Touch Screen with Audio Feedback: Content Analysis and the Effect of Spatial Ability on Blind People's Sense of Position of Web pages

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Abstract- **This article presents findings from a Content Analysis of verbal and audio protocol of Mental Model study. When using touch screen display with audio feedback, it was found that the users' mental model is in one dimensional as using screen-reader program. Previous experience using screen-reader program may affected the users' experience using a touch screen with audio feedback. In addition, investigation of blind users' spatial ability on users' performance was also conducted. This study revealed that there was a significant interaction effect between the user's spatial ability and the time taken to answer a question using touch display with audio feedback.**

Keywords- Web Accessibility, Two Dimensional Mental Model , Non-visual navigation.

I. INTRODUCTION

Most web pages are designed with some kind of two dimensional structure or layout. For the sighted people, these two dimensional structures are usually far more effective in conveying information. On the other hand, for screen-reader users, there is only one-dimensional string of fragments of the original content [1, 2]. The lack of the two dimensional information in the mental models of the screen reader users is the main obstacle for them to use the Internet effectively.

We anticipate that by accessing web pages using a touch screen display with audio feedback, a blind user would be able to gain a two-dimensional perspective of the web page in his or her mental model. If the mental model of the page contains two-dimensional information, it would help the blind user to gain a better orientation of the web page and have a sense of position of the web page. This is important for the user to navigate the web.

The remainder of the paper is structured as follows: Section II discusses Internet navigation issues faced by screen-reader users. Section III discusses the design of the study to generate mental model data. Section IV presents the result of the study. Finally, Section V presents the discussions and conclusions.

II. NAVIGATION ISSUES BY BLIND PEOPLE

Current screen-reader program imposes navigation constraints since the users can only "hear" the content in serial mode that often fails to convey spatial representation of the information on a page. According to Web Content Accessibility Guideline [3], navigation has two main functions:

1. To tell the users where they are
2. To enable the users to go somewhere else

Moreover, this study is interested to investigate the influence of user's spatial ability, since spatial ability is often cited as a good predictor of individual's performance in human computer interactions [4].

Study by Murphy et al. [1] found that current screen-reader program imposes navigational constraints and provides limited information on page layout. The screen-reader users imagine the page as vertical list and have to remember the sequence of the interested item. However, for wide-ranging and complex websites, the vertical list will be so extensive and impossible to be memorized. Moreover, it is a mental load if screen-reader users have to memorize a large set of options. In [2], it is learned that the screen-reader users focused on landing in the main content area by using gambling scanning or exhaustive scanning. Besides, screen-reader users displayed more probing behavior (leave and quickly return to a page) [2]. Obviously, screen-reader program is incapable to tell the users where they are and how to go somewhere in a web page. Consequently, screen-reader users spent more time and needed more effort to perform a task on the Internet [5].

In order to analyze a web page, there are two phases of web page exploration needed as discussed in [6]:

1) Macro-analysis - This phase corresponds to the "where" stage in visual perception and typically associated to the orientation of the page. A macro-analysis phase allows the understanding of the document structure and of the element types used in a particular page.

2) Micro-analysis – This phase correspond to "what" stage and typically associated to the sense of position of the page. A micro-analysis phase lets users focus on one particular object to obtain its content.

These phases are iterated which means the users interactively perform a series of macro- and micro-analysis explorations. The design of web pages and the assistive aids used by the blind people should assist these explorations to enable the blind people get their desired content effectively.

However, in terms of touch screen display with audio feedback, there is a lack of empirically based guidelines for the designers to be adopted. In addition, this study investigated the effect of individual difference on the performance of the users performing tasks using a touch screen with audio feedback. This study examines the effect of users' spatial ability on the performance when using a touch screen display with audio feedback. Spatial ability is important not only for navigating in the real world but also in the World Wide Web.

III. EXPERIMENTAL DESIGN

The purpose of this study was to investigate the differences of the mental models created by the blind people from a two-dimensional web page using two different means: one using a touch screen display with audio feedback and the other using a conventional screen-reader only.

Task scenario experiments were carried out which involve blind participants accessing the experimental pages using a screen-reader only and the other experiment using a touch screen display augmented with audio feedback. The participants were asked to perform specific tasks. Think-aloud protocol with modified version dedicated for screen-reader users was adopted in this study [7]. The participants' interactions with the experimental pages were observed and recorded for later analysis.

From the literature, it is found that previous researches on mental model of the blind people focused on performance data, verbal protocol and on-line protocol [8]. However, this study extends the previous works with another protocol which is diagrammatic representation. Foam blocks with different types of surfaces (rough and smooth) were used to represent different web elements (Figure 1). However, only two elements were asked; headings (rough surface blocks) and data (smooth surface blocks). The report on the quantitative studies of this project was reported in [9].

Ten blind people participated in this experiment (3 females, 7 males). Call for participation in this study was distributed through the blind association's mailing list. Interested participants have to contact the researchers by email or phone to discuss suitable date and time. The researchers focused on recruiting blind people with some basic skill using JAWS screen-reader.

The study was conducted at a room in the blind associations. The study started with the explanation about the study. Next, consent to participate in the study was recorded. All consents were given orally by the participant and audio-recorded for future reference. Before the participants started with the actual experiment, the participants were trained about the procedure of the experiment using two training pages for about 10-15 minutes each. This is to make sure that any issues or doubt should be resolved before the actual experiment started.

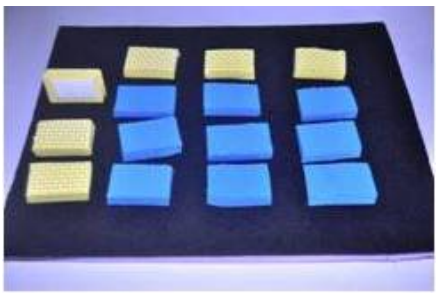

Figure 1. Diagrammatic Representation using Foam Blocks

The experiment started by asking the participant to explore the experimental pages using JAWS screen-reader. There are altogether six experimental pages with different layout complexity used in the study as shown in Figure 3. Layout complexity was determined objectively, based on based on the previous studies [10] [11]. After exploring each page, the participants were asked to briefly describe the page. The participants were then asked to construct the layout of the table using diagrammatic representation.

After the construction of diagrammatic representation, the participants were asked to answer a question. The list of questions is in Table 1.

To investigate the influence of user's spatial ability on the performance using touch screen with audio feedback, this study accessed user's spatial ability using Tactual Performance Test (TPT) (refer Figure 2) or also known as Form Board Test and Seguin-Goddard Formboard [12]. The test consists of ten holes of board with ten shapes of blocks, instruction manual and scoring form.

The experiment repeats the previous steps above but at this time using a touch screen display augmented with audio feedback. This study chooses an Apple iPad as the experiment's apparatus. VoiceOver program is available as screen-reading software for Apple iPad. The participants were trained on how to use the device prior the actual experiment. Two types of gestures were trained; "gliding" and flicking. Finally, the experiment ends with demographic survey.

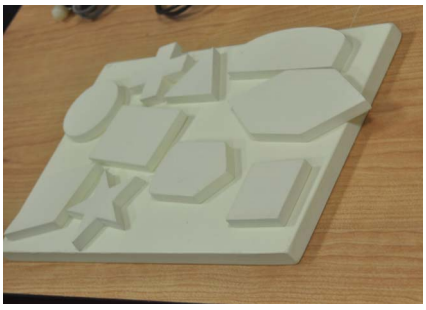

Figure 2. Spatial ability test

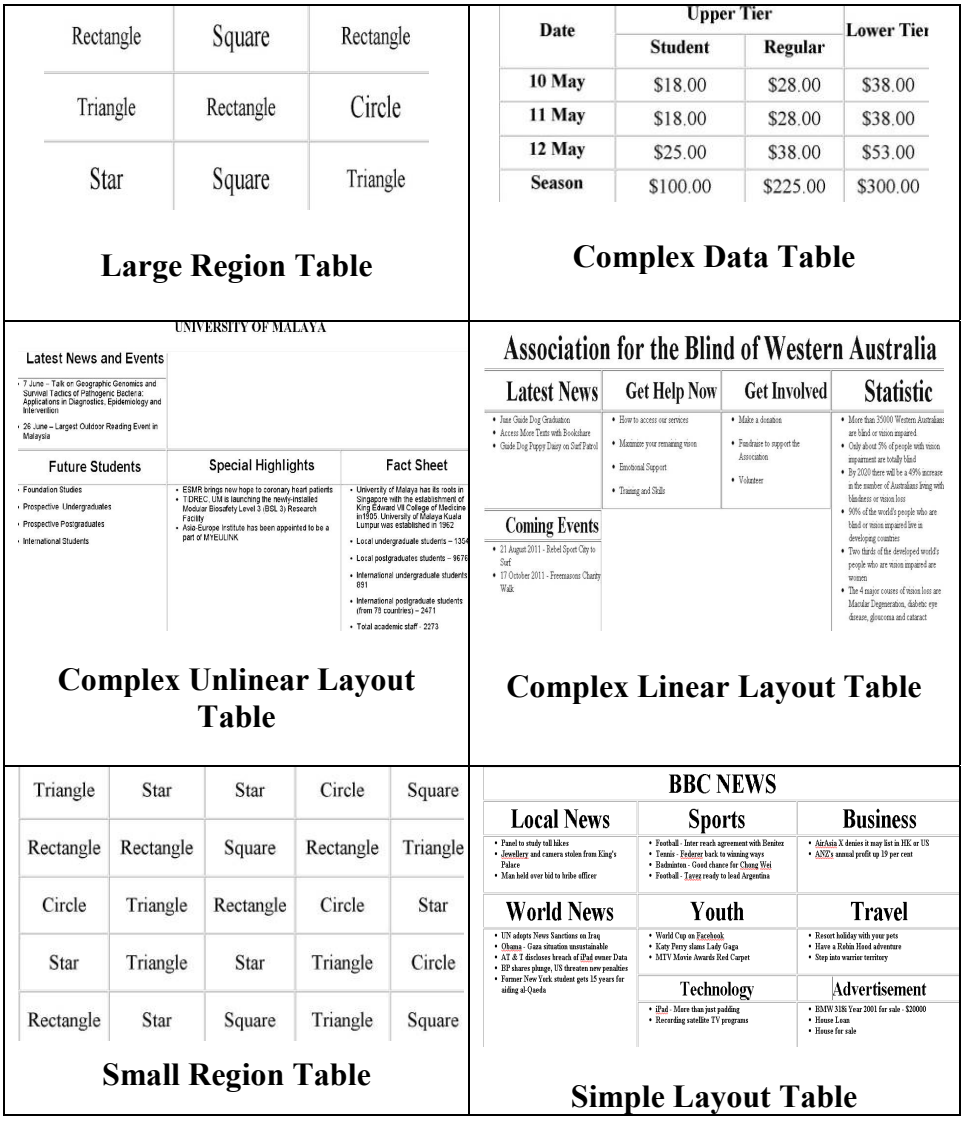

Figure 3. Experimental pages

This study adopted a within-subject crossover design[13]. This means that each user performed both experiments. To control learning effect, half of the participants accessed the experimental pages using touch-screen display with audio feedback first, and then the screen-reader only and the other half of the participants conducted the two experiments in the opposite order.

Each session normally lasted 2-3 hours and the whole session was recorded using video and audio recorder.

IV. RESULTS

None of the participants have any experience in using Apple iPad but a few of them have used Apple iPod or iPhone before. The experiment was the first time that all participants use the Apple iPad. On the other hand, all participants are familiar with JAWS screen-reader program in their daily life when using personal computer. In terms of their ability in using Assistive Technology, three participants are considered as expert, while the other seven are considered as good.

A. Content Analysis of Transcribed data

Video recording was used to assist the analysis phase. Verbal data was gathered using think-aloud protocol with modified version dedicated for screen-reader users [7]. The participants were asked to speak out any thought and feeling while interacting with the system or give his or her remark at the end of each session.

The investigator sat next to the participant, who was allowed to ask the participants to comment on their actions. Comments and explanations have been added to users' verbal statements and users' interaction with the system by the researcher where appropriate.

Most (60%) of the blind participants utilized gliding gesture almost all the time when accessing the experimental pages using touch screen with audio feedback. A few of the blind participants (30%) used combination of flicking and gliding gestures.

At the end of the experiments, the blind participants were asked a question:

Do you think using touch screen with audio feedback is helpful for you to get a better orientation and better sense of position?

Other comments about the use of touch screen with audio feedback were also observed and recorded.

Table 1 is a summarization of the comments and elements that support the participants' opinion.

The content of comments and observations were classified into two categories; Agree and Disagree. Most of the blind participants (60%) agree that touch screen with audio feedback is helpful to get a better orientation and better sense of position. On the other hand, 40% of the blind participants disagree that touch screen with audio feedback is helpful.

TABLE 2
SUMMARIZATION OF THE COMMENTS

	Comments/Elements support
Agree	If I have been using this (iPad) as long as I have been using JAWS (pause) Yes, I can tell it is going to be better (pause)in the long run. I am going to buy an iPad. It helps me. I have an iPod but I have never used it. It gives me a better idea on how iPod works as well. I always have problem dealing with table. If you want to analyze the data, the overview is so important. It was a very good experience.
Disagree	If the layout of the information is important, the iPad can be helpful. But it is a pain. It is easier to use iPhone because of the small screen A person like me, the spatial awareness is not important. Still prefer to receive the info one by one.

TABLE 1
LIST OF QUESTIONS

Page	***Question***
#1	What is the shape at the third column and second row?
#2	What is the Season rate for the Lower Tier?
#3	In what year was University of Malaya Kuala Lumpur established?
#4	How many Australian people are blind or visually impaired?
#5	What is the shape at the second column and forth row?
#6	How many years will the former NY student be imprisoned for aiding al Qaeda?

The observations of each experimental page are given below.

Large Region Table

Most (90%) of the blind participants do not face any difficulties to get a correct overview and construct correct diagrammatic representation using JAWS screen-reader. However, a participant (10%) ignores the number of row and column information and is unable to construct correct diagrammatic representation. Another participant asked the investigator how she can know any merged cell. She also initially constructed the diagrammatic representation in a vertical order. When answering a question asked, she was initially accessing the table from bottom to top. The first answer was incorrect but she double checked the answer by accessing the table from top to bottom and got the correct answer.

Similar to the experiment with JAWS screen-reader, most (90%) of the participants have do not face any difficulties to get correct overview and construct correct diagrammatic representation using touch screen with audio feedback except a participant who was facing difficulty to perform the flicking gesture correctly. When the system does not recognize the gesture, the VoiceOver program will start the process of reading the content from the beginning of the page.

Complex Data Table

Using JAWS screen reader, many participants (60%) commented about the difficulty to identify merging cell. They are confused and not sure about the merging cell and as a result could not get the correct relationship between row and cell.

Using touch screen with audio feedback, most (86%) of the participants commented positively (Table 3) except for a participant who reported to have difficulty using touch screen with audio feedback to access tables. Two participants feel that they need more time to learn the technology. The participants also commented that it makes more sense using touch screen with audio feedback to access the experimental pages and have a better concept and understanding about touch screen display with audio feedback.

Using JAWS screen-reader, few participants reported that the page is confusing and extremely challenging. As a result, three of the participants constructed diagrammatic representation in a vertical order.

Complex Unlinear Layout Table

Table 4 shows comments and elements that support participants' opinion when accessing complex unlinear layout table using touch screen with audio feedback. When using touch screen with audio feedback, a few participants reported that the page was confusing and difficult for them to get an overview. They do not know where to focus since there is too much information on the page and they are unfamiliar with the searching function. Because of that, they have to spend more time to explore the page before they can get a correct overview. An expert participant claims that ordinary people could not easily get this concept.

TABLE 3
COMMENTS WHEN USING TOUCH SCREEN WITH AUDIO FEEDBACK TO ACCESS COMPLEX DATA TABLE

Codes	Frequency
Difficult	1
Need more experience/better in the long run	2
Make much more sense	1
Have better concept	1
Now I know what you mean	1
Confident	1

TABLE 4
COMMENTS WHEN USING TOUCH SCREEN WITH AUDIO FEEDBACK TO ACCESS COMPLEX UNLINEAR TABLE

Codes	Frequency
Complicated	2
Difficult	2
Do not know what to focus	1
Lack of searchable function	1
Too much info	1
Take some time to explore to get correct overview	1
Ordinary user could not get the concept	1

Complex Linear Layout Table

Using JAWS screen-reader to access complex linear layout table, two participants were observed to have a vertical mental model of a web page and built a linear list of elements using diagrammatic representations. Four of the participants reported that they were not sure about the shape of the table and were not so happy with the construction of diagrammatic representations. Interestingly, using JAWS screen-reader, a few of the blind people repeatedly claimed that spatial awareness is not important for them. This is a contrast to the literature on effective web design that mentioned that assistive aids should support spatial awareness so that web surfers can easily track their position [14] [1].

On the other hand, using touch screen with audio feedback, two participants commented that they had an idea where to point their finger to get the information. Therefore, they were able to find the information faster.

Small Region Table

Most (90%) of the blind participants do not face any difficulties in getting a correct overview and construct correct diagrammatic representation using JAWS screen-reader. However, similar to the experiment with large region page, two participants (20%) ignored the number of row and column information and were unable to construct correct diagrammatic representation.

On the other hand, using touch screen with audio feedback, most (90%) of the blind participants was unable to get a correct overview and construct correct diagrammatic representations. Almost 80% of the participants used gliding gesture during exploration process.

Linear Layout Table

Using JAWS screen-reader to access Linear Layout table, two of the participants commented that they were not sure and had no idea how to arrange the diagrammatic representations. A participant claimed that the page was the hardest compared to the other experimental pages and another participant commented that this page contained so much data. Another participant commented that he usually did not bother about the columns when accessing a web page with such information. Observation on the construction of diagrammatic representations by this participant shows that he constructed the diagrammatic representation in a vertical order. Other than that, a participant always missed the information he needed because he pressed the navigation key too fast.

In contrast, using touch screen with audio feedback, positive comments and observations were gathered. Three participants claimed that using touch screen display with audio feedback, they were able to point to specific region to get the information. Two of the participants felt more confident with the device. However, during the exploration a participant failed to spot the right hand side region of the page and as a result spent more time to get the information required.

B. The effect of Spatial ability on Sense of Position

The data for user performance was gathered from observing participant's interaction with the experimental pages using touch display with audio feedback. Time taken to answer was recorded using a stop watch during the experiment. The relationship between a blind user's spatial ability and he or her performance to answer a question was investigated using Pearson product-moment correlation coefficient.

For large region layout page (Page1), there was a positive correlation between the two variables ($r = 0.802$) which means that the higher Tactual Performance Test (TPT) total time (lower spatial ability), associated with longer time to answer the question given. Moreover, the strength of the relationship is strong.

For complex data page (Page2), there was a positive correlation between the two variables ($r = 0.745$) which means that higher TPT total time (lower spatial ability) associated with longer time to answer a question.

For complex unlinear layout page (Page3), there was a weak positive correlation between the two variables ($r = 0.138$) which means that higher TPT total time (lower spatial ability) associated with longer time to answer a question.

For complex linear layout page (Page4), there was a strong positive correlation between the two variables ($r = 0.583$) which means that higher TPT total time (lower spatial ability) associated with longer time to answer the question given.

For small region layout page (Page5), there was a positive correlation between the two variables ($r = 0.267$) which means that higher TPT total time (lower spatial ability) associated with longer time to answer the question given. However, the strength of the relationship is weak.

For simple layout page (Page6), there was a perfect positive correlation between the two variables (r = 1) which means that higher TPT total time (lower spatial ability) associated with longer time to answer the question given.

V. DISCUSSIONS AND CONCLUSIONS

From the content analysis, the main findings are:

- Most of the participants agree that touch screen with audio feedback is helpful in getting better orientation and better sense of position. However, lack of training and previous experience using screen-reader program contribute to the divergence of the comments.
- When accessing the web pages using touch screen with audio feedback, the size of the region plays an important role to assist exploration process. If the size is too small, the users easily missed the neighborhood regions. This is also known as "fat finger" [4] and there is very little research currently undergoing to solve this problem.
- There is a significant interaction effect between a user's spatial ability and time to answer a question using touch screen display with audio feedback. Users with higher spatial ability should have better sense of position of the information in the web pages.

As a conclusion, using touch screen display with audio feedback, the blind people's mental model of a page is in a two-dimensional perspective. Because of that, they are able to gain the overview of the web page accurately. This may help them to navigate the page effectively. However, the previous experience using screen-reader program affected the learning of this new concept. The study also revealed that there is a significant interaction effect between user's spatial ability and time to answer a question using touch screen display with audio feedback. Therefore, to improve the navigation performance of blind people with low spatial ability, special tool should be provided to assist the exploration of web pages.

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