Identifying Sound Cues of the Outdoor Environment by Blind People to Represent Landmarks on Audio-Tactile Maps

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Abstract. Blind people often rely on sound cues to gather information about their surrounding whenever they are in an environment. Various sound cues produced by events encourage blind people to identify the source that produces the sound. Having the skill in identifying sound cues could facilitate blind people in wayfinding and increase their awareness of the environment. As the literature suggests, there are 2 dimensions (object and action) that are considered crucial when evaluating the identifiability of sound cues. We therefore conducted a study with blind participants at Malaysian Association for the Blind (MAB) to investigate their ability in identifying sound cues that represent landmarks of an outdoor environment. The objective of this study was to examine which sound cues that were suitable to represent landmarks in the outdoor environment based on the correct identification by the participants according to the 2 dimensions as mentioned above. The findings of this study showed that not all sound cues used in the evaluation could be correctly identified by the blind participants. Lack of auditory skills and dependent on peers when travelling in the outdoor environment were among the factors that contributed to the inability of some blind participants to identify the sound cues. However, blind participants who have exposure to the outdoor environment were able to identify majority of the sound cues correctly. As for the next phase, the sound cues that obtained high scores based on the object and action in the study; will be incorporated on audio-tactile maps for map exploration. This paper also concludes by discussing some recommendations on how to improve the use of sound cues according to blind people preferences.

Keywords: Sound cues · Landmarks · Audio-tactile maps · Blind people

1 Introduction

Human has the ability to listen to a wide range of sounds. Information perceived from sounds tells us about what is happening around us no matter near or distant. On the other hand, sounds can affect listener's emotions, behavior and actions. For example, the sound of train approaching gives us a hint whether we should run for it or not.

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We learn to distinguish sounds that have particular importance based on the information carried by it. Active listeners such as blind people rely on sound cues in daily tasks (e.g. real world navigation) due to the absence of vision as the primary sense. While touch offers limited information, sounds can provide more information beyond the reach of a blind person. Therefore, in this study, we focused on evaluating the identifiability of sound cues (non-speech sound) of the outdoor environment by blind people.

2 Background

Apart from implementing speech on navigation systems, there are a range of related works that proposed the use of non-speech sound to present information to the end user. Ambient sounds are categorized as non-speech sounds that produce from real events (e.g. traffic noise, raining) and can consist of different meanings [1]. Ambient sounds are enriched with information that can simultaneously reach the listener without paying attention to a particular sound. The ability to carry complex information in a single sound enables user to identify the sound easily and relates it to the specific event [2]. For example, the tapping sound produces by a white cane changes when different ground textures are encountered. This provides information not only on the type of ground textures but also awareness to the user whether he or she has deviated from the correct path.

The characteristics displayed by ambient sounds make it an ideal solution to improve the method of presenting geographical information on auditory display. For example, ambient sounds have been used in virtual maps [3] to imitate the environment. In reality, ambient sounds are used as sound cues by blind people to guide their wayfinding. Koutsoklenis and Papadopoulos [4] investigate the use of sound cues by blind people in urban wayfinding. They discovered that each of the sound cues produced by events has different reasons and are associated with the sound sources and causes. These sound cues were used by blind participants in their study to identify landmarks in the environment. The sound cues also were used to help them to determine their orientation, to understand the type of environment and to maintain course towards the intended destination [5]. For instance, the sound of a car passing acknowledges the participants of the direction of the car.

2.1 The Implementation of Sound in Interactive Map Displays

Sounds have been implemented in interactive map displays to convey geographical information to the user. For example, speech is usually used to present information of a landmark or direction to places [5], using ambient sounds for city maps exploration [6, 7] and ambient sounds in tangible user interface [8].

Sounds are also implemented on auditory displays that are specifically designed to cater the needs of blind people to access information. Audio-tactile map is an example of auditory display that enables blind people to learn geographical maps using touch and hearing, which is based on multimodal approach. This is an attempt to improve the design of conventional tactile maps by replacing Braille labelling with auditory elements, for example [5, 9–13]. These studies consist of demonstration of synthesized speech use in relatively simple settings where instruction on where to start and description of the route names and certain landmarks were given. However, there is a lack of evaluations on the effectiveness of the speech use given in the previous studies. Also, less attention has been given so far to devising comprehensive and communication rich systems of audio-tactile maps in the literature. This leads to a concern on how auditory elements are intelligible enough to provide the basis for configurationally understanding of the environment of a place to blind people using audio-tactile maps (Fig. 1).

Fig. 1. A user was using an audio-tactile map to explore a map of a town [9]

Koutsoklenis [4] and Papadopoulos [14] points out that ambient sound has high potential that can be implemented on auditory display, for example audio-tactile maps to support blind people in learning maps of the real world. By integrating ambient sounds, it enables the user to perceive information of the environment that was not able to be conveyed through speech. Furthermore, the use of ambient sound may reduce the map exploration time. For example, user can obtain information of near and distal landmarks at a time when exploring a map. In contrast, speech is normally used to describe every object presented on a map which demands user's attention to focus on the content of the message. To alleviate this problem, ambient sounds can be implemented in auditory display by researchers as an alternative way to provide additional information to the user.

As mentioned, ambient sounds are able to present a variety of visual information in a simplified format and recognized way [15]. They are even can be easily located than speech because user can obtain the meaning directly from the produced sounds [16]. However, to produce a map where the information of the landmarks is presented using ambient sounds cannot be simply made, especially for blind user. Many ambient sounds are naturally conflict. For example, the sound of water fountain and raining can be mistaken for each other. Therefore, a careful design of ambient sound as the auditory icons on auditory interface such as audio-tactile map, is necessary because it is complicated to recognize events.

Mynatt [17] evaluated the auditory icons to represent icons on the Mercator interface for blind users. Her study showed that the blind users had problems to identify the auditory icons presented in the interface. Therefore, Mynatt proposed a methodology on how to identify and design auditory icons [17]. There were a few works which incorporated auditory icons on audio-tactile maps, for instance [18], however, none of these studies evaluated the identifiability of the auditory icons with blind users. As our research involves incorporating auditory icons on audio-tactile maps, therefore, we initially carried out this study to identify sound cues of the outdoor environment by adopting methodology proposed by Mynatt's [17].

3 Objective

The objective of this study is to evaluate the identifiability of the sound cues by blind people.

4 Methodology

To achieve our objective, we carried out a user study with a group of blind people at Malaysian Association for the Blind (MAB) complex.

4.1 Blind Participants

Ten (10) totally blind people (3 females and 7 males) from Malaysian Association for the Blind (MAB) volunteered to take part in the study. The participants have different level of experience in performing independent travelling in the outdoor environment and varied mobility skills. The mean age of the participants was 23 years.

4.2 Sound Cues

There were seven (7) type of sound cues used in this study which were derived from our previous study with blind participants at MAB [19]. Most of the sound cues listed in Table 1 can be used to represent the outdoor environment of MAB complex. For each sound cue, they were represented by 3 to 5 identical sound cues which made up a total number of 50 sound cues. Each sound cue was differed based on the object and action that produce the sound. The sound cues that were tested in this study were listed as in Table 1 next page.

Table 1. List of sound cues

No.	Type of sound cues	Sound cues
1	Vehicle	Car passing by
		Monorail passing by
2	Roadwork	Worker drilling
3	Street traffic	Vehicle passing by on a busy street
4	Ground textures	Concrete pavement
		Grass
		Gravel
		Wooden floor
5	White cane	Person walking using a white cane on concrete floor
		Person walking using a white cane on gravel
6	Water	Water flowing
7	Sound made by animals	Birds chirping

4.3 User Study

The evaluation was done individually in a room provided at MAB. Participants were first introduced to the audio-tactile map to ensure that they understood how the audio-tactile map generally worked. Later, they were asked to identify the sound cues and then would be acknowledged if their sound cues were chosen to be incorporated on audio-tactile map. Each blind participant was exposed to each sound for approximately 15 s. Before the sound cues were played, the participants were reminded that they could request to repeat the sound if they had trouble in identifying them. After listening to each sound cue, participants needed to describe the object and action that produced the sound cue. The activities done in this study were video recorded. Time was not recorded for this study. At the end of the study, participants were required to answer open-ended questions. Participants were compensated with light refreshments for their time and participation in the study.

5 Results

The sounds were analyzed based on the accuracy of participants' identification on the object and action that produced the sound. The percentage of participants who correctly identified each sound according to the action and object required to produce the sound are presented in Table 2.

From the table above, there were seven sound cues that obtained highest score on action and object. This means that most participants had no problem in identifying these sound cues regardless of the object and action. These sound cues are S1 for 'Worker drilling' (50% action, 70% object), S4 for 'Person walking on concrete pavement' (80% action, 90% object), S1 for 'Person walking on grass' (50% action, 80% object), S2 for 'Person walking on gravel' (80% action, 90% object), S1 for 'Person walking using white cane on gravel' (30% action, 70% object), S5 for 'Water flowing' (60% action, 80% object) and S2 for 'Birds chirping' (90% action, 90% object).

Table 2. Percentage of participants with correct action and object identification by sound

Type	Description	Sound	% correct by participants (action)	% correct by participants (object)
Vehicle passing	Car passes by	S1	50%	60%
		S2	80%	60%
		S3	80%	20%
		S4	70%	10%
		S5	10%	0%
	Monorail passes by	S1	80%	50%
		S2	80%	70%
		S3	40%	50%
		S4	20%	10%
		S5	90%	60%
Roadwork	Worker drilling	S1	50%	70%
		S2	0%	0%
		S3	10%	10%
		S4	30%	10%
		S5	10%	10%
Street traffic	Vehicle passes by on a busy street	S1	20%	10%
		S2	80%	10%
		S3	30%	20%
		S4	0%	0%
		S5	10%	10%
Ground textures	Person walking on concrete pavement	S1	70%	10%
		S2	50%	90%
		S3	50%	70%
		S4	80%	90%
		S5	20%	80%
	Person walking on grass	S1	50%	80%
		S2	10%	30%
		S3	10%	60%
		S4	0%	40%
	Person walking on gravel	S1	40%	90%
		S2	80%	90%
		S3	10%	60%
	Person walking on wooden floor	S1	60%	70%
		S2	20%	80%
		S3	30%	70%
		S4	20%	60%
		S5	10%	60%

(*continued*)

Table 2. (*continued*)

Type	Description	Sound	% correct by participants (action)	% correct by participants (object)
White cane	Person walking using white cane on concrete floor	S1	0%	70%
	Person walking using white cane on gravel	S1	30%	70%
		S2	20%	60%
Water	Water flowing	S1	20%	50%
		S2	10%	60%
		S3	30%	70%
		S4	10%	70%
		S5	60%	80%
Sound made by animals	Birds chirping	S1	10%	10%
		S2	90%	90%
		S3	60%	60%
		S4	60%	60%
		S5	80%	80%

The following four sound cues had inconsistencies in the percentage of correct identification by participants which made it difficult to identify which is the best sound cue to be selected. For 'Car passing', S1 and S2 obtained the highest percentage where 60% of the participants managed to identify the object of the sound cues. However, most participants managed to identify correctly for the action of S2 and S3. For 'Monorail passes by', 70% of the participants managed to identify S2 for the object dimension but 90% of the participants managed to identify correctly the action for S5. Similarly, for 'Vehicle passes by on a busy street', only 20% of the participants managed to identify the object correctly for S3 although it is the highest percentage among other sound cues of the same type. Surprisingly, 80% of the participants managed to identify correctly for action for S2. There is 80% of the participants who managed to correctly identified object of S2 for 'Person walking on wooden floor'. However, 60% of the participants managed to identify the action correctly for S1.

Overall, it can be seen that participants had problems in identifying the object or action for sound cues that representing vehicles as mentioned above.

Post-test interview

The following describes responses from participants on the open-ended questions:

- *Question 1 Suitability of the sound cues used*

All 10 participants agreed that the sound cues used in this study were suitable to represent landmarks and incorporated on audio-tactile maps.

- *Question 2 Sound cue characteristics*

Participants were asked about the characteristics of a sound cue that should have to represent landmarks on maps. Some of them suggested that a sound cue needs to be clear for the listener to recognize and can be repeated if they are not sure of the sounds, the length of the sounds played needs to be appropriate (not too short or too long) and the loudness should be appropriate (not too slow or too loud).

- *Question 3 Memorizing map layout*

All 10 participants thought that through the use of sound cues on maps can possibly help them to be able to memorize and recognize of a place.

- *Question 4 Comments or suggestions*

None of the participants provided any further comments or suggestions.

6 Discussion

There are many identical sounds that can represent a landmark, it can be a difficult task for a designer to choose the best sound because it cannot be based on the designer's intuition but on the user's preference. The main purpose to conduct the identifiability study is to avoid usability issues occurred among the end users, in this case, the blind people, at the end of the day.

From this study, results on the accuracy of participants' identification on the object and action that produced the sound have been gathered as presented in Table 2. The percentage of participants who correctly identified each sound according to the action and object was different. For certain sound cues, most participants were able to identify the object that produces the sound. Similar case goes to action. Although the sound cues that were used were from the same type of sound cues however, the characteristics of the object that produce the sound were different. For example, the sound of a car passing, although every sound cues that were used in this study to represent a car passing consists of same object (car) and action (passing), some participants were unable to identify the object or action correctly. Another example is the sound of a person walking using a white cane on a concrete pavement. The tapping sound made by the white cane seems was not familiar by some participants in this study. It was surprising because it was expected that the blind participants are already familiar with the sound of white cane however, it was the other way round. Based on observation, this could be due to only some blind students who frequently used white cane when travelling around MAB meanwhile others prefer to be free from using the white cane around the MAB area. Therefore, the familiarity of some blind participants with the tapping sound made by the white cane on concrete pavement can be reduced to certain extent since they are not exposed frequently to the sound. Another reason is, even if some of them have experienced listening to the sound cue, they are probably not aware of the importance of getting to know the sound. However, although some of the sound cues were unable to be identified correctly by some participants, there are still other sound cues from the same type that can be identified by most participants. The sound of roadwork was among the sound cues that is difficult to be identified by the participants.

This could be due to the lack of exposure to such sound cues when travelling in the outdoor environment. Roadwork can only be encountered by coincidence. In contrast, the sound of birds chirping was familiar by most participants and they managed to identify the object and action that produce the sounds very well. It can be concluded that sound of birds chirping is the easiest sound that can be identified by the participants compared to other sounds listed in Table 2.

6.1 Factors Contribute to the Results

The following discusses the factors that possibly contribute towards the results obtained on the accuracy of identifying object and action that produce the sound cues as listed in Table 2 by blind participants in this study.

- *Confused with other sounds*

Mynatt states that sounds are naturally conflict [17]. One sound can be mistakenly identified as another sound. Participants in this study also faced similar problem. For instance, the sound of train passing by was mistakenly identified as air conditioner or lorry by some participants. The sound cue used reminded them to different object that produce the sound. There are many different objects that produce nearly or the same sound. It has been expected that this factor would influence the result of this study. Therefore, only the most identifiable sound cue will be chosen to be used for future work.

- *Lack of exposure to outdoor environment*

Identifying sound cues based on the object and the action that produced the sound can be a difficult task not only for blind population but also for sighted population as well [20]. During the interview session, blind participants were asked about their frequency of travelling independently in the outdoor environment. The aim was to understand whether the frequency of travelling in the outdoor environment independently can increase the auditory skills among blind participants. Six (6) participants mentioned that they never travel alone in the outdoor environment and rely mostly on their friends help whenever they need to go out. Two (2) of the participants mentioned that they travel less than once a week and the other two (2) travel about a couple of times a week independently in the outdoor environment. From the answers given, it can be seen that majority of the participants have lack of exposure to outdoor environment. The six (6) participants never travel alone and preferred to be accompanied by friends. When they travel with others, they rely on their friends' help and this probably limits them to learn about their surrounding on their own. They possibly set in their mind on getting to the intended place safe and sound without encountering hassles as their main priority. When they have this in mind, they maybe forget about the importance of themselves creating awareness on important landmarks and sound cues that are available along the journey. This somehow restricts these participants' ability not only in auditory skills, but also their level of confidence. Participants who frequently travel independently have a good exposure on different kinds of sound which they hear throughout their journey. For example, they may gain new knowledge about sounds that they never encounter and these sounds can be additional perception to them. Participants who use public transport will familiar with the sounds of public transport that they usually ride. For instance, these participants may be able to identify the sound of a monorail approaching.

- *Lack of awareness about the importance of sound cues*

As mentioned above, some blind participants rely on their friends' help to travel within places in the outdoor environment. This factor reduces their awareness of the importance in identifying sound cues that are available around them. From listening to sound cues and being able to distinguish them, requires continuous learning. Questions like what produces this sound and where this sound comes from, should be asked in one's mind when one listening to certain sound cues. Sound cues carry rich information that can facilitate one to understand about his or her surroundings. Therefore, one should be taught to create the awareness within themselves about the importance of the information that sound cues try to convey. Otherwise, it would be difficult for them to develop at least a nearly accurate internal representation of a place.

- *Individual differences*

Age and experience in travelling. Ranging from children to adult, the increase of age and the frequency of exposure to sound cues in the environment can help people in developing their auditory skills. However, even with the increase of age does not guarantee for a person to be skilled in auditory if the frequency of exposure to sounds is lack. This has been proven by the findings obtained in this study. P1, P2, P6, P7, P8 and P9 have the same age however P2, P6, P7 and P9 never travel alone in an outdoor environment. There are several sound cues that were not able to be correctly identified by these participants on the action or the object dimension. It is yet true that when the age of a person increased, it is assumed that the person should acquire more experiences in identifying sounds since he or she has been exposed to travelling between places in the environment. Through age and increase experience exploring the environment may increase hearing sensitivity of blind people than those who have less experience [21].

Background. Participants in this study came from different backgrounds. Some of them came from rural areas. Growing up in different areas influences the way the participants identify the sound cues in this study. There exist conflicts of misidentifying sound cues such as mistaken sound cue A for B since the sound cues used in this study were representing the urban area of the outdoor environment outside of MAB complex. Participants from rural areas might have different assumptions of what they hear to participants from urban areas. For example, the sound of worker drilling into something usually takes place at the urban area where roadwork or building construction is done. For some participants from the rural areas mistakenly identify the sound cue as the sound of a motorbike, a car or a bus. Another example is the sound of a car passing might be different from person to person. This could be influenced by the occurrence of the person listening to the different type of car that usually passing by in their surroundings. The sound produce by a car may vary according to their fuel source, the age of the car, and the condition of the car.

Mobility training. One of the factors that may contribute to the results is the experience of each participant in mobility training. There were three (3) participants who never received mobility training in their entire life. Other participants received mobility training but the training that they received was at different frequency. P1 undergo training once a month, P3 only received basic mobility training in 2015, P4 undergo training once per two weeks, P5 received the training once a week, P7 received training if there is an activity, P9 received training at blind welfare once a week and twice a week at MAB, P10 received mobility training during primary school and secondary school around 2 to 3 times and once at MAB. Participants who received mobility training explained that they learned on how to use white cane for walking between places, going up and down the stairs and use of tactile paving. One participant (P5) mentioned that during her mobility training, she learned how to differentiate the surface area using white cane, use senses and perform road crossing. Most of the trainings involved inside the building or at the building compound. The training was emphasized more on the use of white cane instead. There was a lack of exposure on listening to different sounds in the outdoor environment. However, P5 learned to cross the road using white cane during the training and she had the opportunity to listen to sound of car passing and sound of street traffic.

7 Conclusion

This paper presents an initial study on identifying sound cues by blind people. The findings showed that there are various factors that influenced the results of this study. Apart from the nature of the sound which is naturally conflict, the lack of exposure and awareness to the importance of getting to know about sound cues among the participants also plays important roles. Added to that, individual differences also play an important role that contributes to the result. Based on these factors, it is important to carry a study to identify sound cues that before incorporating them on any auditory display. Therefore, the need for the involvement by the end user from the early phase is really important.

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