to complete the task, rather than representing their knowledge. Tasks such as the cloze procedure and recognition tests, although at present under utilised, seem particularly suited as techniques for" measuring the configurational knowledge of blind individuals because they reduce the need for

Figure 3. The bidimensional regression results for the three respondents



Respondent A	Respondent B	Respondent C
r2 = 94.87	r2 = 88.41	r2 = 57.43
Scale = 1.01	Scale = 0.96	Scale = 0.97
Angle = 7.67	Angle = 6.79	Angle = 7.12
al = -18.34	al = -21.66	a1 = -21.71
a2 = 18.00	a2 = 21.76	a2 = 16.42
Distortion index = 16.11	Distortion index = 24.42	Distortion index = 49.20
Absolute distortion = 104.82	Absolute distortion = 144.86	Absolute distortion = 129.10
Relative distortion= 121.82	Relative distortion = 174.39	Relative distortion = 1376.18
Total distortion = 154.56	Total distortion = 193.10	Total distortion = 363.10

Figure 4. The aggregated results for the three respondents



0 Ellipse   10(14) **Location code** and aggregate familiarity **score**

—— Magnitude shift

externalising skills, such as graphic ability. More work investigating the configurational knowledge of people with visual impairments or blindness is currently being carried out at Aberystwyth in a study which assesses the utility of various navigation and mobility aids.

References

Aitken, S.C., Cutter, S.L., Foote, K.E. and Sell, J.L. (1989). 'Environmental perception and behavioral geography'. In Wilmott, C. and Gaille, G. (Eds.), *Geography in America.* Merrill: London, 218-238.

Balachandran, W. (1995). 'Satellite navigation system for blind pedestrians: Research at the University of Surrey'. *Paper Presented at Conference on Orientation and Navigation Systems for Blind Persons,* Hatfield, l-2 February.

Beck, R.J. and Wood, D. (1976a). 'Cognitive transformations from urban geographic fields to mental maps'. *Environment and Behaviour, 8,* 199-238.

Beck, R.J. and Wood, D. (1976b). 'Comparative developmental analysis of individual and aggregated cognitive maps of London'. In Moore, G.T. and Golledge, R.G. (Eds.), *Environmental Knowing.* Dowden, Hutchinson and Ross: Stroudsberg, PA, 173-184.

Blades, M. (1990). 'The reliability of data collected from sketch maps'. *Journal of Environmental Psychology,* 10, *327-339.*

Boyle, J.M. and Robinson, M.E., (1 978). 'Cognitive mapping and understanding'. In Herbert, D.T. and Johnston, R.J. (Eds.), *Geography in the Urban Environment*, Vol. 2, Wiley: London, pp. *59-82.*

Brabyn, J. (1995). 'Orientation and navigation systems for the blind: *An* overview of different approaches'. *Paper Presented at Conference on Orientation and Navigation Systems for Blind Persons,* Hatfield, l-2 February 1995.

Bryant, K.J. (1 984). 'Methodological convergence as an issue within environmental cognition research', *Journal of Environmental Psychology, 4,* 43-60.

Burroughs, W. and Sadalla, E. (1979). 'Asymmetries in distance cognition'. *Geographical Analysis,* 11, *4 14-42 1.*

Buttenfield, B.P. (1986). 'Comparing distortion on sketch maps and MDS configurations'. *Professional Geographer, 38, 238-246.*

Cadwallader, M.T. (1979). 'Problems in cognitive distance and their implications to cognitive mapping'. *Environment and Behaviour,* 11, 559-*576.*

Casey, S.M. (1978). 'Cognitive mapping by the blind'. *Journal of Visual Impairment and Blindness, 72, 297-301.*

Downs, R. and Stea, D. (1977). *Maps in Minds: Reflections on Cognitive Mapping.* Harper and Row: New York.

Evans, G.W. and Pezdek, K. (1980). 'Cognitive mapping: Knowledge of real-world distance and location information'. *Journal of Experimental Psychology: Human Learning and Memory, 6, 13-24.*

Evans, G.W., Skorpanich, M.A., Gärling, T., Bryant, K. and Bresolin, B. (1984). 'The effects of pathway configuration, landmarks, and stress on environmental cognition'. *Journal of Environmental Psychology, 4, 323-335.*

Fruchterman, J. (1995). 'Arkenstone's orientation tools: Atlas Speaks and Strider'. *Paper Presented at Conference on Orientation and Navigation Systems for Blind Persons,* Hatfield, 1-2 February 1995.

Gärling, T., Book, A., Lindberg, E. and Arce, C. (1991). 'Evidence of a response-bias explanation of non-euclidean cognitive maps'. *Professional Geographer, 43,* 143-149.

Golledge, R.G. (1 977). 'Environmental cues, cognitive mapping and spatial behaviour'. In Burke, D. *et al.,* (Eds.), *Behaviour - Environment Research Methods.* Institute for Environmental studies, Univ of Wisconsin, Wisconsin, 35-46.

Golledge, R.G. (1992). 'Place recognition and wayfinding: Making sense of space'. *Geoforum, 23,* 199-214.

Golledge, R.G. (1993). 'Geography and the disabled: A survey with special reference to vision impaired and blind populations', *Transactions of the Institute of British Geographers,* 18, *63-85.*

Golledge, R.G., Loomis, J.M., Klatzky, R.L., Flury, A. and Yang, X.L. (1991). 'Designing a personal guidance system to aid navigation without sight: Progress on the GIS component', *International Journal Of Geographical Information Systems*, *5. 373-395.*

Goodchild, B. (1974). 'Class differences in environmental perception: An exploratory study'. *Urban Studies,* 11,157- 169.

Haber, R.N., Haber, L.R., Levin, C.A. and Hollyfield, R. (1993). 'Properties of spatial representations: Data from sighted and blind subjects'. *Perception and Psychophysics, 54,* 1- 13.

Hardwick, D.A., McIntyre, C.W. and Pick, H.L. (1976). 'The content and manipulation of cognitive maps in children and adults'. *Monographs of the Society for Research in Child Development, 4* 1,1-*55.*

Hill, E.W., Rieser, J.J., Hill, M.-M, Hill, M., Halpin, J. and Halpin, R. (1993). 'How persons with visual impairments explore novel spaces: Strategies of good and poor performers'. *Journal of Visual Impairment and Blindness, 87, 295-30* 1.

Howard, R.B., Chase, SD. and Rothman, M. (1973). 'An analysis of four measures of cognitive maps'. In Preisner, W.F.E. (Ed.), *Environmental Design Research,* 1, Dowden, Hutchinson and Ross: Stroudsberg, PA.

Humphreys, J.S. (1 990). 'Place learning and spatial cognition: A longitudinal study of urban newcomers'. *Tijdschrift Voor Econmische en Sociale Geografie*, *8* 1, 364-380.

Jacobson, R.D. (1992). 'Spatial cognition through tactile mapping'. *Swansea Geographer, 29, 79-88.*

Kirasic, K.C. Siegel, A.W. and Allen, G. (1981). 'The development of basic processes in cognitive mapping: Recognition in context memory'. *Child Development, 5* 1, *302-305.*

Kirasic, K.C., Allen, G. and Siegel, A. (1984). 'Expression of configurational knowledge of large scale environments'. *Environment and Behaviour, 16, 687-712.*

Kirasic, K.C. and Allen, G. (1985). 'Ageing, spatial performance and spatial competence'. In Chamess, N. (Ed.), *Ageing and human performance.* John Wiley: New York, 191-223.

Kitchin, R.M. (1990). *A Study of Children's Cognitive Distance and Direction Estimates in West Wirral Schools.* Unpublished Undergraduate Dissertation, University of Lancaster.

Kitchin, R.M. (1993). 'Using bidemensional regression to analyse cognitive maps'. *Swansea Geographer, 30, 33-50.*

Kitchin, R.M. (1994a). 'Cognitive maps what are they and why study them?' *Journal of Environmental Psychology, 14,* 1- *19.*

Kitchin, R.M. (1994b). *CMAP (Cognitive Mapping Analysis Package).* University of Wales Swansea.

Kitchin, R.M. (1994c). 'Spatial familiarity as a variable in cognitive mapping', *Swansea Geographer, 3* 1, *42-52.*

Kitchin, R.M. (1995). *Issues of Validity and Integrity in Cognitive Mapping Research: Investigating Configurational Know/edge.* Unpublished Doctoral Thesis, University of Wales Swansea.

Liben, L.S. (1988). 'Conceptual issues in the development of spatial cognition'. In Stiles-Davis, J., Kritchevsky, M. and Bellugi, U. (Eds.), *Spatial Cognition: Brain Bases and Development.* Lawerence Erlbaum Associates: Hillsdale, N.J., 167-194.

Matthews, M.H. (1984). 'Cognitive maps: A comparison of graphic and iconic techniques'. *Area, 16, 33-40.*

Montello, D.R. (1991 a). 'The measurement of cognitive distance: Methods and construct validity'. *Journal of Environmental Psychology*, 11, 101- 122.

Montello, D.R. (1991 b). 'Spatial orientation and the angularity of urban routes - A field study'. *Environment and Behaviour, 23,* 47-69.

Parkes, D. (1989). 'NOMAD - An audio-tactile tool for the acquisition, use and management of spatially distributed information by partially sighted and blind people'. *Proceedings of the Second International Conference on Maps and Graphics for the Visually Disabled, 24-29.*

Passini, R. & Proulx, G. (1988). 'Wayfinding without vision: An experiment with congenitally blind people'. *Environment and Behavior, 20, 227-252.*

Pearce, P.L. (1981). 'A study of travellers' perceptions of a piece of countryside'. *Journal of Environmental Psychology,* 1,141-155.

Petrie, H. (1995). 'User requirements for a GPS-based travel aid for blind people'. *Paper Presented at Conference on Orientation and Navigation Systems for Blind Persons,* Hatfield, 1-2 February 1995.

Pick, H.L. (1987). 'Perception, locomotion and orientation'. In Welsch, R.L. and Blasch, B.B. (Eds.), *Foundations of Orientation and Mobility.* American Foundation for the Blind: New York.

Robinson, M.E. (1974). 'Cloze procedure and spatial comprehension test'. *Area,* 9, 137-142.

Saarinen, T.F., MacCabe, C.L. and Morehouse, B. (1 988). *Sketch Maps of the World as Surrogates for World Geographic Knowledge,* Discussion Paper 83-3 Department of Geography and Regional Development, University of Arizona, Tucson.

Spencer, C., Blades, M. and Morsley, K. (1989). *The Child in the Physical Environment.* Wiley: Chichester.

Thomdyke, P.W. and Hayes-Roth, B. (1982). 'Differences in spatial knowledge aquired from maps and navigation'. *Cognitive Psychology, 14, 560-589.*

Wood, D. and Beck, R. (1976). 'Talking with environmental A: An experimental mapping language'. In Moore. G.T. and Golledge. R.G. (Eds. j, *Environmental Knowing,* Dowden, Hutchinson and Ross, Stroudsberg, PA., 35 1-36 1.