OTASCE Map: A Mobile Map Tool with Customizable Audio–Tactile Cues for the Visually Impaired

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Abstract

A mobile map viewer for visually impaired people that delivers customizable audio–tactile presentations of routes is developed. Combinations of sound effects, voice cues, and vibration cues evaluated for usability.

Keywords

Visually impaired people; Audio–tactile map; Smartphones; Map viewer

Introduction

Many methods for conveying graphic and terrain information to visually impaired people have used either sound or tactile information to improve accessibility in mobility and learning applications. For example, tactile maps present graphic information using raised surfaces. People with visual impairment can use their fingertips to touch this surface to gain an overview and even content details about an environment. However, people with visual impairments sometimes need to read the same tactile map repeatedly because the informational content and scale of the map cannot be updated dynamically.

Numerous methods that use sound and tactile effects have been proposed to enhance blind people's understanding of terrain information. In a simple implementation, a screen reader can be used to convey route information by spoken cues. For example, the Kotonavi application can read out transcriptions of routes between the nearest station and the user's destination [6]. While using this service, visually impaired people may experience difficulties in returning to a pre-determined route if they stop or stray along the way.

Before the widespread adoption of smartphones, several navigation systems for visually impaired people were developed that used dedicated hardware [5, 9, 10, 12, 13]. Parente et al. proposed a device that uses both voice and sound effects [9]. Ichikari et al. developed a device that presents tactile maps and sounds using a system based on augmented reality [12]. With the rapid spread of smartphone ownership and advances in the accessibility features of smartphone operating systems, various navigation applications have been proposed for visually impaired people [2, 3, 4]. NavCog is an indoor navigation system that enables visually impaired smartphone users to walk easily to a destination in a building [3, 4]. This system excels in the quality of its audio information and presentation timing. However, few navigation applications feature flexible and customizable presentations of audio and tactile stimuli.

In previous work, we developed a mapping tool for blind people that presents a map using sound effects [7, 8]. This tool effectively creates two-dimensional (2D) maps that blind people can use like they would in an action role-playing game with 2D terrain. The mapping tool can present a range of sound effects and voice cues to improve usability as users become more skilled with the device. This mapping tool also presents tactile information when the tool is connected to a dot-matrix display. Because the mapping tool has these multimedia features, blind people can interact with and understand maps more effectively. Comparable mapping tools on the market today do not include these dynamic multimedia features that allow the blind to gain a more-intuitive understanding of maps.

Therefore, our goal was to develop an audio–tactile mapping tool that allows blind people to grasp, modify, and create 2D figures like maps in the real-world. We aimed to investigate the most useful combinations of audio–tactile cues for people with visual impairments including low vision and blindness. First, we developed an audio–tactile map viewer that can represent real-world route information and information about facilities near the route. This device is based on our previous work developing a mapping tool for gaming applications. We improved the tool with customizable audio–tactile cues based on feedback from test users at an exhibition and a workshop. Finally, we explored presentation methods that best serve the individual needs of visually impaired users. At this stage of our evaluation of the device, participants with visual impairments tended to focus on finding facility information and following travel routes, suggesting that visually impaired people will use the device for learning routes before going out in the world.

Design of the audio–tactile map viewer

We named our map viewer OTASCE Map for Oto-Tactile SCapE Map. “Otasce” can be pronounced as “O-ta-su-ke,” which means “help” in Japanese. The device presents 2D figures like maps using auditory and tactile stimuli (see Figs. 1 – 3).

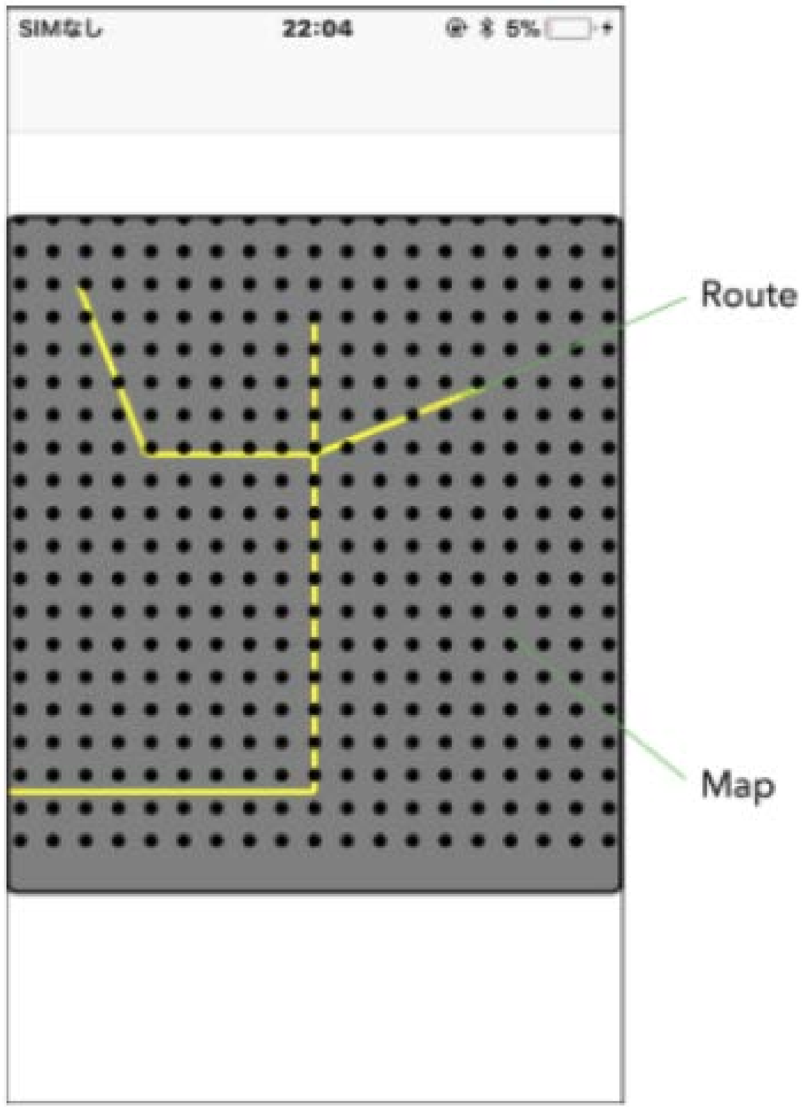

Fig. 1. Interface of the Prototype System.

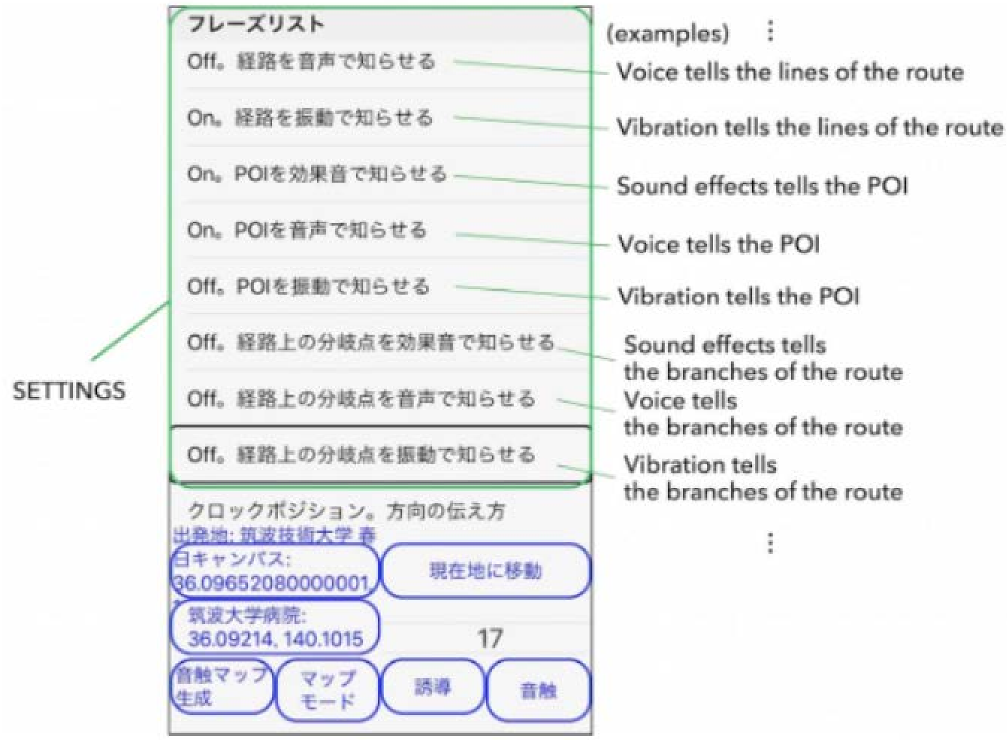

Fig. 2. Setting View of the Combination of Audio–Tactile Effects.

Fig. 3. Interface of the OTASCE Map Evaluated in the Workshop.

Table 1a. List of Functions Implemented in Audio-Tactile Map Viewer

(Screen Objects)

Screen objects	Represented content
Points	Vertices and branches in a route
Area	POI
Line	Lines on the route

Table 1b. List of Functions Implemented in Audio-Tactile Map Viewer

(Audio-Tactile Stimuli)

Audio-tactile stimuli	Variations
Sound effects types	Presence / absence of figure / shape of figure
Sound effects	Sound pressure change (Volume) / Sound pressure asymmetry (Panning) / pitch change
Voice information	Figure name / detailed information
Vibration pattern	Strength / length of vibration

Table 1c. List of Functions Implemented in Audio-Tactile Map Viewer

(User Controls)

User Controls	Tool Functions
One-finger scan	Audio-tactile presentation of figure shape according to touch position
Update graphic information	Outline of the entire shape of the displayed graphic
Touch a branch point	Present the shape and direction of the branch point
Dual interaction modes	Audio-tactile map reading mode / route guidance mode

Table 1 presents a list of the functions included in OTASCE Map, which is implemented on an iPhone. The tool produces a sound effect, voice cues, and vibrations depending on the icons that the user touches on the touchscreen with his/her finger. The user can customize the audio–tactile effects with different combinations of sound effects, voice cues, and vibrations. The effects convey information about points, planes, and lines on the displayed map. The user is also given cues about the route and points of interest (POIs) as he or she touches the screen. The user can adjust the effects as depicted in Fig. 2.

OTASCE Map also has a route-guidance function that allows users to preview the route from the starting point to the destination. This function presents the user's upcoming direction of travel on the route by guiding their finger to the starting point, stating the direction to turn at each branch points, and finally guiding the finger to the destination.

The map viewer enables the user to roughly grasp the shape of the route from the starting point to the destination. The user cannot, however, acquire information about the width of the road or the presence or absence of sidewalks, obstacles, and side roads.

Preliminary Evaluation

We exhibited and evaluated the map viewer at the *Sight World 2018* conference [11] to confirm that blind users could feasibly use the app to understand travel routes. Twenty participants with visual impairments participated in the evaluation, and all routinely used screen readers on their smartphones. We asked them to follow a route (see Fig. 1) displayed on the screen using their fingers. The map viewer presents a combination of sound effects and voice cues to guide the finger on the screen. These interactions confirmed that all the participants could follow the route from the start to the end point. Moreover, based on participant feedback (given in the left part of Table 2), we implemented the additional functions shown on the right-hand side of Table 2.

Table 2. Feedback on Prototype in the Preliminary Evaluation and Changes Made

User Feedback	Implemented Features
Difficulty in finding the branch point on figure	Notification of direction to turn at the branch point
Difficulty in detecting edges of the display area	Added function that generates a notification as sound effects/voice/vibration when the user just touches the edge of map area
Want to touch simultaneously using multiple fingers	Added the multi-touch gestures
Difficulty in distinguishing the sound effects between places where shapes are present and the places where shapes are not present	Updated existing sound effects to make them more distinct and added more sound effects

After this preliminary testing at the conference, we conducted a workshop to allow blind users to experience the improved map viewer. We were testing how different users would have different preferred combinations of sound effects and vibration cues. Before organizing the workshop, a preliminary study was conducted with 5 participants (4 sighted and 1 blind) to check the procedures of the workshop and debug the app. Anticipating that some of the blind participants would be unfamiliar with screen readers, we taught the sighted group to close their eyes and trace the screen. The sighted participants were unfamiliar with tracing the screen, so we predicted that they would face similar problems that novice visually impaired users of screen readers face. Based on feedback from the sighted people, we implemented a function that announces the exact distance between two points on the route (see the details in Table 3).

Table 3. Feedback from Simulated Blind Persons (Sighted Persons Who Close Their Eyes) and the Corresponding Additional Functions.

User Feedback	Implemented Functions
Losing the last position on the route or skipping part of a route once the finger deflected from the route.	Guiding to the last position on the route and navigating again

User Feedback	Implemented Functions
Difficulty in understanding the correspondence between the trace length and the actual distance	Voice cues for the distance from the current position to the destination on the route

Evaluation

We conducted a workshop test combination of audio–tactile effects with visually impaired people using OTASCE Map.

Evaluation setup

Figures 2 and 3 depict mockups of the screen of the map viewer app. The map, developed using the Google Maps API, displayed the area surrounding the Tsukuba University of Technology (Japan), the route from the university to the nearest hospital, and the locations of several POIs. The users can customize the audio–tactile effects presented while following a route on the settings screen (see Fig. 2). This menu is compatible with the standard accessibility features included in iOS. After customizing the effects, users can test the audio–tactile presentation by touching the map that is depicted in Fig. 3.

Workshop with the visually impaired people

As shown in Table 4, five participants (3 blind and 2 people with low vision) participated in the workshop. Except for one blind person, all participants had experience in using map and navigation applications while walking outside.

Table 4. Details of Workshop Participants.

Participant ID	**Gender**	**Age**	**Visual status**	**Details of vision loss**	**Accessibility features**	**Tactile Figure Experience: Usage frequency**	**Tactile Figure Experience: Types of Figures Used**
A	Male	20s	Blind	No vision in both eyes	Screen reader	Less than once a month	Map representing wide area / Floor plan of building / Graphs and shapes / figures of people and animals
B	Female	20s	low vision	Sight type 1 grade 2, visual field impairment grade 5, visual acuity 0.02	Screen reader / zoom function / color change	About once a month	Map representing wide area / Floor plan of building / Graphs and shapes
C	Male	40s	Blind	Blind	Screen reader	Less than once a month	Floor plan of building
D	Female	50s	low vision	Sight type 1 grade 2. No visual acuity and no visual field except that a partial visual field remains at the left eye margin. Cannot detect shapes of letters and objects.	Screen reader	Less than once a month	Landscape painting / map used in this workshop

Participant ID	Gender	Age	Visual status	Details of vision loss	Accessibility features	Tactile Figure Experience: Usage frequency	Tactile Figure Experience: Types of Figures Used
E	Male	20s	Blind	Some light sense.	Screen reader	About 4-5 times a week	Map representing wide area / Floor plan of building / Graphs and shapes / figures of people and animals

First, we asked participants to touch and trace a route in OTASCE Map. They were then asked to repeatedly adjust and check audio–tactile effects corresponding to various objects on the map. Audio cues were presented with wearable speakers because we assumed general usage of the map viewer.

Subsequently, we asked participants to explain and discuss their preferred combinations of audio–tactile cues. Finally, they answered surveys about usability. During the workshop, we recorded the participants’ finger movements and the time each took to trace the route from the start to the end points.

After the workshop, we summarized and implemented combinations of audio–tactile effects that the workshop participants recommended. Then, we asked them to rate the cues that were presented in the workshop and fill out the system usability scale (SUS).

Results and Discussion

Table 5 lists the different combinations of cues that the participants chose in the settings menu. The preferred audio–tactile effects varied with the user’s degree of disability and the time of onset of blindness.

Table 5. Customized Audio-Tactile Effects by Workshop Participants.

Participant ID	A Blind	B Low vision	C Blind	D Low vision	E Blind
Horizontal sound effect (none / panning / volume / pitch)	-	Pitch (Coordinates on the screen cannot be specified with this combination)	Volume (Coordinates on the screen cannot be specified with this combination)	-	Panning
Vertical sound effect (none / panning / volume / pitch)	-	Pitch (Coordinates on the screen cannot be specified with this combination)	Volume (Coordinates on the screen cannot be specified with this combination)	-	Pitch
Presentation of route	Sound effect / Voice / Vibration	Vibration	Sound effect / Voice / Vibration	Voice	Sound / Voice / Vibration
Presentation of POI (point of information)	Sound effect / Voice / Vibration	Voice/Vibration	Sound effect / Voice	Voice	Sound / Voice / Vibration
Voice speed	Normal (default)	Normal (default)	Normal (default)	Normal (default)	Normal (Default)
Direction wording (up down left right / clock position / east west south north)	Up down left right	Up down left right	Up down left right	Clock position	Up down left right
Division number of direction instruction (4/8/12/16)	12 directions	4 directions	8 directions	8 directions	8 directions

Participant ID	A Blind	B Low vision	C Blind	D Low vision	E Blind
Presentation of route guidance function	Sound effect / Voice / vibration	Voice / Vibration	Voice / Vibration	Voice	Voice / Vibration
Presentation of guidance after departing from the route	Sound effect / Voice / Vibration	Sound effect / Voice / Vibration	Sound effect / Voice	Voice	Voice / Vibration
Presentation of screen edge	Sound effect / Voice	Sound effect	Sound effect	Sound effect	Voice
Notification of screen touch	Sound effect / Voice	Sound effect	Sound effect / Vibration	-	-
Interaction mode (once during touch / always during touch)	Once during touch	Always during touch	Once during touch	Once during touch	Once during touch

Blind participants (A, C, and E) were likely to combine two or more effects, including sound effects, voice cues, and vibrations. However, participants with low vision (B and D) tended to select only a single type of cue; one selected voice while the other selected vibration. These results might be explained with the sense modalities the participants are accustomed to using. All the blind participants were accustomed to distinguishing sound effects while the participants with low vision were either not accustomed to detecting differences in sounds or they were accustomed to using sound effects only for supplemental information.

All the workshop participants customizes the audio–tactile effects to their preferred setting without difficulty. However, the participants learned to trace the guide route at different speeds. Table 6 shows the data logged as the workshop participants followed the route. Except for Participant D, all were able to follow the route at least once.

Table 6. Task Completion Time and Number of Deviations from the Route Out of Three Trials of Route Tracing.

Parameters	**Times**	**Participant A**	**Participant B**	**Participant C**	**Participant D**	**Participant E**
Task completion time(s)	1	258	62	201	-	55
Task completion time(s)	2	103	17	113	-	-
Task completion time(s)	3	96	-	143	-	-
Deviations from the route	1	7	5	15	-	6
Deviations from the route	2	1	2	8	-	-
Deviations from the route	3	3	-	12	-	-

The blind participants could trace the route to the destination at least once. On the other hand, one of the participants with low vision (B) reached the destination by watching the screen twice. The other (D) could find the starting point, but could not reach the destination. Moreover, participant D reported that she was not skilled at tracing the route on the screen with her finger, probably because she had no experience of using tactile maps.

Table 7. Feedback from the Participants.

Participants	**Feedback for Question:** What kind of situation do you want to use this map reader for?
B, C, E	Study route confirmation before going out
B	When going out with someone
A, B	When grasping context around the route (Grasping the surrounding area for the first time, Find a cafe for a detour)
D	If I get lost on the way, give instructions on how to reach my destination

Participants	**Feedback for Question:** Please tell us if you have any feelings or thoughts by comparing the Customizable map in this workshop with map apps you have used before.
C	My map app uses voice to give directions, but I think that this app can understand the situation properly because it includes voice and tactile feedback.
E	The experience of being able to touch the map directly was new. I felt that it would be easier to imagine the route if I could get used to the operation.
B	Although it is possible to see the map app, the amount of information is too much, so I felt that this app was more convenient.

Participants	**Feedback for Question:** What are the difficulties of using this map reader? If you have any requests for improvement, please describe them.
C	I want guidelines on how to use this app.
A	I felt that the high-pitched sound effect was annoying.
C	My finger quickly deviated from the route.
C	I want to know the shape of the route before following the route with my finger.
B	Although it was not in this Customizable option, I felt it would be useful if I could adjust the difference between the sound effect and the sound volume.
D	I understand how to use it, but I didn't follow it well.

Table 7 shows participant feedback. Participants had strong opinions about the guide function because participants' fingers quickly strayed from the route. A few commented that the sound effects were annoying, and that they wanted to adjust the balance between sound effects. Other participants requested operation guidelines and route reviews before they moved their fingers. In response, we adjusted the sound effects and improved the route-guidance function. Particularly, the route-guidance function used in the workshop always announced the direction from the previous branch point to the next branch point. We improved the behavior of this function so that it provides the direction from the current fingertip coordinates to the next branch point. With this change, users were better able to follow the route without deviations.

Table 8. Responses to the Items in the System Usability Scale.

Question	**Participant A**	**Participant B**	**Participant C**	**Participant D**	**Participant E**	**Blind**	**Low vision**	**All**
I think that I would like to use this map reader frequently.	4	4	5	4	4	4.3 ± 0.5	4.0 ± 0	4.2 ± 0.5
I found the map reader unnecessarily complex.	2	1	3	5	3	2.7 ± 0.5	3.0 ± 2.0	2.8 ± 1.3
I thought the map reader was easy to use.	3	4	4	3	5	4.0 ± 0.8	3.5 ± 0.5	3.8 ± 0.7
I think that I would need the support of a technical person to be able to use this map reader.	3	1	3	4	2	2.7 ± 0.5	2.5 ± 1.5	2.6 ± 1.0

Question	Participant A	Participant B	Participant C	Participant D	Participant E	Blind	Low vision	All
I found the various functions in this map reader were well integrated.	2	4	4	5	5	3.7 ± 1.2	4.5 ± 0.5	4.0 ± 1.1
I thought there was too much inconsistency in this map reader.	3	1	4	1	1	2.7 ± 1.2	1.0 ± 0	2.0 ± 1.3
I would imagine that most people would learn to use this map reader very quickly.	2	3	3	4	3	2.7 ± 0.5	3.5 ± 0.5	3.0 ± 0.6
I found the map reader very cumbersome to use.	3	1	2	3	1	2.0 ± 0.8	2.0 ± 1.0	2.0 ± 0.9
I felt very confident using the map reader.	2	4	3	4	5	3.3 ± 1.2	4.0 ± 0	3.6 ± 1.0
I needed to learn a lot of things before I could get going with this map reader.	4	3	3	4	2	3.0 ± 0.8	3.5 ± 0.5	3.2 ± 0.7
Overall SUS Score	45	80	60	58	83	62.5 ± 15.4	68.8 ± 11.3	65.0 ± 14.2

Table 8 shows the SUS responses and overall SUS scores. Though participant D could not reach the end point in the workshop, all participants could follow the route to the end point. The average of overall SUS scores was 65.0. The acceptability range and adjective ratings proposed by Bangor’s study were marginally high and acceptable, respectively [1]. The results for the blind and those for the low vision participants in the evaluation showed no significant difference. Among the participants who highly rated our map viewer, participant B (low vision) reported that she could reach the end point with the help of the direction guidance given by voice and sound effects. However, participant C (blind) reported that even without voice cues, he could determine the directions of finger movements by only hearing changes in the sound effects. Participant E (blind) said that the combination of sound effects and vibration cues made it difficult to deviate from the route. All participants who could follow the route using sound effects and vibrations without voice cues rated the app highly. The correlation between the task completion times of the first trials shown in Fig. 6 and the overall SUS scores shown in Fig. 8 was -0.992 ($p = 0.008 < 0.001$). This correlation coefficient also confirms that participants who liked intuitive control and smoothly controlled our map viewer tended to prefer the OTASCE Map. Finally, Table 9 summarizes the specific patterns of audio–tactile stimuli that we determined as preferable from the workshop results.

Table 9. Audio–Tactile Feedback Created Based on Workshop Results.

Parameters	**Low vision users**	**Blind users**
Feedback Pattern	Voice + Vibration	Voice + Vibration
Horizontal sound effect (None / Panning / Volume / Pitch)	-	Panning
Vertical sound effect (None / Panning / Volume / Pitch)	-	Pitch

Parameters	Low vision users	Blind users
Presentation of route	Vibration	Sound effect / Vibration
Presentation of POI (Point of Information)	Voice / Vibration	Sound effect / Voice / Vibration
Direction wording (Up down left right / Clock position / East west south north)	Clock position	Clock position
Division number of direction instruction (4/8/12/16)	12 directions	12 directions
Presentation of route guidance function	Voice / Vibration	Sound effect / Voice / Vibration
Presentation of screen edge	Sound effect	Sound effect
Notification of screen touch	-	Sound effect
Interaction mode (Once during touch / Always during touch)	Once during touch	Once during touch

These patterns need to be evaluated quantitatively by many visually impaired persons in the future. In addition, we need to design patterns that can be used by beginners with no or little experience in using text-to-speech and tactile map applications.

The preferred combinations of audio-tactile effects obtained in this study can be extended in application beyond map viewing; the same cues can be used in a map-drawing application. According to our previous study [7, 8], the sound effects on the Audible Mapper, a 2D map-creation tool for blind developers, could be used by blind gamers to recognize game conditions. We are currently prototyping a mapping tool that implements combinations of audio-tactile effects and voice cues. This tool can be used to create a figure by touching the figure with the first finger (viewing) and pressing a pen or delete button with another finger (drawing). This map-creation tool is currently in development, and represents an interesting extension of the present work.

Summary and Future work

We designed the OTASCE Map viewer for presenting maps and routes to visually impaired people using customizable audio–tactile effects. From preliminary evaluations of a prototype and a subsequent workshop we found that the preferred combination of audio–tactile stimuli varies depending on the degree of a user's disability: blind participants tend to prefer a combination of two or more kinds of cues while participants with low vision preferred to use only a single cue. Also, participants who use the app with sound effects and vibrations without voice cues tend to rate OTASCE Map highly.

Future work will include creating a tutorial mode to teach users how to operate the map viewer efficiently. This mode should improve traceability of the route. Participants with no experience of using tactile maps (participant D) had trouble while tracing the route on the screen at the beginning. We have compiled several types of audio–tactile stimuli patterns from the results, listed in Table 9, and we plan to evaluate these audio–tactile patterns quantitatively with a larger study. To this end, we plan to publish apps that offers customizable guidance cues to serve the needs of users with a wide range of visual impairments and demonstrate them at exhibitions to gather feedback from many visually impaired people.

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