Facilitating Route Learning Using Interactive Audio-Tactile Maps for Blind and Visually Impaired People

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Abstract
In preparing to navigate in an unfamiliar location, a blind person may use non-visual maps. This project is aimed at developing more effective, interactive audio-tactile maps. The maps will be novel in using speech and non-speech sounds and allowing the user to rotate the map, thereby facilitating the building of an *egocentric* cognitive map. Initial requirements have been gathered from mobility instructors. Their main conclusions are that immoveable objects represent the most useful landmarks and that certain ambient sounds can provide most valuable orientation information.

Author Keywords
Blindness; visual impairment; tactile maps; audio-tactile maps; route learning; multimodal; touch; speech; auditory icons; orientation; accessibility.

ACM Classification Keywords
K.4.2. [Computers and Society]: Social Issues – Assistive Technologies for Persons with Disabilities.

General Terms
Design, Human Factors

Introduction

Navigating in the real world represents a significant challenge for blind people. Vision is a very powerful sense. On the one hand a large amount of information is available simultaneously but at the same time vision can literally focus on that information which is relevant at any given time. Since blind people[1] are unable to use this sense, other senses (notably touch and hearing) are recruited to substitute. Touch and hearing perceive information in a more sequential form. In substituting for vision they face the so-called 'bandwidth problem' that they cannot match the capacity of vision. However, it may be that if both senses are utilized simultaneously, they can provide more information to the user: the whole may be greater than the sum of the parts. The objective of this research is to investigate the use of combined tactile and auditory information in navigational planning.

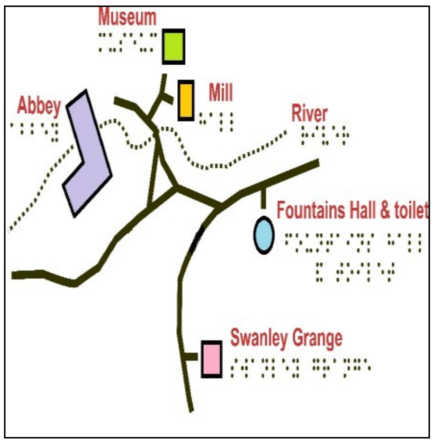

Figure 1. Conventional tactile map

Non-Visual Access to Geographical Information

Conventional tactile maps

Tactile maps (Figure 1) can be an effective tool to aid route learning for people with visual disabilities [1, 8]. One use is in advanced planning, whereby the user obtains information about a novel location before they visit it. They may able to decide which route to proceed to certain destination by memorizing landmarks or junctions that are displayed on the map. In this way, they can develop a cognitive map through the information gathered based on what they feel using the sense of touch. However, depending on a single modality (touch) to learn the map can be difficult. For example, the map may be cluttered with tactile symbols and Braille labels, some of which are likely to be redundant with regard to the user's current task. For instance, there may be confusion between the raised tactile symbols and Braille dots. Tactile maps are inherently static and restricted in the information they can convey and hence their usefulness is limited, especially when it comes to a complex map.

[1] Throughout this paper we refer mainly to 'blind' people, that is those with no useful sight. The needs of visually impaired people who have some sight are different, but they can also benefit from some of the technologies we are developing.

Audio-tactile maps

The limitations of conventional tactile prompts the investigation of multimodal approaches in which auditory and tactile are combined together in order to achieve the better learning of geographical information. Integrating auditory elements has a number of advantages. These elements can be interactive, sounded on demand, reducing clutter. They can add information that cannot (easily) be represented tactually and that information may be more ecological (i.e. closer matched to the real environment). Current audio-tactile maps commonly rely on synthetic speech [2, 9].

Speech

Speech is essential in giving verbal information to the user such as street name and route directions. Speech has some disadvantages, including the slow presentation rate and the need for the user's attention until the end of the spoken message [3]. Some of these limitations may be overcome by using non-speech sounds to present abstract information which is hard or impossible to convey through speech.

Non-Speech Sounds

Non-speech sounds include non-linguistic content generated by natural objects such as wind in trees, moving

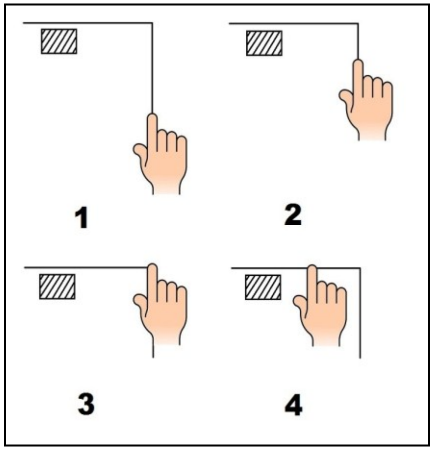

Figure 2. Allocentric map reading strategies

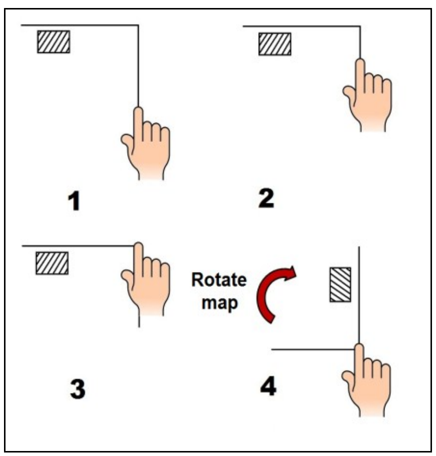

Figure 3. Egocentric map reading strategies

trains and people running. These types of non-speech sounds are also known as *ambient sounds*. Blind travellers rely on such ambient sounds during route learning activity. For example, the sounds of vehicle passing can become as an alarm of danger. In addition, ambient sounds can provide distance estimation and assist the user in self-orientation. The richness of spatial information carried by ambient sound make it a promising potential element that to enhance the functionality of an auditory display interface beyond synthetic speech [7].

Strategy in Reading Tactile Maps

The common style of reading a tactile map (either conventional or interactive) is in *allocentric,* as shown in Figure 2. The user follows the straight line (representing a route) moving their hand forward until a junction is met (Steps 1-3). After the junction is encountered in Step 3, the user follows the line to the left. The hand remains in the same orientation but is moved sideways, as illustrated in Step 4. Information perceived during the map learning will be structured in the cognitive map as allocentric. In reality, blind people tend to employ an *egocentric* approach to spatial perception [4]. By consulting the map in preparation, the blind traveller develops an internal cognitive map which they will access during navigation. However, that cognitive map may be inadequate if it does not match the real world. When walking, if one reaches a junction (Step 3), the walker turns in the appropriate direction; they do not crab sideways.

Most experiments reported in the literature relate to the use of portable tactile maps during route learning [1, 5]. In that situation, the user can reorient themselves – and their map – to be congruent to their surroundings [6]. In our studies, the same condition is applied during the map reading in preparation phase to avoid spatial confusion during active exploration.

Our Approach

Based on the previous discussions, we proposed two main components to be integrated with tactile maps: (1) auditory elements (2) rotation. The aim of this research is to provide spatial information naturally to the blind user. We are interested to identify how the route learning process during preparation phase can be facilitated. Moreover, we would like to investigate whether the proposed elements can improve the blind user's learning and enhance their cognitive maps of their surroundings.

Auditory elements

There are two forms of auditory elements that will be employed: speech and non-speech. There are two kind of information that will be examined: (1) spatial information (2) orientation information.

Rotation

A rotation feature will be integrated with audio-tactile maps to aid egocentric map reading strategies, as depicted in Figure 3. In egocentric map reading, the user will rotate the map whenever a junction is met. Therefore, the finger will always follow the line in an upward position. This resembles the user when he or she walking on a street. Thus, it is expected that the user's cognitive map will be egocentric in form.

Data Gathering

In the early phase of our research, we first identify what information is needed by blind people. We conducted a discussion with a Mobility and Orientation instructor to understand how people with visual disabilities move around in real environment. Following the discussion, we distributed an online survey to 15 Mobility and Orientation instructors.

Discussion with Mobility and Orientation instructor
An informal discussion was carried out with a Mobility and Orientation instructor. He has seven years of experience in giving route-learning training to blind adults.

He asserted that blind people are dependent on landmarks and auditory cues in the environment to understand the type of area they are travelling in. The mobility instructor pointed out that the landmarks must be immoveable features. Thus, they can become permanent anchor points that can be referred by the blind traveller for their journey at any time. He also suggested that auditory cues are important to assist during route learning and maintaining orientation on the travelled path. The auditory cues also help them to get information regarding the distance between objects or places. The mobility instructor strongly approved of the idea of integrating non-speech sounds into tactile maps since it would facilitate interactive learning and introduce the user to the real environment of the novel area.

Another significant finding regarded the understanding of the types of junction. For any route, there are segments that are connected with different types of junction (e.g. Y-, T- and L-junctions). The angle of junctions is vital information to enable the blind traveller to perform the necessary turning. It is common to use a clock-face measure: straight ahead is 12 o'clock, 90° to the right is 3 o'clock, etc. However, the mobility instructor pointed out that such visualizations are only accessible to late-blind people. Thus, "Turn to your 3 o'clock" may be appropriate for one group, where for the others it might be better to say "Move more to the left".

An online survey study
The aim of the online survey study was to build on the information obtained from the mobility instructor by surveying others in the profession. The questionnaire concentrated on detailed information of the type of auditory features and landmarks they feel important in guiding people with visual disabilities in route learning. An online survey enabled us to reach a large number of 15 instructors, while not requiring a large time commitment on their part. Participants were volunteers, recruited through a mailing list. There were 3 sections: map usage, landmarks and auditory cues, making 9 questions all together. The lists of landmarks and auditory cues used in this study were obtained from the literature and through previous discussion with the mobility instructor.

i) Map usage
This section asked about participant's experience in using maps to train the clients and how they create their maps if they use them.

ii) Landmarks
This section asked whether landmarks are useful for blind people, whether landmarks should be immoveable features. Respondents were asked to rate listed landmark features as to their importance. The rating question used a 7-point Likert scale (1 = Not important; 7 = Very important).

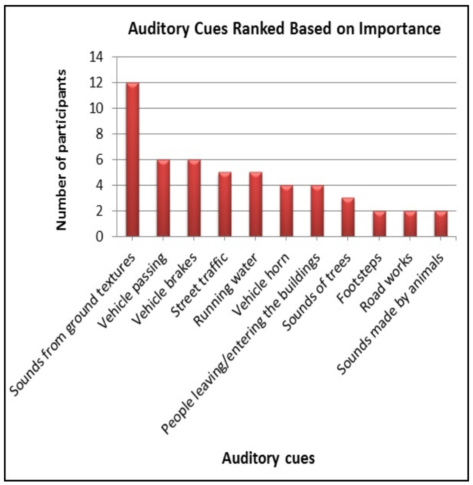

Figure 5. Auditory cues ranked based on importance

iii) Auditory cues

This section asked whether auditory cues are useful for blind people. Participants also rated listed auditory cues as to their importance. The rating question used a 7-point Likert scale (1 = Not important; 7 = Very important).

Results and Analysis

All the data gathered through the online survey study is analyzed and presented as the following:

i) Map usage

All of the participants have experience in using maps in mobility training with the blind people. Only one of them does not create his own maps. Others create their maps using swell paper while one uses a tactile pen.

ii) Landmarks

All of the participants agreed that landmarks are useful to guide the blind traveller in independent exploration. All of them also agreed that landmarks should be immoveable features which have permanent position and static. As shown in Figure 4, road crossings were rated as the most important landmarks. During independent travelling, the blind traveller relies on road crossings to safely cross the road. Therefore, they need to understand the location of each road crossing in the area beforehand. Open spaces like parking lots and fields were rated as less important by the majority of participants. This is probably due to very limited cues these areas can offer. However, this is at variance with [5] who found that it is necessary to highlight the open spaces to the blind people since they often confuse between open spaces (e.g. parking lots) and alleyways.

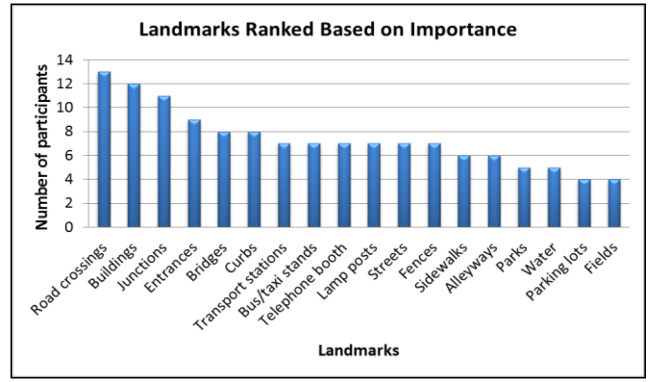

Figure 4. Landmarks ranked based on importance

iii) Auditory cues

All of the participants agreed that auditory cues are useful to guide the blind traveller. As shown in Figure 5, sounds from ground textures were rated as the most important auditory cues by the majority of participants. The sounds from ground textures can change, as when the traveller walks from a paved surface to a grassy lane, for instance. This is important for maintaining user orientation. The blind traveller can be alert whether they have deviated from the intended path based on the changing sounds. The least important auditory cues are footsteps, road works and the sounds made by animals, such as birds chirping. This may be because these sounds depend on the frequency of the presence of the objects or events at the particular environment, be it urban city or countryside.

However, the aim of this study is to understand the importance of each cue in general. The information gathered will be incorporated into audio-tactile maps and test with the blind user who will identify which cues work for them for independent travelling.

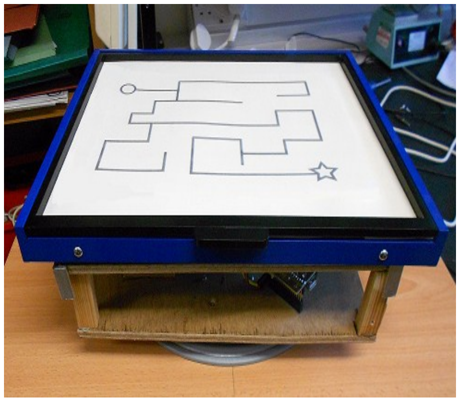

Figure 6. Talking Tactile Tablet (T3) is placed on a turntable

Prototype Design

In order to test the proposed approach, we use a swell paper to produce a map and place it on a Talking Tactile Tablet[2]. We developed a system that can produce sounds whenever a particular region on the map is pressed by user. As mentioned before, there will be speech and non-speech sounds to represent the information on the map. We placed the tablet on a turntable (see Figure 6) to enable the egocentric map reading task performed by blind people. When reading the map, the user will have to rotate the tablet manually according to the direction they intend to proceed. A rotation sensor is integrated within the turntable to give a rotation value. Both data from the tablet (finger coordinate) and rotation sensor (rotation value) are sent to the system on a computer via Bluetooth. This would activate the particular sounds and informed the user about orientation information.

Conclusions and Further Work

This paper discusses our approaches to make route learning using audio-tactile maps more interactive and accessible to the blind user. Initially, we investigated what information is needed by the blind people in perceiving and understanding space from mobility instructors through discussion and an online survey. From the online survey, we obtained important landmarks and auditory cues to be incorporated into audio-tactile maps which later will be tested with blind participants. As this research is still at early stage, more evaluations need to be done. For example, the presentation of information through synthetic speech and auditory icons needs to be investigated and evaluated. Also, the effect of allocentric and egocentric map reading strategies on the performance and cognitive maps of blind users need to be examined. Thus, a new method of reading audio-tactile maps can possibly be introduced as the outcome of this research study.

[2] http://www.touchgraphics.com/research/ttt.htm

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