TALKING TACTILE MAPS AND ENVIRONMENTAL AUDIO BEACONS: AN ORIENTATION AND MOBILITY DEVELOPMENT TOOL FOR VISUALLY IMPAIRED PEOPLE

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Abstract

Pedestrian navigation through the built environment is a fundamental human activity. Environmental scales may range from the micro, the room of a house, to the macro, a cityscape, for example. In order to navigate effectively through this range of environments visually impaired people need to develop orientation and mobility skills. Auditory beacons, accessed in a model as a talking tactile map, and in the environment by beacons which transmit audio messages to a small receiver carried by the pedestrian, serve to integrate the model representation and the environment, and act as mobility and orientation development tool. This technical approach is assessed using a multi-task analysis of the cognitive maps of people using the system when learning a new route. Although analysis was not conclusive, those who used the system expressed great interest, suggesting that both maps and audio complimented and enhanced each other. This study demonstrates that access to audio beacons in environment and model leads to increased spatial comprehension and confidence about the route and shows the need for a mixture of quantitative and qualitative approaches when assessing cognitive mapping ability.

Introduction

In order to function in an environment a degree of spatial knowledge is a necessity; there is a basic human need to know about the world (Kitchin, 1996). For visually impaired and blind people the development of orientation and mobility skills are crucial if a degree of independence is to be achieved (Dodds, 1993). Mobility whilst being one of the most fundamental, basic tasks, necessary for ordinary, everyday functioning is a "complex determined activity" (Warren and Kocon, 1973). It is necessary in order to function at a very basic level, to find one's clothes and to get dressed, or to find your way about your own home, and also as a means for acquiring information about the environment. Mobility requires the integration of perception and cognition needing motor, perceptual and representational skills (Spencer *et al*., 1989). Ideally travel without vision should be as independent, efficient, safe and relaxed as travel with vision (Foulke 1982). In order to achieve this the blind pedestrian needs to employ a multitude of skills, a mixture of the micro, obstacle avoidance in the next few steps, and the macro their general frame of reference and the directional orientation (Petrie, 1995). As these two facets are obviously closely linked and interwoven, it is difficult to have the benefits of one without the other. This paper addresses the development of the methodology and technical aids that can help bridge these two facets and act as a mobility development tool. The methodology is then examined in a small route learning study with a new intake of students at the Royal National College for the Blind, Hereford, UK.

Vision, for most travellers, is regarded as the most efficient sense for gathering environmental information (Warren, 1978). It commonly provides information such as location, landmark, direction, orientation, distance and speed. For the blind and visually impaired, who lack all or some of this vital sense, they have to rely on their remaining senses to gather the data that leads to a spatial understanding. Prior to travel the sighted traveller may consult maps and journey guides relevant to their route or area of interest. Verbal and pictorial guides all help build a mental 'picture' of the environment (Golledge, 1993). This information can be pre-processed and then stored for later use. During travel itself vision is used to sense local and distant landmarks, which provide information about direction and orientation, and help to avoid obstacles and hazards. With a turn of the head, a wide array of information can be taken in providing data on the route itself and also about nearby information. Visual optical flow provides accessible information for dead-reckoning and time of travel sensing. Guides, maps, signs and technical aids, such as a compass can all be easily consulted en-route to update travel information.

The traveller lacking in vision usually has impoverished access to pre-route information due to its scarcity in a suitable format (Golledge et al., 1994). Even if the information is available, this is often unknown to the blind traveller. Their prior mental conception and appreciation of the route is therefore limited. The sighted traveller has much potential for flexibility, both about the choice of route and of navigation decisions en-route. Whereas the blind traveller is usually tied to a previously learned route with little degree of flexibility. At scales greater than the immediate body space (or an extension of that space such as that provided by the white cane) the blind traveller is faced with the difficult problem of comprehending layout, direction and orientation. Without visible cues serving to update information or to perceive patterns within the environment they are severely disadvantaged (Golledge, 1993; Golledge, 1994).

Route learning

If spatial relationships are to be attained, they have to be organised. Route knowledge is the easiest level of knowledge for the visually impaired traveller to learn (Spencer *et al.,* 1989). Mobility training often requires the learning of desired routes (Dodds,1993). A route may consist of a series of segments, linked by a listing of their component turns and parts. However route learning is inflexible, travellers are restricted to the route they have learned, detours and shortcuts are problematic, and the conceptual integration of different routes difficult (Downs and Stea, 1977). An egocentric listing of a route is difficult to extrapolate from self referenced to Euclidean distances or angles between places (Spencer et al, 1989). A flexible knowledge of the spatial pattern of paths travelled is far more versatile, however, by the lack of their visual sense, the blind necessitate direct contact with the environment. If congenitally blind (blind from birth) they have not had any experience of simultaneous and direct perception of spatial relations and perspective. Some researchers suggest the visually impaired are limited to a route like representation of space. Small scale tasks support the above theory (Millar,1979;Berg and Worchel, 1956; Merry and Merry, 1934), although Kennedy (1983) was able obtain perspective sketches of objects from congenitally blind students The integration of environment and model aims to explore this question, in a limited way, within the Hereford route learning study (intra-route rather than inter-route) by making various assessments of the respondents' ability to navigate the route.

Non visual navigation, micro and macro

> 'Navigation is a fundamental human activity and an integral part of everyday life. People use their knowledge and their previous experiences with geographic space to find their way'
>
> Timpf *et al*. (1992, p.348)

In order to be mobile the blind need to be able to conceptualise space and their place in space (Spencer et al. 1989) and how activity alters their position relative to locations in the environment. In order to be mobile the wayfinder has to know the following facts :

(1) Where they are in relation to their cognitive representation ***[micro and macro]***
(2) Where, relative to their current position their destination is ***[macro]*** or their next link, node, path, landmark along their route ***[micro]***
(3) How to move towards it ***[micro]***
(4) To be able to use perception ***[micro]*** to update and monitor their position within their cognitive representation ***[macro].***

Derived from Spencer *et al*., 1989
Information in brackets added

To illustrate this point consider a sighted individual who cannot see his/her destination from their point of origin, but knowing where the destination is he/she can use his/her cognitive representation to infer direction and then to update and feed back to his/her cognitive map (Garling et al., 1984). At the macro level the problem facing the visually impaired traveller is one of orientation, Where am I facing? In which direction is my destination? This is a cognitive problem requiring updating of their cognitive map and a degree of configurational knowledge. At the micro level, the next few steps in the immediate environment the foremost problem is obstacle detection. With this comes obstacle avoidance, the need to select a detour or alternative path. This is a perceptual problem, what can I sense immediately infront of me?

Table 1 - Micro-Macro orientation and mobility - broad differences

Micro	**Macro**
Perception	Cognition
Mobility	Orientation
Short term memory	Long term memory
Tactile/ haptic sense	Auditory and olfactory senses
Auditory beacon →	
←	Tactile map

Spatial representation, the knowledge base of the world as we believe it to be, comes through the synthesis of information perceived through our senses (visual, auditory, tactile, olfactory and kinaesthetic). This information emerges directly from the environment or from representations of that environment such as a map or photograph (Boyle and Robinson, 1979).

Audio information plays an important role in the development of spatial skill. It is “the main channel for providing distal information” (Spencer et al., 1989) and in spite of conclusions made by Foulke (1982) is superior to all other sensory alternatives (Wanet and Veraart, 1985). Unlike the remaining senses available to the visually impaired, with the auditory sense there is no need for direct contact, it will work in any environment, indoors and outside, and both in an active and a passive way. This audio information may come in the form of verbal guidance and instruction, from a mobility instructor, for example, and also as auditory environmental cues encountered during travel, such as traffic noise.

Technical Aids

To date the majority of technical aids have addressed the micro problems of obstacle detection and avoidance for example, the long cane, guide dog, and sonic devices for obstacle detection (see Kay, 1973). The macro problems of geographic orientation, and location within the navigational environment are only recently being addressed by new technologies, the Personal Guidance System of Golledge et al (1991), incorporating Global Positioning Systems and large digital spatial databases with novel virtual interfaces (Loomis et al., 1990), and the MoBIC project in Europe (Gill, 1996). At present these high-tech solutions, require large and costly infrastructure inputs, such as the development of large scale digital maps with information of relevance to the blind traveller. The equipment carried by the pedestrian is bulky and cumbersome, although is likely to reduce considerably in size with further technological innovation. The equipment is also prone to problems, such as global positioning satellite signals being obscured in urban areas (Whitney, 1995). The development of small electronic audio beacons offers an interim solution, providing audio orientation information, within a designated macro area, such as a town centre or college campus.

Audio Beacons

Small electronic audio beacons are a simple and effective way to provide additional audio cues, either in the form of speech, or other recorded sound such as traffic noise. They employ a variety of technologies including infra-red, microwave and radio signals (Whitney, 1995). These can be used as tools for developing orientation and mobility skills in reconstructed training settings. When placed in the real world, the environment that the visually impaired pedestrian travels through, audio beacons can provide additional cues and information that is not normally accessible, such as road names. Various systems are available around the world, Talking Signs in the USA (Brabyn and Brabyn, 1983), the OPEN project in the UK (Stephens, 1995), and Pennine Talking Signs in the UK (Draper,1995). Although differences exist between these various approaches, employing infra red, radio or microwave radiation for information exchange, the basic concept is similar. The audio information is recorded or generated in the beacon, and is then placed in a suitable location in the environment. As the beacon is approached by the visually impaired traveller, the audio message sounds, either in the beacon itself, or in a small (pocket calculator size) receiver, with or without an earpiece, that the pedestrian carries. Depending on the system, volume, message length, and the zone of triggering are all variable. There may be other options such as a tree structure of messages, different messages for different users and repeat or playback options. Such systems have been successfully installed in San Francisco Railway Stations and streets (Brabyn, 1995), and bus terminals in the UK(Draper, 1995).

Map-like presentations

Tactile maps have been used for a long time in education to convey ideas with a spatial component. There is a wealth of literature on the design and production issues associated with tactile maps (Weidel, 1983; Tatham and Dodds, 1988). They hare also been used as a wayfinding aid (Bentzen, 1980; Golledge,1991), and recently as mobility learning aids (Ungar et al., 1994). In this context they can be used to increase the individual's overall awareness of the area being learned by presenting the environment in a small scale model (Jacobson, 1992; Yngstrom, 1988). Although maps present an overall view, survey knowledge of an area, they have to be explored sequentially by the blind user which places great demands on memory. Information has to be integrated from the hand movements and the fingertips. Differences in the effectiveness of scanning strategies, and how these are taught will influence the usability of the maps (Ungar *et al.*, 1993; Ungar *et al.*, 1995) Maps are able to extend the conception of an environment beyond that gained by direct experience from the environment.

Traditionally maps used in education, such as those showing the countries of the world, have conveyed as much information to the blind reader as possible, often resulting in a perceptual overload for the reader (Hinton, 1993). For mobility maps there needs to be a shift in emphasis to displaying the minimum amount of detail necessary for the individual to learn, comprehend and navigate through an environment (Golledge, 1991). Maps serving as navigational aids may take a strip map form detailing, choice points, changes in direction and the landmarks necessary for motor guidance. A common problem with tactile maps is labelling, a map devoid of labels is meaningless. Braille labelling is inflexible, and if enough labels are applied to facilitate understanding the map is cluttered and illegible (Tatham, 1991). Using labels in a separate legend or key reduces the immediacy of the graphic and introduces interpretation problems as referencing is disrupted (Hinton, 1993).

One solution is an audio-tactile “multi-media” approach. Here computer audio based systems augment the linework on the tactile graphic by applying sound labels to points, lines and areas on the map. This makes the map inherently more user friendly. The map sits on a small tablet connected to a computer, when the map is touched the corresponding sound label is triggered. Such systems include NOMAD (Parkes, 1988), talking tactile maps (Blenkhorn and Evans1994). Figure 1 shows the main components of the NOMAD system. The touch pad can be connected to any personnal computer. Audio is generated through an internal or external speech synthesiser, and additional sounds can be added and created using commonly available sound production software and hard ware.

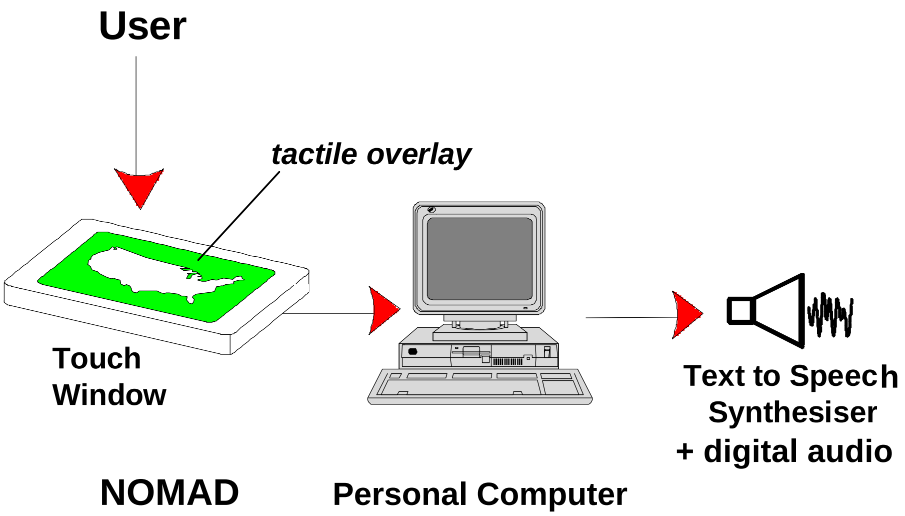


Figure 1: Audio - tactile model - the NOMAD system

Integration of Environment and Model

Yngstrom (1988) adopted a non-technical integration between blind childrens' familiar environment and models of that environment through map familiarisation, orienteering and map and model building. This worked well leading to "increased confidence" through "learning by doing" (p.92, ibid), and statements that "it is easy to find the way with the help of a tactile map" (p. 91, ibid).

By using auditory icons, termed "earcons" (Blattner et al., 1989) which are non verbal audio messages such as the noise of traffic or the sound of a pedestrian crossing the real world environment can be imaginatively replicated in a small scale model. The integration of environment and model, a holistic approach, where audio beacons give messages and information in the environment and these are then replicated in an audio-tactile model is proposed as a valuable tool in the acquisition of orientation and mobility skills in a novel geographical area.

Hereford Study

The study at the Royal National College for the Blind, Hereford, U.K. used eight students with a range of visual impairment. Its aim was to assess the utility of auditory beacons in environment and model by examing the integration of the environment and a tactile model through the use of auditory beacons. Sounds from the environment were replicated in a large scale tactile model (Figures 1 and 2). An audio-tactile map of the route to be studied was made using microcapsule paper (see Andrews 1985). Audio information was added using the NOMAD device. Auditory icons (earcons) on the graphic included traffic noise along Venns Lane and the bleep of the pelican crossing. Figure 2 shows the visual equivalent of the audio-tactile model. The text label would be "spoken" when the appropiate region was touched. In the environment some of the students (group 1) carried a small electronic receiver around their neck. When approaching the pelican gate, they received the message "you are now approaching the pelican gate - turn left for the college campus".

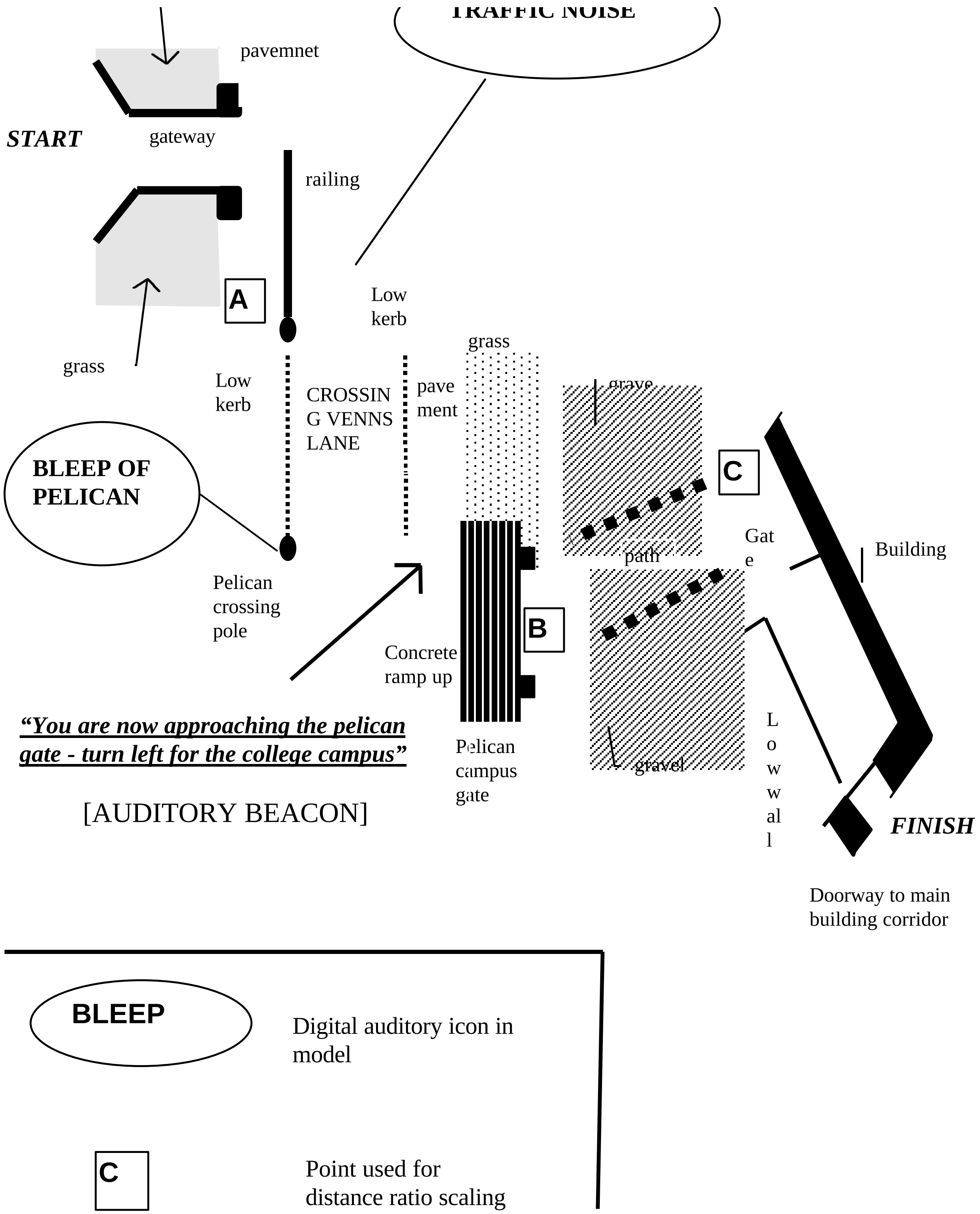


Figure 2: Visual representation of the audio-tactile model showing the route learned

Methodology

All the students were mobile in surroundings which they were familiar with using long cane techniques. None of the students had attempted the study route before from a hall of residence on the fringe of the campus to a centrally located main building leading to the refectory. The participants' ages ranged from 16 years 3 months to 17 years 1 month, with an average age of 16 years 6 months. Three were female and five were male. After an initial short interview the participants were split into two groups, each group having a similar range of visual impairment.

The study area was part of the college campus, a route from the halls of residence on the fringe of the campus to the centrally located refectory. This involved navigating a series of obstacles including gateways and crossing a main road. One group learned the route in the traditional manner by walking the route with a mobility instructor (group 2), the other group had similar instruction but also came to know the route and area through an audio-tactile model and when walking the route had access to an environmental audio beacon (group 1). When a student felt comfortable with the route they were observed attempting the route unaided. Each student then completed a small set of qualitative and quantitative assessments, which included verbally describing the route, a free recall sketch of the route. Here respondents wer presented with a blank tactile drawing pad and were asked to draw and descibe the route in a much detail as they could. Distances to landmarks along the route, were investigated after route completion by ratio-scaling. A respondent would indicate on a ruler by a sliding a pointer along the ruler representing the total route length, the distance to key landmarks. A tactile scanning assessment was used as a msimple measure of table top graphic ability. Each respondent was encouraged to verbally talk aloud while they completed the tasks. In addition each respondent completed a short follow up interview at the end of the study.

Many studies in the sighted cognitive mapping literature have noted that convergent validity is weak with different tests producing different answers when they were meant to be measuring the same knowledge (Howard *et al*. 1973, Cadwallader 1979, Magana *et al*. 1981, Montello 1991). These differences exist, not because the tests are measuring different knowledge bases, or invoke the use of different strategies of spatial thought, but because of methodological biases (Kitchin 1995).

The study adopted multiple, mutually supportive tests in order to build a more complete 'picture' of a respondents' knowledge (Jacobson and Kitchin, 1995) and used a real world environment, recommendations from Kitchin and Jacobson (in press). The sample size was small to allow for a mix of quantitative tests and phenomenological qualitative interviews. This obviously has implications on the nature of any generalisations drawn from the study. The study was designed to provide an insight into the utility of the integration of audio beacons in environment and model, through the experiences of the respondents, not as a comprehensive, definitive assessment. As far as the author is aware this small study represents the first attempt to assess the integration of environment and model of a real world geographic environment using auditory beacons. However it is noted that Zimmerman (1990) compared the spatial accuracy of psuedo map information presented tactually and through auditory icons on a computer screen.

Results

With such a small sample it is noted that differences in individual ability are often greater than the aggregated average of the group, and that aggregating the results has the potential for misinterpretation (Newcombe 1985), however the comparison of two contrasting groups is seen as a useful indicator of the utility of the technique.

Independent navigation of the route

Both groups of students were able to complete the route unaided, with the exception of one respondent from group 1 (normal mobility techniques, participant 7), who generally lacked confidence, appeared hesitant and uncertain when navigating on his own, frequently halting and retracing his movements.

Verbal route desciption

With the exception of the above student all participants were able to verbally describe the route. There were individual differences between respondents, some descriptions being verbose and detailed (see example participant 3) while others were less detailed but still contained the essential components, the structure and framework of the route (see example participant 6) .Although employing differing levels of detail all the route descriptions were sequentially “correct” and navigationally comprehendable.

Participant 3 - NOMAD and talking sign (Group 1) - verbal route desciption

Square off with back door of Armitage Hall. Come across there is a small downcurb, go down kerb, across until you find a little raised kerb line. Turn left. Follow that kerbline around, it bends to the right, follow it straight on until it passes a gap on the right. Pass that gap then square off at the kerb line turn left, follow that kerb line until you find a sleeping policeman. Go over that sleeping policeman. Next small ramp. Carry on. Kerb then bends around to the right. Go up. Straight forward to metal barrier. Turn right following metal barrier to the pelican pole. Press button and only cross when you hear the pelican bleeping. Keep as straight as you can - there are tactile pavings on either side of the crossing. Once across the other side go straight forward until you hit another kerbline. Follow that kerbline around - it bends around to the left through the college gate. At entrance cross over to other shoreline. Follow that around it goes straight on then to the right and there is a barrier. Another barrier on the right, go to the right and through the gate and follow low wall to door of building.

Participant 6 - Conventional route learning (Group 2) - verbal route desciption

Come out of door, then you walk straight on, turn to right and follow kerb along - it has a sharp turn, then walk up a ramp and towards the barrier. Then at lights press button and wait, cross road. Walk straight on, till you find another kerb, turn right and follow this, go up ramp into college. Keep walking straight, then eventually go to right, right round to the right, and then follow to door

Sketch of route

While the respondents drew a minimally defined sketch map of the route (for a review of techniques see Kitchin 1995), they were asked to verbally talk aloud, explaining what they were doing, and describing what they were drawing.

Sketches were copied and annotated. They were presented in a random table top arrangement to three independent scrutineers who viewed the sketches and were asked to rank them for their accuracy when compared to the visual analogue of the tactile map of the route. Figure 3 shows the sketch with the highest average rank, drawn by a participant from group 1. Figure 4 shows the sketch with the lowest average rank, drawn by a participant from group 2. The maps

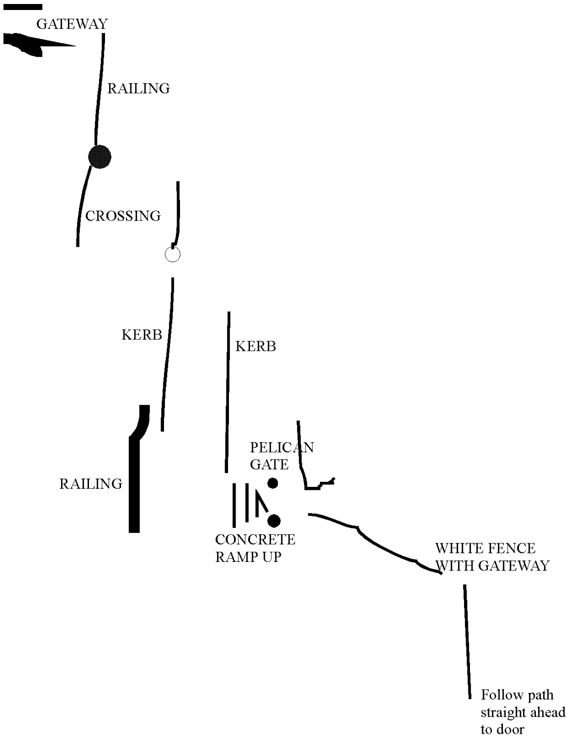


Figure 3: Sketch of route learned from group 1 participant (ranked highest)

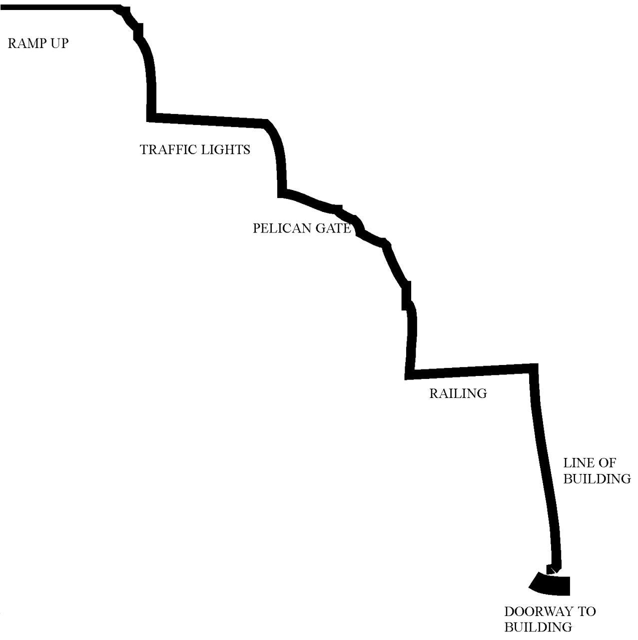


Figure 4: Sketch of route learned from group 2 participant (ranked lowest)

drawn by group 1 who had viewed the route map on NOMAD, the audio tactile interface, were consistently ranked with a higher average than the maps drawn by the group who had only walked the route. Table 2 shows the t test results for the two groups.

Table 2 - Sketches ranked by three independent scrutineers
T-test results

Group 1 - Auditory beacons and audio-tactile model route learning
Group 2 - Conventional orientation and mobiltiy route learning

Group	N	Mean (of rank)	St Dev (of rank)	Se Mean (of rank)
1	4	2.80	1.03	0.51
2	4	6.18	1.15	0.57

T = 4.38, P = 0.0072, Significant difference at 99% confidence interval.

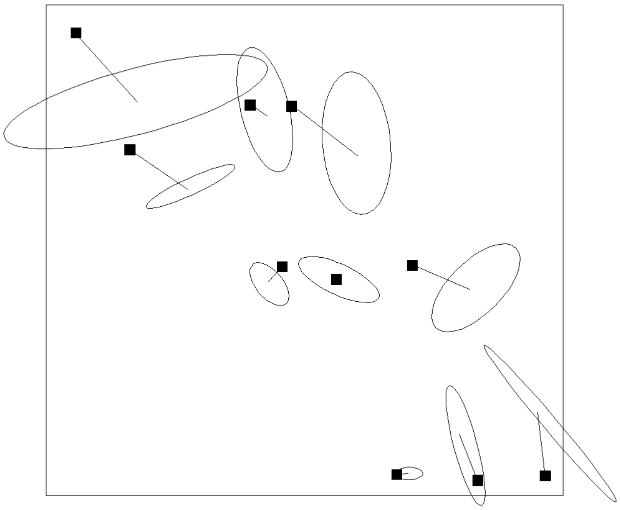
When the spatial arrangement of the sketches was analysed using bidimensional regression (Kithchin, 1993; Tobler, 1965), all sketches showed a high degree of completeness and accuracy, both in terms of visual cartographic appeal and bidimensional regression scores.(group 1 mean r^2 = 96.33, group 2 mean r^2 = 87.57) The sketches of group 1 (NOMAD) were slightly more accurate than those of group 2, although not significantly so. This suggests that the maps drawn by group2 who had map viewing experience, blended their tactile map and route gained knowledge, to supplement their sketch maps and draw a more visually pleasing cartographic representation. It is possible that the maps drawn by group 2 were slightly more accurate due to spatial judgements made from the audio-tactile map, however the graphical nature of the participants' drawing of the route is likely to have impeded any entirely spatially accurate reconstruction. Table 3 shows the t test results for the bidimensional regression scores.

Table 3 - Bidimensional regession scores (r2)
T-test results

Group 1 - Auditory beacons and audio-tactile model route learning
Group 2 - Conventional orientation and mobiltiy route learning

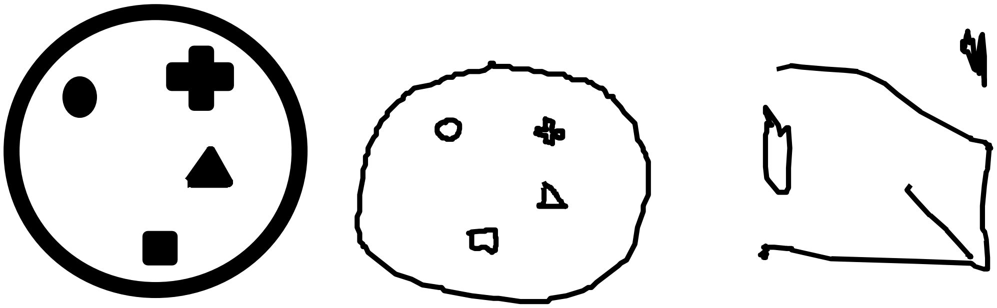
Group	N	Mean (of r2)	St Dev (of r2)	Se Mean (of r2)
1	4	96.33	1.93	0.97
2	4	87.57	5.92	3.01

T = 2.81, P = 0.067, No significant difference at 95% confidence interval



Figures 5 and 6 show the aggregated bidimensional regession resullts for group 1 (Figure 5) and group 2 (Figure 6). (Square symbol is true location of point along route, the ellipse represents the estimated location, when sketched by the respondents)

Tactile scanning exercise



(A) (b) (c)

Figure 7 Tactile scanning exercise (a) tactile shapes scanned (b) successful reconstruction (participant 3) (c) unsuccessful reconstruction by participant 7 who was also unable to complete the route unaided

All respondents with one exception were able to complete the tactile scanning assessment, by naming the components of the pseudo map (circle, square, triangle etc.), and then redrawing these with varying degrees of accuracy. It is worth noting that the participant who was least successful in the tactile reconstruction (Figure 7(c)), was the participant who was unable to complete the route independently.

Ratio scaling

All respondents completed the ratio-scaling exercise, the results are displayed graphically in Figure 6, and in Table 4. Haber et al, (1993) were successfully able to reconstruct a complex environment from Euclidean distance estimates using multi-dimensional scaling (MDS). They found that blind respondents' estimates were less accurately scaled and less internally consistent than those of the sighted. However they concluded that the blind do have an accurate internal representation of space, which is comparable to those of the sighted, although the representations of the blind are qualitatively and quantitatively different.

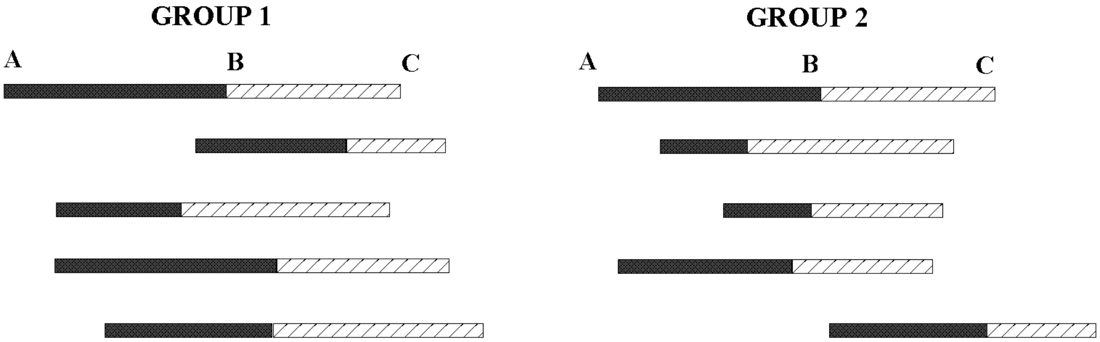


Figure 8: Graphical representation of ratio scaling exercise (labelled bar represents objective distance)

Table 4 - Ratio scaling results for 3 key points on the route

A - Start of pelican road crossing
B - Pelican gate
C - Turn after gravel

(For location see Figure 2: Visual representation of audio-tactile model)

Objective Distance		**8**	**15**	**23**	**12**	**35**	**27**
	Turn	**A**	**a-b**	**B**	**b-c**	**C**	**c-a**
Group							
1		20	10	30	7	37	17
1		10	9	19	14	33	23
1		10	16	26	14	37	27
1		15	11	26	14	40	25
Mean		13.75	11.5	25.25	11.5	36.75	23.00
St Dev		4.7871	3.1091	4.573	3.3166	2.8722	4.3205
2		12	6	18	12	30	18
2		16	6	22	9	31	15
2		8	12	20	9	29	21
2		22	11	33	7	40	18
Mean		14.50	8.75	23.25	9.25	32.50	18.00
St Dev		5.9722	3.2016	6.7020	2.0616	5.0662	2.4495

In this study there was no sighted control group. Although there was no significant difference at the 95% confidence interval between the two visually impaired groups for any of the measured variables displayed in Table 4 (A, a-b, B, b-c, C, c-a) both groups' recorded data was spatially "accurate" The data is far more complicated than it appears at first glance, respondents from group 1 possibly being able to gauge distances from the environment and the tactile map (see Ungar et al, 1994). Environmental differences when participants walked the route may have affected their distance estimates, such as the time they had to wait at the crossing before being able to cross. The individual differences in mobility skill, and their internal cognitive construct of the route, appeared to be greater than a distinct difference between the groups.

Discussion

The integration of environment and model through the use of audio-tactile maps, and audio-beacons had noticeable effects on the respondents who used the system. They expressed interest and enjoyment when exploring the talking map, particularly noting the independent exploration of the map, and amusement at the “earcons”, the bleep of the pelican crossing traffic lights, for example. When negotiating the route the audio beacon served as a key landmark at a critical turn, which, if missed meant the students would bypass the campus entirely. When learning the route this turn (pelican gate) was particularly stressful for group 2 (no additional audio or map access). This was gauged by body posture, facial expression and comments to mobility instructor. In contrast respondents, with access to the audio beacon, appeared visibly relieved on hearing the beacon, confirming they were on the route, and had not passed by the critical entrance. This was confirmed by their statements in the interviews, "learning the route with the beacon gave me the confidence to relax, on other new routes I would be anxious about making a wrong turn, or missing a shoreline, so I would make more mistakes. Once I was clear about the route I didn't really need to check where I was with the beacon, but for a new student or in a new place they would be great" (male respondent , group 1). When reconstructing the route graphically all the respondents from group 2 said they imagined travelling along the route as they drew, while group 1 respondents used a mixture of this strategy and trying to picture or copy the audio-tactile map. One respondent who could recall visual experience prior to becoming blind talked of having a floating birds-eye view of the route.

The technical difficulties and infrastructure problems should not be underestimated, of the 8 students interviewed, 7 expressed concerns about vandalism, 5 about responsibility for installation and maintenance, 6 about information given, “when it speaks turn left, when exactly do I turn left?”, 4 spoke of the wider problems of navigating in the geographic world. “I need the audio-tactile map to tell me where the signs are. If I go looking for a sign that is not there due to my mistake or vandalism, and need to rely on the beacon for information I’m stumped. The audio-tactile map tells me what I need, but I can’t carry that with me”.

Conclusion

This study clearly demonstrates the necessity for a multi-task approach to any analysis of the cognitive mapping ability of the visually impaired, and also for the tasks to be tailored to account for a loss or reduction in the visual sense of the respondent completing the task. Each task placed subtly different cognitive demands on the respondent, serving to present a more complete picture of their spatial competence and the utility of the audio beacons. The mixture of quantitative and qualitative methodologies complimented each other. The use of verbal protocol helped to set a respondent's results on quantitative tasks into context.

In a semi-controlled environment such as a campus, shopping centre, or transport terminal this study suggests that there is great potential for auditory beacons as a technical aid for en-route assistance. For orientation and mobility training it is suggested that this technique can help to build confidence and the cognitive constructs necessary for navigating within the environment. From the results of this study it is clear by the significant differences between the two groups, that audio beacons have the potential to be used for the enhanced development of orientation and mobility skills.

Even by their serial route-like understanding of space the visually impaired are competent route navigators (all but one student completed the route), and by the use of audio-tactile and environmental audio beacons their understanding of space can be greatly improved.

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