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Research paper



Exploring Maps at Different Orientations and Effects on Blind Users

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Abstract

Maps have been used to facilitate travellers in wayfinding and they are normally read at different orientations. A multimodal map has been introduced to enable blind people to learn maps. However, such maps usually enable them to explore maps in a fixed orientation. The effect of exploring maps in such way on user cognitive maps and sense of directions is unknown. Therefore, this paper investigates the effect on blind people's cognitive maps and their sense of directions. Results showed that in the rotatable condition, some blind people have the ability to build accurate cognitive maps of the tested maps as accurate as in the static condition. Blind people were found able to point to the direction accurately in the rotatable condition than in the static condition. This was supported by their scores when reconstructing maps. However, there were no correlations found between user sense of directions and their pointing accuracy.

Keywords: *Orientation; audio-tactile maps; blindness; cognitive maps; sense of direction.*

1. Introduction

Before a journey to a novel place is carried out, people usually prepare in a number of ways. Some people may explore the place first in order to get familiar with the new environment and some may choose to use secondary materials for example, maps. The use of maps benefits the traveller in terms of providing the overview of a place in advance compared to explore the place without having any information about the place. Besides providing information of a place, another function of a map is to assist the map user with an understanding of one orientation from the maps. The knowledge that they gained would enable the traveller form a correct representation of the direction to the place that they intend to travel. There are different ways of interacting with maps to understand directions between places by map user. Those who have the ability to perform mental operation on the directions based on a fixed map (static) might have no problem in translating the internal representation to the real world. However, there will be a different issue with those who has difficulty in doing the same thing. To some extent, some map users prefer to rotate the map in order to align the map with the real world. These alternative ways of interacting with maps used by map users assist them to understand the map better.

This paper presents the findings of experiments with multimodal maps that combine touch with auditory output (audio-tactile maps), but with the novel aspect of using the map's orientation as an additional interactive element. The objectives of this study was threefold; 1) to examine whether the cognitive map constructed on the basis of an audio-tactile map that the person is allowed to orientate as they wish is as good as those generated when the person is directed to use an aligned map, 2) to compare user pointing accuracy between static and rotatable conditions, and user accuracy in reconstructing maps and 3) to examine the correlations between user ratings of their sense of direction and their pointing accuracy.

2. Background

2.1. Visual Impairment

Visual impairment can be defined as the vision system of a person has a limited function which is unable to be rectified to a normal level [1]. Until 2014, there are 50,827 visually impaired people in Malaysia registered with Malaysian Social Welfare Department [2]. The number of people who are totally blind however is unknown as the data was not reported by the department. Meanwhile, there are 413,000 Malaysians with the age of 50 and above were living with vision problems [3]. The main factor that leads to the figure is cataract problem which can cause blindness [3]. Based on the Second National Survey, it is expected that there are approximately 43,000 individuals will have cataract blindness and 1.3 million people over 50 will have different stages of cataract [3].

2.2. Cognitive Maps of Blind People

Blind people experience space through their intact senses that contribute to the construction of their cognitive maps. They encode spatial information sequentially based on the features they encountered along the route they travelled frequently in everyday life [4] or when exploring a novel route. The developing process of cognitive maps in blind people happens in stages. The information perceived during a wayfinding will gradually develop when they repeatedly visit the same place for several times. After many exposures, they are able to connect the landmarks into sequences to develop route knowledge. Similar process of the encoding information also happens during tactile map reading.

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Through a repetitive exploration of a map helps blind people to perceive information that build up their cognitive maps. Blind people are likely to form an analog representation of cognitive map [5]. However, the type of representation that is formed among blind people is still a controversial issue among the psychologists [5].

2.3. Map Alignment Effect

The alignment of a map influences the map reader on the judgments of direction that is presented on the map and the real world. The effect of the map alignment happens when the map reader able to memorized an aligned map with the environment accurately compared to the similar map but is misaligned or rotated 180° (contra-aligned) [6], [7], see Figure 1 for the illustration.

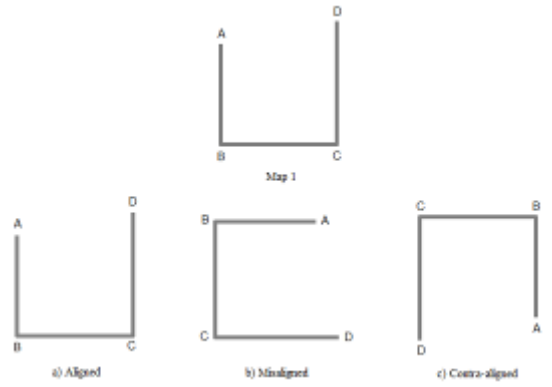


Fig. 1: The above shows a) is aligned with Map 1, b) is misaligned with Map 1 and c) is contra-aligned (rotated 180 degree) with Map 1 [6].

2.4. Map Alignment Effect on Blind People

Research has shown that when learning from a map sighted people's transfer of knowledge to the real world is less accurate when the map is misaligned with the real world [7]. This has also been found for blind people using tactile maps [6]. Findings showed that the blind participants were more accurate in directional judgments with aligned maps than with misaligned maps. Increased response time with misaligned maps suggest that the participants were attempting some mental operation most probably to attain alignment. Some of the blind participants reported they rotate themselves onto a static representation of the map while others performed the mental rotation of the map image. All of blind participants in the study mentioned that the mental operations would be easier if the map was aligned than misaligned. The feedbacks obtained from blind participants are consistent with those from sighted participants in other studies which related to map alignment, e.g. [8]–[10]. The result shows that similar to sighted people, blind people also encode maps using the 'up equals forward' assumption. This is an important finding because it establishes the consistency of the map encoding process across different types of maps (visual or tactual) used by different groups (sighted or blind people). Many of the map design discussed in connection with sighted participants may be extended to map use by blind participants for example fixed maps should always be positioned with 'up' on the map corresponding to 'forward' in the environment. However, it has been proven in Rossano's study [6] that some blind people had difficulty when using maps that are not aligned with the environment.

2.5. Sense of Direction

The sense of direction is defined as an individual's awareness and knowledge of the person's orientation in the environment [11]–[13]. The sense of direction is primarily assessed through an interview where participants need to estimate their own abilities and complete the self-report measure. The assessment can be done by answering simple questions, "How good is your sense of direction?" e.g. [11]. Another example of measuring sense of direction is using Santa Barbara Sense of Direction scale (SBSOD) [14]. SBSOD scores obtained by participants mostly showed that their performance on learning the relationship between directions and landmarks [15]. Previous works measured participants sense of direction before they explored familiar or novel environment. Following to their exploration, participants were tested on spatial orientation task e.g. the pointing task [16]. Their scores on the sense of direction and pointing accuracy was compared to examine the relationship. Findings discovered that people with higher ratings on sense of direction possessed good accuracy on the pointing task which is in contrast to people with low ratings on sense of direction, e.g. [11], [17] and even the viewpoint was misaligned with their forward facing [17]. In addition, participants with poor ratings on sense of direction were found took longer time on the pointing task [16], [18]. From these findings, the sense of direction is suggested related to the accuracy of cognitive maps [11].

2.6. Multimodal Maps

Due to the clutter and non-reactive problems of the conventional tactile maps, previous works have investigated of multimodal approaches in which auditory and tactile are combined together. The main purpose is to achieve the better learning of geographical information by blind people. Incorporating auditory elements has a number of advantages in making the map learning process for the blind people interactive, sounded on demand and reducing clutter. Different works have experimented audio-tactile maps with blind people for example [19]–[24]. Nevertheless, the map exploration process using the audio-tactile map (Figure 2) limits the blind user to explore the map at different orientations.

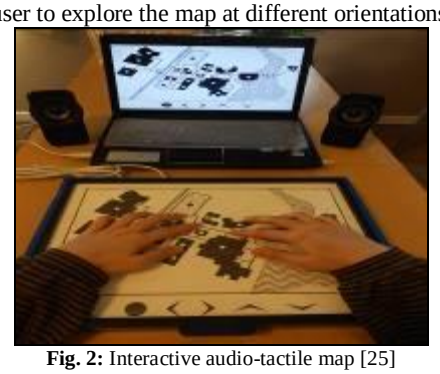


Fig. 2: Interactive audio-tactile map [25]

3. Methodology

3.1. Participants

There were 12 participants (4 females and 8 males) from Malaysian Association for the Blind (MAB) recruited for this study. Their ages ranged from 19 to 30 (M = 22) years. All 12 participants were totally blind. Six of the participants had an early-onset visual impairment. The other 6 participants had a late-onset visual impairment. They came from different backgrounds, e.g. mobility training experience, education and work backgrounds. In terms of experience in independent travelling, all of them had the experience of travelling alone in the street regularly except for one participant. Every participant uses the standard white cane as their primary navigation tool. All of the participants never heard and never had any experience in using tactile maps and audio-tactile maps. The participants also never use maps for planning a way-finding.

3.2. Design

This study was a within subject design. There were 2 independent variables (IVs) which are the map alignments and orientation conditions. There were 2 orientation conditions: a) static map (control) and b) rotatable map. Maps and order effects were controlled by counterbalancing the maps and the conditions. All participants were requested to try both orientation conditions. Each participant tried one condition and then the other. Half of the participants were introduced to the first condition (static map) while the others started with the second condition (rotatable map). Then the groups were effectively swapped after each condition. There were 3 dependent variables (DVs) which were participants' response on Santa Barbara Sense of Direction (SBSOD) scale [14], pointing accuracy which was measured in degrees from 0° to 360° and map reconstruction task.

3.2.1. Directional Response

i) Angular error

A measure of angular error was taken on the aligned and misalignment trials. This measure is the absolute value of the difference between the participant's response angle and the correct angle. Mean angular error measures were computed for each participant across the aligned and misalignment trials.

ii) Response classification

The response was classified according to the method used by previous work, see [6]. A detailed explanation on the response classification is described in Table 1 below.

Table 1: Response classification adopted from [6]

Type of response	Explanation
Correct response (CR)	The vector which represented the correct direction of travel was identified. All responses that fall within 30° of this vector were classified as correct.
Misalignment error response (MI)	The error vectors representing mirror-image error was identified. Responses that fall within 30° of these vectors were classified accordingly.
Alignment error response (AI)	The error vectors representing alignment error was identified and responses that fall within 30° of these vectors were classified accordingly.
Undefined error response (UD)	Any response which falls outside of the labelled sectors (CR, MI and AI sectors) is classified as an undefined error.

The classification process resulted in three 60° sectors, one bisected by the correct response vector, one bisected by the mirror-image error vector and one bisected by the alignment error vector (Figure 3).

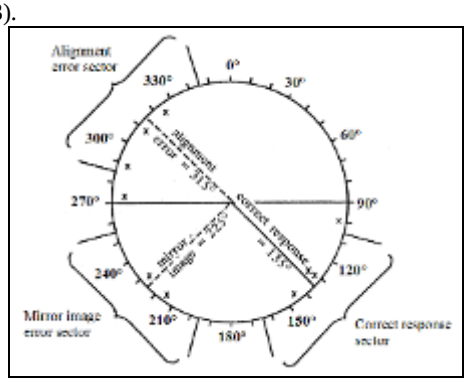


Fig. 3: Response classifications for participant's directional responses as adopted from [6]. Responses that are labeled as 'X' are classified as in Table 1.

iii) Map reconstruction accuracy measure

The map reconstruction accuracy measure was developed for this study. There are 7 fundamental transformations that can be applied; rotations of 90°, -90°, 180° and 4 reflections as shown in Figure 4. Reflections may be about a horizontal or a vertical axis, but also they may be about a diagonal axis – particularly in the case of a diagonally arranged map, for which the participant might perceive an internal axis of reflection. Any one of those carries a cost of 1.

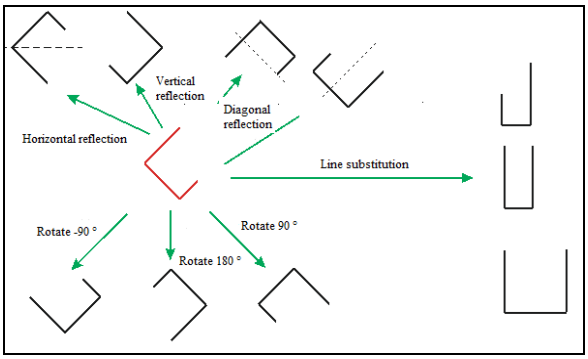


Fig. 4: The 7 fundamental transformations were used for measuring the map accuracy; rotations of 90°, -90°, 180° and 4 reflections

Some multiple transformations are equivalent to single transformations (e.g. rotate (180^0) ≡ reflect(vertical).reflect(horizontal)) but the minimum cost will always be chosen, thus one rotation is cheaper than two reflections. This minimization does not necessarily reflect people's internal errors (e.g. perhaps the person did perform two erroneous reflections internally). It is difficult to know what the users think. Although the very complex and costly alternatives could be constructed, it is consistent to use the minimum cost. On the other hand, rotations can be combined with reflections, at a cost of 1 each. Corners (90^0) will be treated as correct if $45^0 < \Theta < 135^0$. There are always two lines of equal length and one of half length. Thus, there seem to be three likely substitutions, as illustrated in Figure 4. Any one of them represents a cost of 1. Then it is possible to apply any of the five transformations, so that (for instance) one of the line substitutions followed by a rotation would have a cost of 2.

Rotations of less than 30^0 will not be counted. Exact line lengths will not be measured. That is to say, for instance, that a line which is substantially shorter than average will be counted as half-length. Any drawing which cannot be edited back to the original through these transformations will score 5.

3.3. Materials

i) Tactile maps

A practice map and 5 test maps with different orientations were used in this experiment. The test maps were constructed based on the guidelines proposed by [7]. All maps were produced using a microcapsule paper in an A3 size. The practice map (Figure 5) which was used in a pre-training session consists of 4 points – W, X, Y and Z. These points were presented in symbols (unfilled circles) and were identified in speech. Each point was connected through a raised line that represents a path.

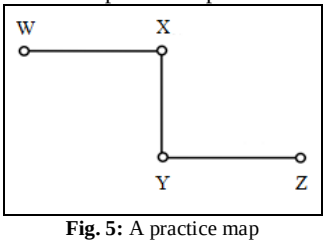
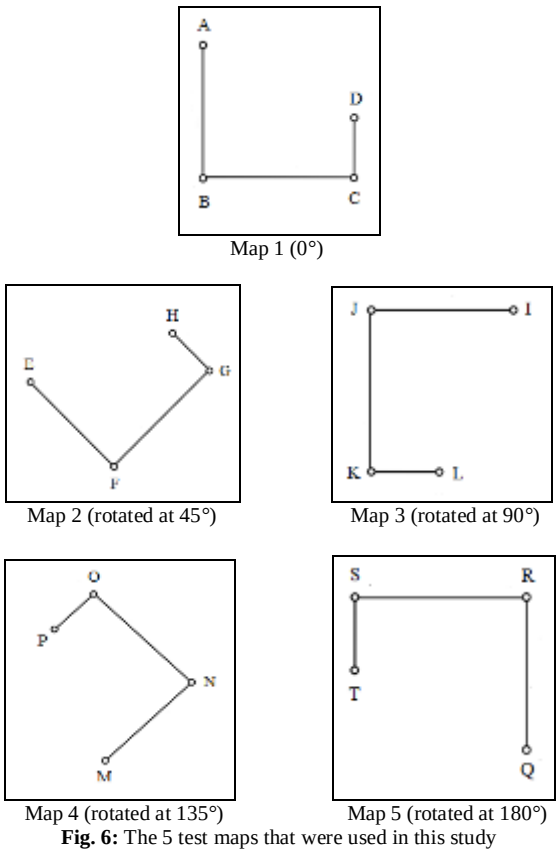


Fig. 5: A practice map

Similar to the practice map, the 5 test maps also consist of a simple path formed by 3 single straight lines and 4 points with the following features – the middle line in any 5 test maps (for example BC line in Map 1 in Figure 6) is either 45°, 90° or 135° to the right or left of the longest line (for example AB line in Map 1 in Figure 6). The AB line is always parallel to the DC line and this is similar to other maps (Map 2-Map 5). Points on the maps were presented using unfilled circles and were identified in speech.



Map 1 (0°)

Map 2 (rotated at 45°)

Map 3 (rotated at 90°)

Map 4 (rotated at 135°)

Map 5 (rotated at 180°)

Fig. 6: The 5 test maps that were used in this study

ii) Turning Talking Tactile Tablet (T4)

The T4 is a tablet that has a sensitive surface which is placed on a turntable that comes with a locking mechanism (Figure 7). The tablet used in this study was the Talking Tactile Tablet (T3)[1]. The tablet was connected to a system on a computer through a Bluetooth. The following explains about T4 for the 2 conditions:

- Static T4 condition – The turntable was locked off so its orientation will always constant.
- Rotatable T4 condition – The turntable was put unlocked to allow the map to be orientated by the user.



Fig. 7: A T4 on a turntable

3.4. Procedure

The participants took part in the experiment individually. They were guided to the experimental room, seated at a table and were briefly introduced to the experiment. The participants' consent was obtained before the experiment was conducted. After consent has been given, the participants were asked questions about their experience in mobility training, experience in planning and travelling in an outdoor environment and their personal information. Then the participants were required to give a rate on a Santa Barbara Sense of Direction (SBSOD) rating scale. After the interview session, the procedure of the experiment was explained. Five maps were used (see Figure 6 for Map 1-5) for static condition and rotatable condition. Explanation about the task was given to the participants. Initially, a map was placed on the tablet. The first map was placed based on the order of the maps that have been counterbalanced. Participants in both conditions were required to familiar with the map. Participants in the static condition explored the map without changing its orientation. Participants in the rotatable condition were reminded that they can orientate the turntable while exploring the map.

Once they were ready, the participants were given a directional task and they can start to find the direction from the start point to the target point. When they were satisfied, the participants were required to stand up and they were guided to an empty space next to the turntable where they needed to stand on an 'X' mark. The participants were given a bean bag and they were told that they were required to drop the bean bag to indicate the direction of the target point. They were asked similar directional question again. The participants have to respond by pointing directly at the target point and drop the bean bag. The angles of where the bean bags have been dropped by the participants were captured through WiFi camera which was mounted on a ceiling. After that, the participants were guided back to the table and they were asked to reconstruct the map. Then the next directional task was given for the next trial. There were five trials for each condition. The trials were counterbalanced between the participants. On each trial, participants were only performed one directional task. The directional tasks were varied from trial to trial. Participants were given a two minutes break between each trial. The participants were swapped from one condition to another condition and the same procedure will be conducted.

4. Results and Analysis

4.1. Error Distribution of the Pointing Task

A paired samples T-Test on the error distribution of the pointing task for static and rotatable conditions showed that the difference between the conditions approached significant with $p = 0.074$, ($t = 1.970$, $df = 11$, $p > 0.05$, two-tailed).

4.2 User Response on the Pointing Task

The user response on the pointing task was classified into 4 categories: correct response (CR), mirror-image error (MI), alignment error (AI) and undefined error (UD) as mentioned in Table 2. The following Table 3 and Table 4 demonstrated the results on user response for 12 participants across the 5 alignments with proportions in the parentheses.

Table 2: The frequency of responses across the 5 alignments for static condition

Static condition	Response			
	Correct	Mirror-image error	Alignment error	Undefined error
Map 1 (0°)	4 (0.33)	4 (0.33)	0	4 (0.33)
Map 2 (45°)	5 (0.42)	0	0	7 (0.58)
Map 3 (90°)	6 (0.50)	2 (0.17)	0	4 (0.33)
Map 4 (135°)	3 (0.25)	1 (0.08)	0	8 (0.67)
Map 5 (180°)	4 (0.33)	5 (0.42)	1 (0.08)	2 (0.17)
Total	22 (0.44)	12 (0.24)	1 (0.02)	25 (0.5)

Based on the result in Table 2, participants performed well for Map 3 where 6 participants got correct response for the directional task given meanwhile Map 4 has 4 participants who got correct response. For mirror-image error, no error was recorded by the participants Map 2. For alignment error response, only 1 participant produced the error that is for Map 5. As for undefined error, Map 4 recorded the highest number of participants (8) who produced the error, followed by Map 2 (7), Map 1 (4), Map 3 (4) and Map 5 (2).

[1] http://touchgraphics.com/

Table 3: The frequency of responses across the 5 alignments for rotatable condition

Rotatable condition	Response			
	Correct	Mirror-image error	Alignment error	Undefined error
Map 1 (0°)	9 (0.75)	1 (0.08)	0	2 (0.17)
Map 2 (45°)	5 (0.42)	2 (0.17)	1 (0.08)	4 (0.33)
Map 3 (90°)	9 (0.75)	2 (0.17)	0	1 (0.08)
Map 4 (135°)	5 (0.42)	2 (0.17)	0	5 (0.42)
Map 5 (180°)	7 (0.58)	1 (0.08)	3 (0.25)	1 (0.08)
Total	35 (0.70)	8 (0.16)	4 (0.08)	13 (0.26)

The result from Table 3 shows that Map 1 and Map 3 have the highest number of correct response compared to other maps. There were 1 alignment error recorded for Map 2. Meanwhile, Map 5 has 3 participants who contributed to the alignment error. For mirror-image error, every map of the 5 alignments recorded the error response. For undefined error, Map 4 has the highest error response (5).

Overall, rotatable condition leads the percentage for correct response with 70%. This means that most participants managed to point to the correct angle in solving the directional task. Meanwhile, 44% of correct response was produced by participants in the static condition. In terms of error response, participants made more undefined error and mirror-image error in the static condition than in the rotatable condition. In contrast, participants in the rotatable condition produced more alignment error than in the static condition.

The results on the frequency of responses from the pointing task for Map 1 in the static condition and the total of responses for the 5 alignments in the rotatable condition in this study were compared with the result for Map 1 from the study conducted by [6]. The aim of this comparison was to examine the differences in the frequency of responses produced by participants in both studies.

Table 4: A comparison between the frequency of user responses for aligned condition, with proportions in parentheses, from the present work and the work by [6]

Result	Response			
	Correct	Mirror-image error	Alignment error	Undefined error
Map 1 (0°) in static condition in the present experiment	4 (0.33)	4 (0.33)	0	4 (0.33)
Total of responses for 5 alignments (0°, 45°, 90°, 135°, 180°) in rotatable condition in the present experiment	35 (0.70)	8 (0.16)	4 (0.08)	13 (0.26)
Map 1 (0°) in Rossano and Warren (1989b)	17 (0.85)	0	0	3 (0.15)

Table 4 demonstrates the differences of the total frequency of responses for Map 1 in the static condition and the total responses for 5 alignments in the rotatable condition in the present study, and from [6]. Map 1 in [6] has 85% correct response meanwhile the total of correct response for maps with 5 alignments in rotatable condition is 70%. Map 1 in the static condition has only 33% correct response where this percentage is lesser than the percentage obtained in [6] and the total responses for 5 alignments in rotatable condition in the present work. As for mirror image error response, there were no errors recorded for Map 1 from [6]. However, there were mirror image error response recorded for Map 1 in static condition with 33%, and the 5 maps in rotatable condition with 16%, in the present experiment. There was also alignment error response with 8% recorded for rotatable condition. The Map 1 in [6] and Map 1 in static condition of this experiment recorded no error response for the same error. For undefined error, both conditions (static and rotatable) in the present experiment and Map 1 from [6] have undefined error response. The percentage for undefined error for Map 1 in [6] was 15% and the five maps in rotatable condition in the present experiment was 26%. The error percentage obtained for Map 1 for static condition in this experiment was 33% which is quite high compared to the percentages from [6] and rotatable condition. However, it can be concluded that these aligned maps from rotatable condition of the present work and [6] have almost similar results despite of the different proportions obtained.

4.3. Map Reconstruction Task

The analysis of map reconstruction task was done manually based on the scoring proposed.

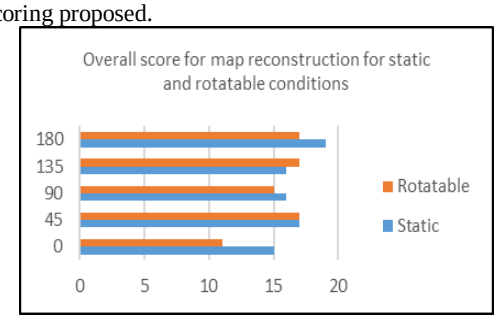


Fig. 8: Total scores for map reconstruction task for static and rotatable conditions

The above Figure 8 illustrates the overall score obtained by all participants for map reconstruction for 5 alignments (0°, 45°, 90°, 135°, 180°) in static and rotatable conditions. Obviously, it can be seen that the scores for both conditions, static and rotatable are different for the 5 alignments (0°, 45°, 90°, 135°, 180°). The higher the score means the participants perform poorer on the task and the lower the score means the participants perform well on the task. On the other hand, this also means that the higher the score but the lower the level of accuracy of the reconstructed map. If the score is lower, the level of accuracy of the reconstructed map is higher. From the figure above, static condition has a higher score on Map 1 (0°), Map 3 (90°) and Map 5 (180°) over rotatable condition. Meanwhile, rotatable condition has a higher score on Map 4 (135°). As for Map 2 (45°), both conditions, static and rotatable obtained same score. It can thus be concluded that most participants had problems in recreating map after performing the pointing task in static condition. This is shown by the scores obtained by static condition for the three maps in the above graph. This also means that many participants made more error mistakes when recreating the three maps. The following Figure 9 and Figure 10 present the example of good and poor map reconstruction models by different participants.

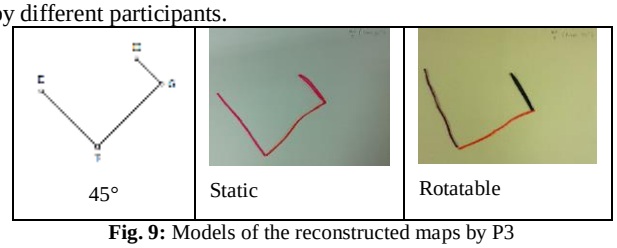


Fig. 9: Models of the reconstructed maps by P3

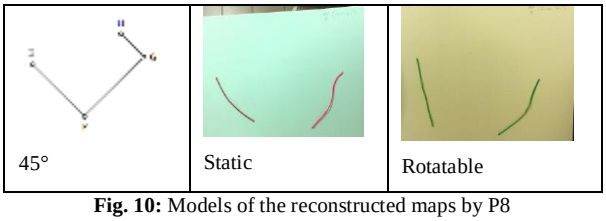


Fig. 10: Models of the reconstructed maps by P8

4.4. Correlations between User Sense of Direction and User Response

Correlations between user scores on the sense of direction and user response on the pointing tasks on static condition and rotata-

ble condition were calculated to explore the relationships between these components. The correlation (Spearman's coefficients) matrix showed that there was a significant negative correlation between user scores on SBSOD and user response on static condition ($r = -.237$, $N = 12$, $p > 0.05$, two-tailed). There was also a significant negative correlation between user scores on SBSOD and user response on rotatable condition ($r = -.237$, $N = 12$, $p > 0.05$, two-tailed.

5. Discussion

5.1. Effect on Blind User's Cognitive Maps

The first objective was to examine whether the cognitive map constructed on the basis of an audio-tactile map that the person is allowed to orientate as they wish is as good as those generated when the person is directed to use an aligned map. Findings from the pointing task and map reconstruction task show that the participants were able to develop cognitive maps of the maps that they explored when using the rotatable map. The results on the correct response for the maps that was rotated in this study were compared with the result for aligned map (Map 1) obtained in [6]. The percentage of the correct response for the current study and in [6] was nearly similar. Based on the pointing accuracy, the blind participants who orientated the maps produced a number of correct responses that were similar to the participants who used an aligned map in [6]. The cognitive maps that were formed during map learning using the rotated maps contributed to the participants' performance in completing the pointing and map reconstruction tasks. The results from map reconstruction task also shows that the participants who rotated the map had constructed accurate cognitive maps similarly to those who used the static map. This has been proven through the accuracy of the map layout which has been reconstructed by the participants.

The second objective was to compare user pointing accuracy between static and rotatable conditions, and the accuracy on map reconstruction task. Based on the results, more correct response of the 5 alignments were produced in the pointing task for rotatable map over static map. In addition, more errors especially on mirror-image error were produced in the pointing task by participants in the static condition. In the work of [6], their findings also show that blind participants produced more errors in the pointing task after using a fixed map. The results obtained in this study also supported the findings of previous works where more errors are produced in a pointing task when learning an unaligned map. The results on the pointing accuracy of the current study were also compared with the scores that represents the accuracy of the reconstructed maps. From the comparison, there are two elements that can be understood. Firstly, the scores obtained from the map reconstruction task can confirm that the participants had developed an accurate cognitive map of the map learned beforehand which leads to the accuracy of the pointing task. Secondly, the cognitive maps of the participants that were externalized through the reconstructed map can be learned.

5.2. Effect on Blind User's Sense of Directions

The third objective was to examine the correlations between user ratings on user sense of directions and pointing accuracy. There were no correlations found between user ratings on user sense of directions and pointing accuracy for static and rotatable conditions. Participants who rated their sense of directions with higher ratings performed well on the pointing task. In contrast, participants who rated their sense of direction with low ratings less performed on the same task. The use of the SBSOD at the beginning of both studies did not affect the correlations result. Hegarty [14] examined the correlations between SBSOD and pointing performance based on the administration order (beginning or last) of the completion of SBSOD. She predicts that the performance between sense of direction and the criterion tasks should correlate more strongly for participants who completed the SBSOD last compared to those who completed it first. The findings of her study show that the results were inconsistent with her predicts. The results of the correlations obtained in this study were unable to be compared with previous studies since most studies used sighted participants and they were tested in a real environment. Although Rossano and Warren [6] investigated blind people pointing accuracy however the participants' sense of directions were not assessed.

Another reason is the blind participants were found had worse performance than the sighted participants for estimating bearing, e.g. [26]. The current study used totally blind participants and they were tested using a map in a laboratory. Furthermore, the differences in the use of modalities to perceive information of the surrounding could influence the correlations result between the pointing task and participants' rating of the SBSOD. One of the factors that could influence the correlations result was due to the participants greatly overestimate their abilities which cause their self-report measures uncorrelated with the pointing performance [27]. This factor is beyond the control of the researcher since estimating one's ability is made by the person himself.

6 Conclusions and Further Work

This paper presents a comparison between the effect of exploring maps at different orientations on blind people's cognitive maps and sense of directions. A multimodal map that can be rotated was built to enable the user to explore the maps in two conditions; static and rotation. Results from this study shown that in the rotatable condition, some blind people have the ability to build accurate cognitive maps of the tested maps as accurate as in the static condition. Blind people were found able to point to the direction accurately in the rotatable condition than in the static condition. This was supported by their scores when reconstructing maps. However, there was no correlations found between user ratings on their sense of direction and the pointing accuracy. Relating to the findings from previous and current works, it can be seen that map alignment plays an important role in providing accurate information on user orientation. If the map is aligned with the user's orientation, this leads to superior performance compared with a misaligned condition.

In the subsequent work, the inclusion of information on landmarks identification through speech and auditory cues on the audio-tactile map will be done. Then, a similar investigation on user interaction but with the updated version of the audio-tactile map in static and rotatable conditions will be examined. In addition, an investigation on user preference when exploring maps in static and rotatable conditions also will be looked into.

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References

[1] World Health Organization (WHO)., "Visual Impairment and blindness Fact Sheet N° 282," 2012.

[2] Malaysian Social Welfare Department, "Laporan – Statistik Jabatan Kebajikan Masyarakat 2014," 2014. [Online]. Available:

http://www.jkm.gov.my/jkm/index.php?r=portal/full&id=UERPVHoxZktLb3RvVnBxMk5oSW5JUT09.
[3] M. H. A. Rafar, "Many Malaysians Ignorant of the Insidious Effects of Cataract," *Bernama*, 2015. [Online]. Available: http://www.malaysiandigest.com/features/576630-many-malaysians-ignorant-of-the-insidious-effects-of-cataract.html. [Accessed: 12-Jan-2016].
[4] C. Thinus-Blanc and F. Gaunet, "Representation of space in blind persons: vision as a spatial sense?," *Psychol. Bull.*, vol. 121, no. 1, pp. 20–42, 1997.
[5] T. Cattaneo, Zaira and Vecchi, *Blind Vision: The Neuroscience of Visual Impairment*, no. March. 2011.
[6] M. J. Rossano and D. H. Warren, "The importance of alignment in blind subjects' use of tactual maps," *Perception*, vol. 18, no. 6, pp. 805–816, 1989.
[7] M. Levine, I. N. Jankovic, and M. Palij, "Principles of spatial problem solving.," *J. Exp. Psychol. Gen.*, vol. 111, no. 2, pp. 157–175, 1982.
[8] F. Hermann, G. Bieber, and A. Duesterhoeft, "Egocentric Maps on Mobile Devices," *Proc. 4th Int. Work. Mob. Comput.*, pp. 32–37, 2003.
[9] M. J. Rossano and D. H. Warren, "Misaligned maps lead to predictable errors.," *Perception*, vol. 18, no. 2, pp. 215–229, 1989.
[10] W. Seager and D. S. Fraser, "Comparing physical, automatic and manual map rotation for pedestrian navigation," *Proc. SIGCHI Conf. Hum. factors Comput. Syst. - CHI '07*, p. 767, 2007.
[11] L. T. Kozlowski and K. J. Bryant, "Sense of direction, spatial orientation, and cognitive maps," *J. Exp. Psychol. Hum. Percept. Perform.*, vol. 3, no. 4, pp. 590–598, 1977.
[12] L. J. Harris, "Sex variations in spatial skill," in *Spatial representation and behavior across the lifespan*, L. Liben, A. Patterson, and N. Newcombe, Eds. New York: Academic Press, 1981, pp. 83–125.
[13] M. J. Sholl, J. C. Acacio, R. O. Makar, and C. Leon, "The relation of sex and sense of direction to spatial orientation in an unfamiliar environment," *J. Environ. Psychol.*, vol. 20, no. 1, pp. 17–28, 2000.
[14] M. Hegarty, A. E. Richardson, D. R. Montello, K. Lovelace, and I. Subbiah, "Development of a self-report measure of environmental spatial ability," *Intelligence*, vol. 30, no. 5, pp. 425–447, 2002.
[15] T. Ishikawa and D. R. Montello, "Spatial knowledge acquisition from direct experience in the environment: Individual differences in the development of metric knowledge and the integration of separately learned places," *Cogn. Psychol.*, vol. 52, no. 2, pp. 93–129, 2006.
[16] J. L. Prestopnik and B. Roskos–Ewoldsen, "The Relations Among Wayfinding Strategy Use, Sense of Direction, Sex, Familiarity, and Wayfinding Ability," *J. Environ. Psychol.*, vol. 20, no. 2, pp. 177–191, 2000.
[17] M. J. Sholl, "The relation between sense of direction and mental geographic updating," *Intelligence*, vol. 12, no. 3, pp. 299–314, 1988.
[18] K. J. Bryant, "Personality Correlates of Sense of Direction and Geographic Orientation," *J. Pers. Soc. Psychol.*, vol. 43, no. 6, pp. 1318–1324, 1982.
[19] A. M. Brock, P. Truillet, B. Oriola, D. Picard, and C. Jouffrais, "Interactivity Improves Usability of Geographic Maps for Visually Impaired People," *Human-Computer Interact.*, vol. 30, no. 2, pp. 156–194, 2015.
[20] J. A. Miele, "Talking TMAP: Automated generation of audio-tactile maps using Smith-Kettlewell's TMAP software," *Br. J. Vis. Impair.*, vol. 24, no. 2, pp. 93–100, 2006.
[21] T. Watanabe, T. Yamaguchi, S. Koda, and K. Minatani, "Tactile map automated creation system using OpenStreetMap," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2014.
[22] D. A. Paladugu, Z. Wang, and B. Li, "On presenting audio-tactile maps to visually impaired users for getting directions.," *Audio*, pp. 3955–3960, 2010.
[23] L. O'Sullivan, L. Picinali, A. Gerino, and D. Cawthorne, "A prototype audio-tactile map system with an advanced auditory display," *Int. J. Mob. Hum. Comput. Interact.*, vol. 7, no. 4, pp. 53–75, 2015.
[24] L. O'Sullivan, L. Picinali, C. Feakes, and D. Cawthorne, "Audio Tactile Maps (ATM) System for the Exploration of Digital Heritage Buildings by Visually-impaired Individuals - First Prototype and Preliminary Evaluation," in *Forum Acusticum*, 2014.
[25] N. N. Abd Hamid and A. D. N. Edwards, "Facilitating route learning using interactive audio-tactile maps for blind and visually impaired people," *Chi*, pp. 37–42, 2013.
[26] R. W. Byrne and E. Salter, "Distances and Directions in the Cognitive Maps of the Blind*," *Can. J. Psychol.*, vol. 37, no. 2, pp. 293–299, 1983.
[27] J. Kruger and D. Dunning, "Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments.," *J. Pers. Soc. Psychol.*, vol. 77, no. 6, pp. 1121–34, 1999.