LANDMARKS FOR NAVIGATORS WHO ARE VISUALLY IMPAIRED

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We are attempting to understand the benefits and limits associated with multi-media maps by following a human information processing research tradition that compares the performance of experts versus novices in a given domain. For navigation around the built environment we have documented the landmarks utilized by visually impaired participants and compared them to those used by sighted participants. Our preliminary data suggests that the landmarks enunciated by our sighted participants fall within a narrow visual cone associated with their sightlines. In contrast, our participants who are visually impaired enunciated landmarks that fell in a much broader field that included the textures and surfaces below their feet; the wind; sounds; and smells. These findings point to the elements that should be included in tactile maps and provides clues to our understanding of the cognitive maps that all of us create to navigate the world.

1. INTRODUCTION

If you were a first-time visitor to Ottawa and wanted to know how to get from Elgin Street to the Parliament Hill area, you would probably receive the following instructions: “Travel up Elgin until you will see the War Memorial Statue and behind it you will see a big hotel that looks like a castle. There, you need to turn left and you will immediately see the tall bell tower of the Parliament Hill complex”. However, would one give such a description to a visually-impaired person? Or what if it were a cloudy evening and there were no spot lights on the memorial to highlight it? In the studies described here we set out to explore which features and landmarks should be used to aid wayfinding for people who are visually impaired and in vision-degraded situations.

The studies were a part of “Cybercartography and the New Economy”, a multi-year, multi-disciplinary project exploring, researching, and developing innovative ways to represent spatial information and funded by Canada’s Social Sciences and Humanities Research Council. Cybercartography is a new conceptual framework suggesting new opportunities and challenges to maps and mapping in terms of process, organizational concept, and as a product (Taylor, in press). Some of the important tenets of this conceptual framework are exploring innovative ways to map environments and information in ways that can enhance wayfinding and orientation. Specifically, the use of multimedia, multimodal representation of spatial information is a critical component of this effort.

It is commonly accepted that our knowledge of an environment is composed of three knowledge types: landmark, route, and survey knowledge. Landmark knowledge is typically considered the visual representation of salient landmarks in the environment (Ruddle, Payne, & Jones, 1997; Siegel and White, 1975). Such landmarks could be unique human-made structures or elements in the landscape (Goldin & Thorndyke, 1982; Sorrows & Hirtle, 1999). Route knowledge (Hintzman et.al, 1981; Thorndyke & Hays-Roth, 1982) is a procedural description, sequential in nature, of the route between points in the environment, along with identification of all the landmarks at which an action (e.g., turning left) should be taken. Survey knowledge (Hintzman et.al, 1981) is a more simultaneous, image-like or graphic representation of the entire geographic area, including the layout of all elements and the spatial relationships among them.

Most often, landmark knowledge is acquired first when encountering and learning about a new and unfamiliar environment. The recognition of landmarks becomes a part of the construction of route knowledge, where the landmarks are the points that make up the routes. Later, landmarks are the objects and elements in the survey knowledge and they are part of constructing the layout and relational configuration of the elements in the environment (Siegel & White, 1975; Heth,
Cornell, & Alberts, 1997; Chen, 1999; Wickens & Hollands, 1999). Because of the importance of landmark knowledge for route and survey knowledge, much research has been devoted to the impact of landmarks on navigation and orientation. Most of the research has found that the lack of landmarks in the environment degrades navigation and orientation performance (e.g., Abu-Ghazaleh, 1996; Passini, 1996; Darken & Sibert, 1996; Parush & Berman, 2004; Waller, et al., 1998; Vinson, 1999).

Another important line of research has addressed the question of how spatial cognition is acquired. Many studies have compared direct experience in the environment by active navigation and exploration to learning the environment from a map or route descriptions. Active navigation in the environment was classified according to the level by which people were familiar both with the environment and the target (Darken & Sibert, 1996; Allen, 1999). In general, findings indicated that map learning produced better performance with orientation tasks such as direction pointing, map drawing, and relative location estimation (Thorndyke & Hays-Roth, 1982; Parush & Berman, 2004; Ruddle et al., 1997; Moeser, 1986). In comparison, direct navigation produced better performance with navigation tasks such as orienting to unseen targets, route distance estimation and route descriptions (Thorndyke & Hays-Roth, 1982; Hintzman et al., 1981). Studies also indicated that spatial cognition changes as a function of the direct experience in the environment: more experience led to more survey knowledge, and less exposure still produced route knowledge (Golledge & Spector, 1978; Thorndyke & Hays-Roth, 1982).

2. TACTILE MAPS

It is well established that vision plays a critical role in the recognition of landmarks and the acquisition of spatial knowledge. The question is what role do landmarks play when vision is impaired or degraded? Are there non-visual landmarks to help guide navigation? There is much research on the use of other modalities such as touch and sound to aid wayfinding in vision-constrained situations (de Almeida & Tsuji, in press). A good portion of this research explored the effectiveness of tactile maps as an aid to acquisition of spatial cognition (Aldrich, Sheppard, & Hindle, 2003). However, there is little research on the specific nature of landmark information and features that should be implemented in aids such as tactile maps. For example, should information about the hotel that looks like a castle in downtown Ottawa be presented in a tactile map? Is that the kind of information that can be utilized effectively by people who are visually impaired?

The objective of the studies described here was to explore what features and landmarks are used in navigation by people who are visually impaired and in vision-degraded situations. The research question is: should the same features and landmarks that are recognized visually and are used by sighted people also be used in alternative aids based on touch and sound? The research approach was based on two exploratory studies. In the first study we explored how blindfolded sighted people use tactile maps that have a direct translation of the visual features into tactile features. We assumed that if a simple translation of the features is not appropriate then the participants would have difficulties using the tactile map effectively. In the second study we compared the features and environmental landmarks utilized by people who are visually impaired with people who are sighted. We expected that sighted and visually impaired use different aspects of information of the environment when acquiring and using spatial knowledge.

The skin of the human fingertips is extremely finely tuned: it can discern and produce a measurable electrophysiological response to a 5.5 µM dot etched onto the surface of glass (Greenspan & Bolanowski, 1996). Sensitivity increases even further with active movement, as the tactile sense then combines with active kinesthetic perception, than when touching passively without active movement (Heller & Myers, 1983). People are clearly capable of perceiving the features of tactile maps and they have been produced and used for 150 years (Tatham, 2003). However, an enduring question is this: What are the appropriate landmarks? What cues would be most effectively utilized in a tactile map? What are the features of the cognitive landscape that can be utilized to guide people through the built landscape in our cities, towns, and villages? This is a question related to human-computer interaction because it speaks to the multiple modalities that can be used to elaborate virtual worlds as well as how we can enhance our understanding and appreciation of the real world.

To explore this question we asked sighted participants to navigate using a tactile map. However, because of the dominance of the visual modality it was necessary artificially to curtail visual input: we asked participants to wear a blindfold. It should thus be possible for people to navigate via tactile maps. We produced a set of embossed paper maps of the Carleton University campus using microcell (or swell) paper that gave us tactile maps of approximately 27.8 cm by 21.5 cm in total size.
The first lesson we learned was that the direct mapping of physical structure to tactile map elements was wrong. The first maps contained too many physical details, making it almost impossible to distinguish between these, and certainly providing more information than necessary for the task at hand. These landmarks included curbs, lamp posts, trees, bushes, and even outlines of individual parking spots. The difference in elevation between figure and ground was approximately 1mm which, despite the human tactile ability to pick up minute differences in texture, also may have added to the difficulty of discerning the boundaries between physical fixtures. Yet, increasing the paper-size would render the map very difficult to handle while navigating an outdoor environment. One major challenge was therefore to decide which details to remove. No guidance or support was available for making this decision. We believed that large structures like buildings would act both as important landmarks and as navigation aids: in order for a person to find their way using the map, they would have to know where these large structures were relative to each other and to themselves. Other landmarks such as trees and lamp posts were, naively, deemed unimportant. Therefore, landmarks other than buildings and roads were removed before we tested these maps.

2.1 Procedure

Eight members of the cybercartographic research team volunteered their participation. All were very familiar with the University campus, and all had normal or normal-to-corrected vision. Participants worked in pairs. Each pair was given a tactile map, and one member of each pair was taken to an arbitrary starting point of their navigation task and then blindfolded. The other member adopted the role of a “guide” to prevent any falls or other accidents from occurring. All four pairs of participants started and ended in different parts of the campus. The guide selected a route to their final destination and the blindfolded participant was instructed to trace the route with their fingers. Our initial premise was that this was the simplest possible task. Participants were guided on a short (10-minute) walk of the university campus following the route with their fingers on the tactile map. At the end of the route, participants were asked to identify their end-point on the tactile map. Guides were instructed to hold their charges by one elbow and physically provide warning information as appropriate “watch the curb coming up”. Once the first destination had been reached, the two members of a pair swapped roles, so that the guide now was blindfolded and the person who had been blindfolded in the first task became the guide. The destination from the first round now became the starting point for the second round, and a different destination was assigned to each pair. Upon completing the second navigation task and returning to the lab, each participant rated their experience along several different dimensions outlined in a brief questionnaire. They were also invited to offer additional comments. The main findings are summarized below.

2.2 Results and Discussion

Generally speaking, this initial experience of using a tactile map was interesting and insightful but blindfolded navigation was extremely difficult. Indeed, the task was apparently so hard that when asked how long participants estimated it would take them to learn to use a tactile map of the University campus effectively, some thought it would take over four months; others that they would never be able to learn it. Similarly, when asked how long they thought it would take to teach someone else to use a tactile map effectively, some participants thought it would take ‘forever’, that they were ‘not sure it would be possible’, or that it would take at least four months.

Several participants were academic geographers or cartographers with excellent map-reading skills. Not surprisingly therefore, when asked to self-rate their ability with conventional maps, six rated themselves ‘good’ or ‘excellent’; only one rated his skills as ‘fair’ and one as ‘poor’. None of the participants had used a tactile map before, and none had ever tried to navigate while blindfolded. One would therefore expect the task of navigating even a reasonably well-known environment to be quite difficult for at least four reasons. First, when unable to see, it is a huge challenge to know where you are at all times. You are forced to pay close attention to environmental cues that one would not expect sighted people to register under normal circumstances. Second, navigating to where you want to go without the benefit of visual cues requires more, or at least different, cognitive resources than when such cues are available. Third, registering how it feels to turn your body, say, 45 degrees to the right or left in the absence of visual feedback requires highly accurate proprioceptive perception and reading of kinesthetic information that sighted people are not accustomed to use for navigation. Finally, the degree to which the tactile map may actually assist navigation for people who are blindfolded and who have no experience with tactile maps is questionable.
When participants were asked how they knew where they were while navigating, they reported relying on sounds, textures, and temperature. Sounds included traffic noise, fans, and ongoing renovations; textures included road surfaces, types of bricks, and the feel of railings on stairs and ramps. Changes in temperature were noted, for example, when walking from the sun into the shade or vice versa. Yet, despite relying on these cues, only one person thought he had a ‘good idea’ of where he was at any time, while others were quite unsure. One participant reported having “no idea” where he was at all and giving up trying to use the tactile map after a very short period of time. From their comments it would appear that participants were trying to create a mental picture of their current position from the available non-visual cues, relating these to different areas of the campus and different kinds of activity they knew were taking place in certain locations, and then compare these with their mental map of the campus. Participants utilized their spatial memory which may have route and survey knowledge components rather than extract the needed information from the tactile map.

In their attempt to navigate using the tactile map, some participants tried to keep one finger on the starting point, then measure the distance from the edges of the raised areas, keep the map in a particular orientation while recalling the shape of the campus, and trying to get a sense of north and south. However, these attempts were largely unsuccessful. Participants’ ratings of the importance of various map attributes and their comments on these are informative for exploring some of the reasons for this. Of the seven map attributes participants were asked to rate in terms of importance, the density of the raised area achieved the highest rating with an average of 4.3 out of a possible 5.0, followed by orientation of the campus (average 3.8) and the height of the raised area (average 3.75). The University campus is flanked by a river and a canal respectively that together form the apex of a triangle as can be seen in Figure 1. Unfortunately, neither of these waterways was shown on the map, which made it quite difficult to determine the orientation of the campus. Indeed, of the 30 comments made about the map attributes, some 21 concerned the difficulty of distinguishing between figure and ground and between the shapes of physical fixtures shown on the map.

![Figure 1: Carleton University map](image)

All participants agreed that the tactile map was too fine-grained to be of use; it was impossible to distinguish between figure and ground, to discern particular shapes, for example, of the outline of buildings. It was impossible to ‘read’ numbers of buildings even though participants knew these were there. Participants also found the paper on which the map was imprinted too thin and hence too flexible, making it difficult to trace their route with their fingers. Not surprisingly, since it was clear that participants relied on non-visual environmental cues, they called for more landmarks on the map such as stairs, parking lots, roads, trees, and information about road texture. In particular, they wanted a map that focused on differently textured paths and the shapes of grassy areas rather than the emphasis on buildings that we thought would be important. This suggests that participants navigated by route knowledge rather than by survey knowledge even though they almost certainly did possess such knowledge.

At the time we had not appreciated the difference between orientation and mobility maps that depict indoor and outdoor environments. Both are large-scale representations of buildings, routes, streets, transportation networks, neighborhoods, and recreation areas. People with visual impairments use such maps to navigate space and to be aware of the physical
environment, its obstacles and dangerous features. An orientation map gives an overview of the area, while mobility maps provide the kind of detailed information that is needed for an individual to move safely through space. Mobility maps show relevant information for the traveler, elements to use such as sidewalks, or elevators (Araujo de Almeida & Tsuji, 2004). Indeed, the maps produced for our blindfolded participants were really orientation maps, but we employed them as mobility maps. Consequently, much of the information participants wanted and needed had been removed prior to the test in our attempts to reduce the complexity of the maps without realizing which details would prove important for the task. It thus became clear that, in order to support route mapping, we needed to learn a lot more about the kinds of landmarks people note when deprived of visual input.

### 2.3 Navigation By People Who Are Visually Impaired

Because all participants in the above navigation task had normal vision, it was impossible to ascertain the degree to which the findings would apply to people who are visually impaired. In an effort to explore this, we arranged a visit to the Canadian National Institute for the Blind (CNIB) for a discussion with one blind person and two “Orientation & Mobility” (O&M) specialists whose role is to facilitate wayfinding and navigation for visually impaired people. These specialists identify landmarks along specific routes that a visually impaired person might want to learn to navigate independently. They then convey their list of these landmarks in sequence to the other person, who in turn must learn and memorize these to navigate the given route successfully. In fact, the route is learned such that that the learner may start it from either end.

According to the two O&M specialists, tactile maps are being used for teaching geography where students learn about structures such as country boundaries, rivers, and mountains. They thought it would be highly improbable that a visually impaired person would seek to navigate, for example, parts of a city by using a tactile map. By the same token, other people who work with tactile maps seem to find them quite useful for navigation tasks in line with the one we tested on sighted people. Consider, for example, the following claim: “Tactile maps are wonderful tools and the clients I am working with are thrilled with the maps that … volunteers with the CNIB, has[ve] produced…. The maps help them to understand, and become oriented to the spatial layout of a specific area they are learning to navigate independently” (http://www.cnib.ca/eng/publications/pamphlets/gis_maps.htm). And similarly, the following statement by a visually impaired person: “I know Josh and I’ve seen his tactile maps. They’re pretty good. I moved into a new neighborhood and the map he had printed out in braille really helped me get a better idea of my surrounding and what streets were what” (http://www.cnib.ca/eng/publications/pamphlets/gis_maps.htm). Evidently, the potential of tactile maps is yet to be fully exploited and understood.

In terms of landmarks, the O&M specialists asserted that these must be permanent, static fixtures in the environment. Since our sighted participants in the first study said they relied on sounds like traffic and textures like the type of paving on paths, it was worthwhile to determine whether visually impaired people would report using similar landmarks. Traffic varies by the time of day and the day of the week, and the texture of outdoor paths cannot be determined during the Canadian winter when the ground is covered with snow. Neither of these cues can therefore be regarded as permanent or static; from the O&M specialists’ perspective, these would thus not qualify as landmarks. The next study was therefore designed to learn more about landmarks that visually impaired people would report and compare these with those reported by people with normal vision.

### 3. Identification of Landmarks

Six participants who had not taken part in the first study were asked to explain a route they knew well to someone else, pretending that that ‘other’ person was unable to see at all. The objective was to learn more about the features people notice, and what they might think would be helpful for others who try to navigate an unfamiliar route. Three participants were visually impaired, and three had normal or corrected-to-normal vision. All were members of the Carleton University community, and all were asked to select a route within the campus area. No attempt was made to control for the routes, as the intention was to learn more both about the particular landmarks people were using and also about the vocabulary they used to describe the chosen landmarks. Likewise, participants were free to select an indoor- or an outdoor route, or one that included both indoor and
outdoor navigation. The route descriptions were audio taped and transcribed ad verbatim. Descriptions of environmental features in the route explanations were assumed to indicate landmarks.

3.1 Results and Discussion

In total, over one hundred environmental cues were noted by the six participants to describe their chosen routes. These cues were divided into several categories to reduce the problem space. In the data file we distinguished between sighted and visually impaired people to learn the extent to which the choice of landmarks may differ between people who do, and people who do not rely on vision for navigating the environment. In addition, a distinction was made between environmental cues that may act as landmarks in an indoor as opposed to an outdoor environment. These results are summarized in Table 1 below.

Table 1. Indoor and outdoor landmarks noted by both groups

<table>
<thead>
<tr>
<th>Category</th>
<th>People Who Are Visually Impaired</th>
<th></th>
<th>People Who are Sighted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indoor</td>
<td>Outdoor</td>
<td>Indoor</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Physical fixtures</td>
<td>11</td>
<td>11</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Textures</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Orientation</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Sounds</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Smells</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Spaces</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Movements</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>34</strong></td>
<td><strong>34</strong></td>
<td><strong>23</strong></td>
<td><strong>27</strong></td>
</tr>
</tbody>
</table>

The above figures suggest that visually impaired people used a slightly richer vocabulary than sighted people. This is most obvious in the two sensory categories, sounds and smells, but also in the descriptions of textures and of movements. It is interesting to note that not all the features described referred to landmarks; movements, for example, were always described from an egocentric point of view.

Clearly, the reliance on physical fixtures such as buildings, doors, hallways, and bridges was very similar in the two groups, and also equally prominent in descriptions of indoor and outdoor features. However, the way in which the two groups referred to some of the landmarks is notable. Whereas sighted people referred to buildings by name such as “Robertson Hall”, visually impaired people simply referred to “buildings”. It was also interesting, albeit perhaps not surprising, that only sighted people referred to signs such as “Stop”, and “Pedestrian signs”, and visually impaired people referred to carpets, apparently because of the texture underfoot that sighted people may not notice or may not register as landmarks. Orientation issues such as up/down, right/left, were the second most mentioned issues noted. Here, it was noteworthy that only sighted people referred to north and south, a concept that might be meaningless to someone who cannot see the position of the sun. Sounds, mentioned exclusively by visually impaired people, included those that sighted people may not have noted such as the “beeps of the elevator” and the “whirr of the freezer”. Smells, also noted more by visually impaired than by sighted people, included perfume, indicating a shopping centre, and “food”, noted in the vicinity of cafeterias. Movements were turns, L- or T-crossings, passing n doors or crossing the streets; they were invariable noted from the subjective egocentric point of view, in contrast to the objective static physical fixtures described earlier. Spaces referred to maintenance areas, a park area, and a lobby.

4. GENERAL DISCUSSION

Taken together, the findings of both studies suggest that what constitutes an effective landmark for sighted people is not necessarily the case for people who are visually impaired. Moreover, even sighted people use more cues than just the visual features in the environment. These include sounds and textures and smells and more. The general implication of these findings is the need for a paradigm shift in the design of navigation and orientation aids such as maps. The shift should be
in terms of implementing a variety of multimodal features that can serve as landmarks and not only the visual ones. For example, various sounds, textures, or smell sources can be indicated on a tactile map. In addition, a distinction should be made between macro-level landmarks and micro-level landmarks. Macro-level landmarks are visually-salient major buildings, towers, churches, sculptures, etc. Micro-level landmarks can be a lamp post, a parking meter, or an incline in the pavement. Such physical elements in the environment are significant for people who are visually impaired and in vision-degraded situations because they can be touched, be used for wayfinding, and consequently should be implemented in tactile maps.

5. NEXT STEPS

On the surface, this paper is about tactile maps, about people who are visually impaired, and about the landmarks we use to navigate the world. However, one of the objectives of the Cybercartography and the New Economy project is to develop multimedia maps to be used by all people. In order to produce maps that invite the user to rely on more than one modality, it is essential to understand what modalities can effectively and usefully be employed to portray aspects of the space to be navigated. It does not matter whether that space is found in the “real” world, in a virtual world, or in cyberspace: the ability to navigate successfully is likely to be enhanced by relying on more than a visual representation of space. The question is how we mix and match information given in different sensory modalities to assist the user rather than confusing them or causing information overload. There are situations in which simultaneous presentation of, say, text and speech compete with each other, when the user must decide whether to listen or to look. At best this is annoying; at worst, it may cause anxiety, a feeling of incompetence, or utter frustration. The same may be true when confronted with tactile cues, say changes in surface texture, temperature, or vibration to signal a landmark, together with instructions to “be careful of the curb here”.

We already know that people who are visually impaired can learn to very effectively utilize tactile maps. However, we also know that visually impaired people do not enjoy similar degrees of freedom to move and navigate their environment freely, but that they are forced meticulously to learn each route they navigate. What we don’t know is how we might enhance the information provided on tactile maps to improve navigation skills without the benefit of visual cues, thereby also increasing the “naturalness” and the ability to move around freely and confidently in a variety of real and virtual worlds. Ultimately, the production of effective multimodal multimedia navigation aids boils down to a better understanding of the components of people’s cognitive maps, be they people with normal or impaired vision.

Our next step in this line of research includes a more thorough analysis of the kinds of landmarks used by people who are visually impaired and people with sight intact. In the first instance, we will test tactile maps in conjunction with the landmarks noted by our participants in Experiment 2 and presented as sound while the person moves progressively through a given route. We will also explore the landmarks utilized by highly expert navigators, people such as taxi drivers in the built environment or perhaps orienteering experts. We will attempt to embody our findings about the landmarks utilized by different user types into maps and graphs and other visual displays to determine how well we can facilitate more effective information extraction from these. We will also explore different combinations of hardware and software to enable the presentation of these alternate modalities. Ultimately, our goal is to explore and extend the boundaries of cognitive psychology and cartography to facilitate the acquisition of spatial understanding by people who are visually impaired as well as those who are sighted.

6. REFERENCES


