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Spatial representation and low vision: Two studies on the content, accuracy and utility of mental representations

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Spatial representation and low vision: Two studies on the content, accuracy and utility of mental representations

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Abstract. The paper reports on two studies being conducted with students from Dorton College - Royal London Society for the Blind (RLSB) in Kent. The first experiment will examine the content and accuracy of mental representations of a well-known environment. Students will walk a route around the college campus and learn the position of ten buildings or structures. They will then be asked to make heading judgments, estimate distances, complete a spatial cued model and sequentially visit a series of locations. The second experiment will examine the strategies and coding heuristics used to explore a complex novel environment. Students will be asked to explore a maze and learn the location of different places. Their search patterns will be digitally tracked, coded and analyzed using GIS software. Students will be tested using the same methods as in the first experiment and their performance level will be correlated with their exploratory patterns. Throughout the paper we are reminded that construct validity can only be secured by employing multiple converging techniques in the collection and analysis of cognitive data. Methods should be designed to test content and accuracy as well as the utility of mental representations.

Keywords: Spatial representation; strategies; exploration; low vision; blindness

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1. Introduction

Researchers in the field of psychology, geography and planning (Rieser, et al., 1980; Golledge, 1992; Passini 1985) have used a wide variety of methods to assess the extent of the cognitive map knowledge of individuals who are blind or have low vision. Kitchin et al., (1997) examined the validity of drawing conclusions from these tests. They argued that multiple mutually supportive tests are necessary for the interpretation, application and generalization of results. Furthermore, methods should concentrate not only on the content and accuracy of the representation but also in its utility. Zacharias (2000) notes that methods that rely solely on the power of recall of respondents have been shown to be partial, spatially distorted and temporally imprecise. This has lead several authors (Hill et al., 1993; Gaunet et al., 1996; Tellevik, 1992) to pay closer attention to the real-time actions and behaviour as this often conflicts with the accuracy and content of cued externalizations.

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Siegel & Cousins (1985) have argued that one should be cautious when interpreting results from tests that involve an externalization of a mental representation. They argue that same tests can generate different results given that the participants' responses are re-representations of the environment. Errors occur because these re-representations are two levels removed from the actual environment and require different types of mental operations (Huertas & Ochaita, 1992). In fact, the literature on spatial cognition by individuals who are blind or have low vision is filled with contradictions and interpretations (Warren, 1984; Thinus Blanc & Gaunet, 1997). While efforts have been made (Passini, 1990; Kitchin et al., 2001; Ungar et al., 1997), there is still a considerable amount of research conducted with small sample sizes and confined to laboratory type settings (Fletcher, 1980; Landau, 1984; Rieser, 1986; Bigelow, 1991).

This is coupled with the absence of mutually supportive techniques to account for the heterogeneity of skills between participants. One-dimensional testing can lead to incorrect conclusions given that performance may be a consequence of a testing artefact (a person lacking the skills to build an accurate model) rather than ability (Millar, 1994). This is often the case with tests that aim to assess the extent of the configurational knowledge of an environment through the estimation of absolute Euclidean distances. Providing an exact numerical figure to represent distances is often seen as too abstract for individuals with low vision. The same is true for heading judgments given that to point at something at a distance is not an action commonly used by individuals who are blind.

Research in orientation and mobility has identified a series of strategies for exploration and navigation in non-familiar environments (Guth & Rieser, 1997; Geruschat & Smith, 1997). Strategies are defined "[as a] set of functional rules implemented by the participant in order to solve a spatial task" (Hill, 1993, p.65). These studies however, have been set in restrictive rooms that lack any spatial structure. Results should be seen as a starting point for research in more complex environments that have a closer resemblance to our cities (Imrie et al., 2001). Furthermore, as Piagetian developmental concepts continue to be challenged (Millar, 1994) it is crucial to reconsider how one develops and utilizes egocentric (body to object) and allocentric frames of references (object to object) during navigation.

Another major reason for conflicting results has been the insistence on the classification of individuals on the basis of their visual condition. This three-part classification (blind, partially sighted and sighted) is inherently faulty given that it overlooks the reasons behind intra-group differences. As we shall see in the following sections, by focusing on the strategies used to understand and explore space, we can avoid the trap of associating performance on spatial tasks with visual condition. Instead, performance is related to the spatial coding strategies adopted during active exploration (Ungar et al., 1995).

2. Towards a new type of classification

In his book *Blindness & Early Childhood Development*, David Warren (1984) takes great care to warn about some of the problems when comparing the blind, partially sighted and sighted subjects in different spatial tasks. Nevertheless, except for a few notable exceptions (Thinus-Blanc & Gaunet, 1999; Hill et al., 1993) the majority of research tends to pay little attention to this heterogeneity. This has led to the problematic three-part classification where individuals with different types of visual impairments are grouped together e.g., individuals with glaucoma, retinitis pigmentosa or even severe myopia being grouped together to form the “partially sighted” group.

That the eye condition has an impact in the manner in which a person perceives and represents space should not come as a surprise to any professional in the field of low vision. Take for example a subject with *retinitis pigmentosa* who has poor night vision and happens to be tested during the day. While still impaired due to a restricted visual field (Kanski et al., 2003) chances are that his performance will be significantly different in a situation with low light. How can this individual be put in the same group with someone with severe myopia whose condition does not significantly vary in relation to lighting changes?

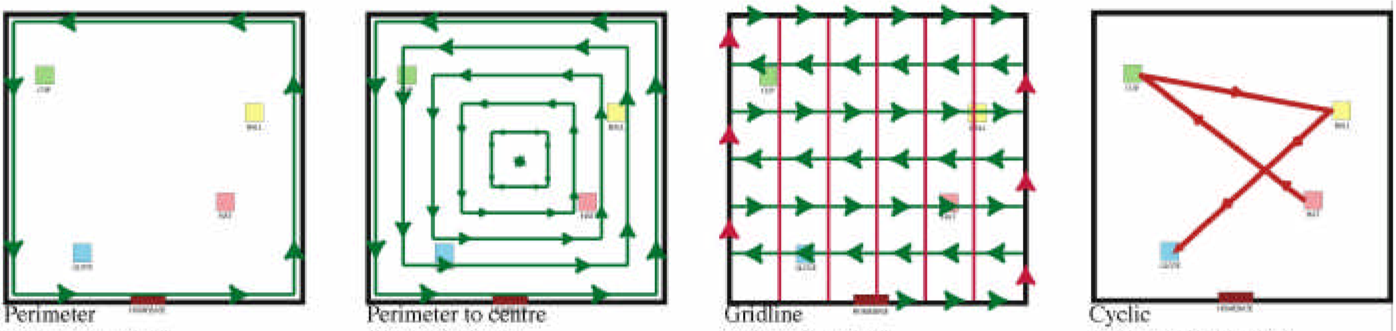
This problem is further complicated given the evidence (Warren, 1984) supporting the variability between individuals with the same eye condition. Furthermore, while efforts have been made to discriminate between the age of onset blindness there is still very little agreement as to what should be used as testing standard. This is coupled with the fact that 67% (http://www.euroblind.org/fichiersGB/statUK.htm) of visually impaired individuals have an additional disability, which is hardly accounted for. The role of early visual experience has been the subject of many experiments (Fletcher, 1980; Rieser, 1980). Millar (1994) however, has continuously argued that no sensory modality is necessary or sufficient for spatial coding. This is on par with Carreiras & Codina (1992) *amodal theory*. This theory questions the central role of vision in the construction of spatial representation while emphasizing training and protocol.

There is enough evidence to support that people with the same or different visual impairments vary to large degrees in their spatial orientation skills. However, very little is known about the reasons behind these differences. Several studies (Thinus-Blanc et al., 1999) have cleverly matched participants in terms of IQ, level of education, confidence & mobility training as a way to avoid grouping in terms of visual impairment. Recent research in phenomenology allows us to further disassociate the eye condition from the observer. Phenomenologists hold that environmental stimuli are mentally represented in a manner that is unique to each individual (Fewtrell & O'Connor, 1995) In this manner, the mental representation of an experience (in this case an image) is not a direct product of the visual field but from the actual mind processing the experience.

3. Hill's experiment

In line with the view that subjects actively construct their own representations through exploration and that experience is better understood in its natural environment, Hill (1993) has put forward a simple method of studying mental representations of space. In his experiment he told blind and partially sighted participants to freely explore an open bounded space with the goal of locating four objects and remembering their position. The exploratory behaviour was videotaped and the spatial patterns were coded into different strategies. Hill identified five strategies of varying complexity. Figure 1 illustrates these strategies (superimposed on Hill's experimental layout) as well as the cyclic strategy identified by Gaunet et al., (1996) and the perimter-2-centre strategy proposed by the author. Participants were then asked to make a series of heading judgments between the places and the accuracy of their response was recorded.

Figure 1 - Strategies for exploration

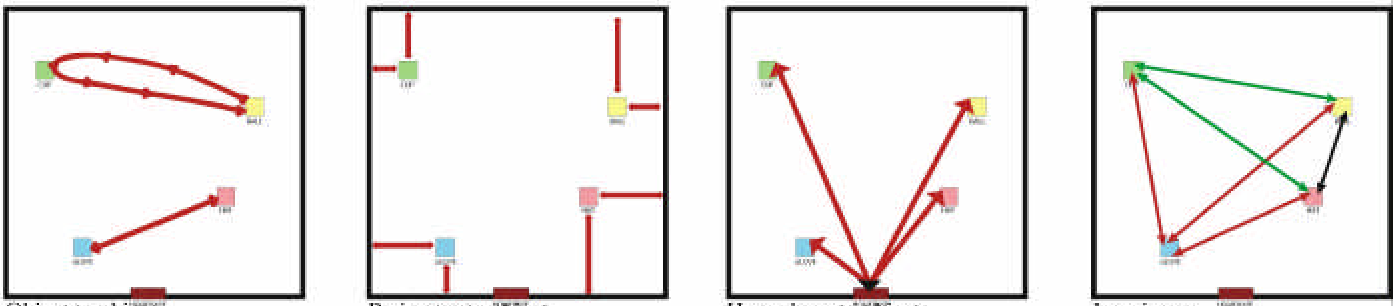


Perimeter
(Hill et. al., 1997)
Size & shape of area
Object on/near border

Perimeter to centre
Not in literature
Total area (h x w)
Object within perimeter

Gridline
(Hill et. al., 1997)
Size & shape of area
Object within perimeter

Cyclic
(Thinus-Blanc, 1997)
Random object to object



Object to object
(Hill et. al., 1997)
Position of object in
to another object

Perimeter to object
(Hill et. al., 1997)
Position of object in
relation to perimeter

Home base to object
(Hill et. al., 1997)
Position of object
relative to home base

Imaginary
(Hill et. al., 1997)
Location of objects
relative to geo-form

Hill argued that there is much to learn in investigating the accuracy of the heading responses in relation to the exploratory behaviour used by the participants. To achieve this, he classified the participants in terms of their performance (top & bottom 25%) and compared the strategies used by the best performers against those of the worst performers. He found that the best performers tended to employ a wider variety of strategies when compared to the worst performers. They also used strategies that facilitated the development of allocentric relationships. More interesting is the fact that eye condition did not play a significant role as blind and partially sighted individuals were found in the best and worst performing groups.

4. Experimental design

Taking in consideration some of the weaknesses in past research two complementary experiments were designed to test the spatial representation of blind and individuals with low vision in known and novel environments.

Experiment 1

The first experiment will examine the content and accuracy of mental representations of teenagers who are blind or have low vision. The experiment will also assess the strength and weaknesses of different techniques for the collection and analysis of cognitive information and will serve as a practice for the second more complex experiment. Participants will walk a route around the college campus and learn the position of ten buildings or structures. Figure 2 is a simplified map of the RLSB campus with ten locations identified during the route exercise.

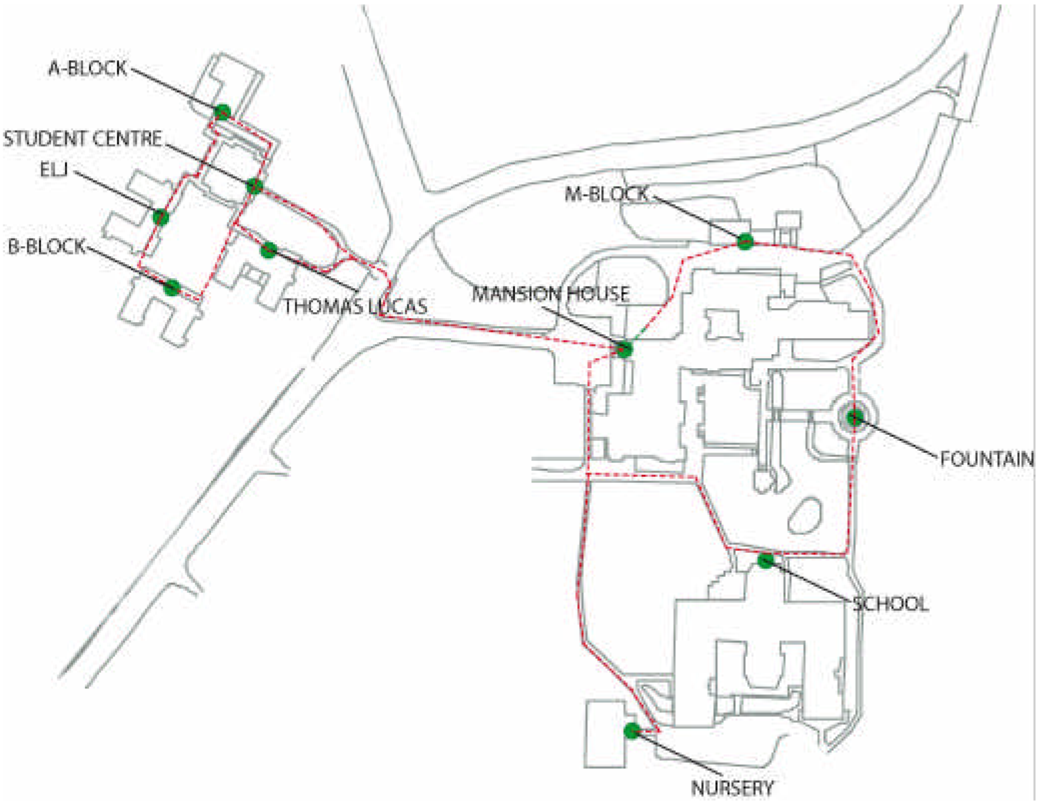


Figure 2 - RLSB Campus

Student will then be asked to complete three tasks:

Heading judgments: Students will be randomly guided to several locations and asked to aim a digital compass towards the different places during the route exercise. In order to avoid any confusion and errors related to the testing procedure students will be given time to familiarize themselves with the compass and the concept of pointing. Performance will be evaluated by comparing the collection of real and estimated angles and mean angle error (the absolute difference between real and estimated direction for a particular location averaged over a number of observations).

Their responses will also be analyzed using the projective converge method. Developed by Siegel (1981) this method allows for the calculation of *locational accuracy* through a triangulation method where the estimated vectors can be extended and intersected to form a hypothetical triangle of error. Accuracy is defined as the distance between the centroid of the triangle and the real location (Golledge, 1992).

Distance estimation: A lambda 4 balanced incomplete block design was used to create a triad questionnaire (Ungar et al., 1996). Students will be given different sets (65 in total) containing three locations visited during the route exercise. They will be asked to judge which two locations are the closest together and which two are the furthest apart. Error scores will be compared relative to the real (Euclidean) and functional (route) distances. Results from the triad will be mapped and analyzed using multidimensional scaling (MDS).

Multidimensional scaling (Jacobson et al., 1995) is a technique that allows for a two-dimensional representation of pattern of proximities among a set of locations. A matrix of ordinal perceived dissimilarities will be created from the results of the triad. The MDS algorithm assesses the goodness of fit of an arrangement of points and provides detailed information on the distortion of mental representations such as size transformations, directional compression and elongation (Gärling, 1999).

Model construction: Ten three-dimensional card pieces representing a scaled version of the locations visited were created. Three will be placed in their real cartographic location on a gridded (1cm X 1cm) magnetic white board. Students will be asked to position the remaining seven structures in relation to these. Spatial cued tests provide the subject with scale and orientation minimizing the motor skill component in tasks completion. Results will be quantitatively analyzed using bidimensional regression (Tobler, 1976; 1993).

Bidimensional regression statistically calculates the measure of association (r^2) between two configurations of related coordinate data (Kitchin, 1993). It provides information on the degree of configurational knowledge by measuring the fidelity in terms of scale, angle and translation between where a place is in reality (referent coordinates) and where a subject thinks it is (variant coordinates). Comparisons of mental representations can be made across participants by using a distortion index first proposed by Waterman & Gordon (1984). This has been substantially reviewed by Friedman & Kohler (2003) who proposed an elegant alternative for calculating distortions without disrupting the relationship between dependent and independent variables in a regression.

Questionnaires: Two questionnaires will be administered in order to collect detailed data on each subject. The will also allow for a form of standardization where comparisons can be made. As a life skills tutor in Dorton College, the author also has access to information on each participant's history and eye condition. The first questionnaire is an adapted version of Turano et al., (1999) independent mobility questionnaire for individuals with *retinitis pigmentosa*. The second questionnaire is the same used by Wolffsohn et al., (2000) to measure the quality of life for individuals with low vision.

Experiment 2

A maze will be constructed (100m X 60m) on the site of the RLSB campus. This will consist of network of barrier fences mounted on wooden posts. Tables (10 in total) will be used to represent different places in a city, i.e., bank, grocer, pub. Figure 3 illustrates the spatial arrangement of the maze and the different locations within it.

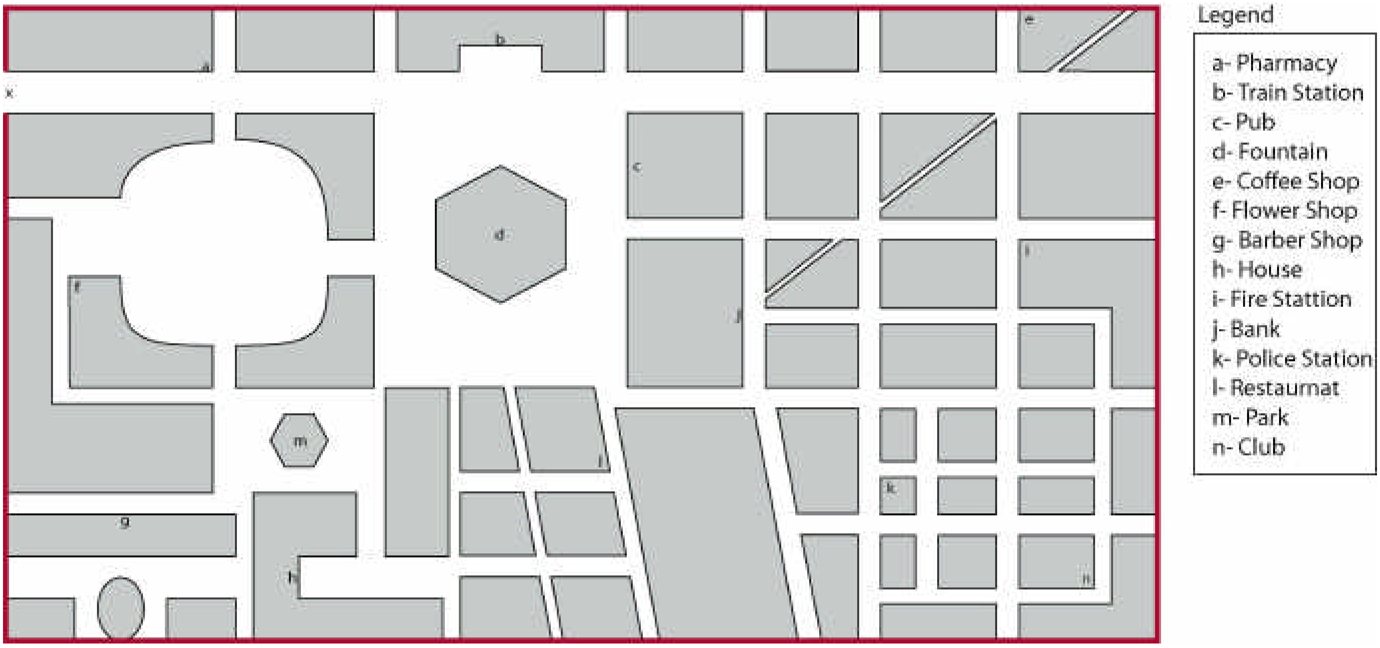


Figure 3 - The maze

Large card signs and Braille tags placed on top of the tables will indicate the name of each location. Figure 4 illustrates an isometric view of the maze and figure 5 is a close up shot of the tables representing the different locations.

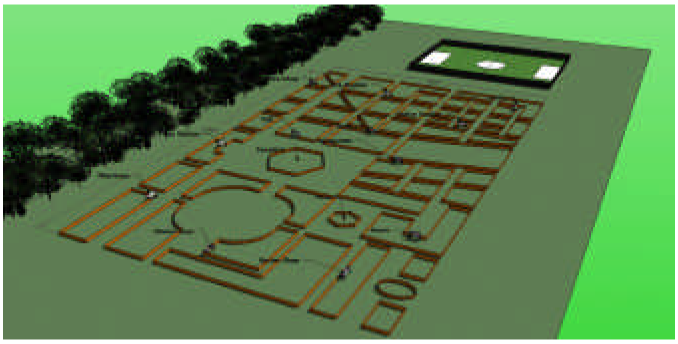


Figure 4 – Isometric view of maze

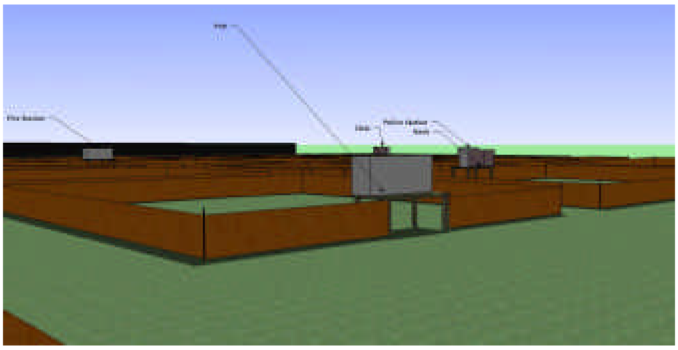


Figure 5 – Maze & Stands

The camera capturing the movement will be placed on a platform at a vantage point in order to capture the entire environment. Video 1 (26 megas) is an animated simulation of the experimental layout.

The same students that completed the first experiment will be asked to explore the maze and learn the location of then ten different places. Their search patterns will be videotaped and digitally tracked using real time technology (Peak Motus®). The captured trajectories will be coded using geographic information system software (ESRI ArcGis®). Zacharias et al., (2003) have used with considerable success a grid style method to code spatial patterns. It consists of digitizing the different trajectory lines on a grid system superimposed on the referent map. Spatial patterns are then identified by a gradient calculated using the intensity of line and grid intersects.

Students will then be tested using the same methods (heading judgments, distance and estimation & model building) as in the first experiment. In addition, in order to test for the utility of their mental representation students will be asked to sequentially visit a series of location in the maze. A separate performance index will be created for each test and students will be grouped accordingly. The final analysis will consist of correlating the coded spatial patterns with performance levels.

5. Conclusion

The paper reports on the progress of a doctoral thesis on the perception and cognition of space by individuals who are blind or have low vision. It presented several arguments in favour of multiple mutually supportive tests that account for the content and accuracy of a representation as well as its utility. It also stressed some of the dangers associated with the strict classification of individuals on the basis of their eye condition and proposed an alternative method that groups individuals in terms of their performance. The two complementary experiments offer a comprehensive and innovative way to study spatial representation in known and novel environments. The use of real time technology in the analysis of exploratory strategies builds on past studies that have used videotape playback by incorporating methods that allow for an accurate analysis of movement in space.

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