Eliciting Mental Model of Blind People for Web Page

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ABSTRACT
This paper highlights the need to investigate whether blind people can get two dimensional perspectives in their mental model using bi-modal interaction. The two dimensional perspectives are very important for effective navigation in the Internet. This paper proposed the novel protocol to elicit mental model from the blind people using diagrammatic representation.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation]:** User Interfaces

General Terms
Experimentation

Keywords
Web Accessibility, Two Dimensional Mental Model, Screen-reader, Touch Screen, Non-visual navigation, Diagrammatic representation.

1. INTRODUCTION
Study by Hollier [1] found that blind people had a strong desire to use computer and the Internet. They require non-visual alternative such as screen-reader program to access the Internet [2]. A screen-reader program will translate the visual screen display into auditory output for all traditionally visual tasks such as reading text. It also provides instructions for tasks such as menu selection, responding to system prompts, analyzing tables and navigating the pages. However, screen-reader program processes pages and produces output to the blind people in a sequential order, from top left of the page to the bottom right of the page.

Using screen-reader program, the blind people can only get one-dimensional string of content fragments [3]. The mental model created from the screen-reader output would have very little two dimensional perspective, such as its two dimensional layout. Current studies have shown that it is time consuming for screen-reader users to serially scan a page for their desired contents [4]. Moreover, without the meta-information provided by the layout, it is confusing for the screen-reader users to interpret the pages. They do not know where they should focus their attention on since they do not have the spatial awareness of the elements' position on the screen [5].

2. MENTAL MODEL
According to mental model theory, user performance is guided by the user's mental model [6]. A mental model in this context is defined as the conception that a human being developed internally to describe the location, function and structure of objects and phenomena in computer systems [7]. A mental model can incorporate information about temporal, spatial, causal, person- and object-related features of a particular event [8]. Mental model is not restricted to a specific modality [9]. It means that the mental model can be constructed not only from visual experiences but also from other senses including hearing and touching. The mental models will help to shape users behavior and approach to solving the problems and carrying out tasks.

Mental model has been studied initially by psychologist. The term mental model was first mentioned by Kenneth Craik in 1943. In his book "The Nature of Explanation", Craik claims that human mind constructs "small-scale models" of the reality that will be used to predict similar future events. The same terminology has been used by cognitive scientist as part of the effort to know how humans learn and make decisions.

In 1980s, the term mental model emerged back when Gentner and Stevens [10] make an effort to compile related studies in mental model. In the book edited by Gentner and Stevens, there are two earliest papers that discuss specifically about mental models of computer systems [11]. The first paper was by Norman [6] that introduced four types of representations which influence user-system interaction. The first type is the target system which is referring to the system that the person is using. The second is the conceptual model that is invented by the designers and engineers which is an appropriate model for the users to develop. To

develop this model, it requires the inventor to engage in analysis and decision-making concerning the viable conceptualization model that will be presented to the users. The third is the mental models that people formulate internally through interaction with the target system. According to Norman, the user's mental models continue to modify in order to get the workable results. Finally, the scientist's conceptualization, which is referring to the model of a model.

Several observations by Norman found that mental models are incomplete and also unstable. People easily forget if they are not using the system for some time. Furthermore, there are no firm boundaries which make people easily get confused with similar operations. Nevertheless, mental models are application or problem specific and are not static [12]. Although there are many shortcomings, mental models are still important as a source of information, providing predictive and explanatory power in understanding the interaction [6].

In terms of modelling the mental models, Norman believes that using only verbal protocol is incomplete. He believes that what people believe and how people act are two different manners. Using verbal protocol, people usually compel to give a reason although they do not have one.

The second paper that discusses mental models of computer systems was by Young [13]. In his paper, Young uses different terminology to describe mental model which is User's Conceptual Model (UCM). If Norman focuses on the users' own views of the world, Young focuses on the conceptual model of the system. Young defines UCM as representation or metaphor that users adopt to guide their actions and help them interpret the device's behavior. This means the users need to adopt certain metaphor or analogy to guide their actions and help them interpret the device's behavior. Similar to Norman, Young suggests that there are four agents of UCM, in which he believes that each agent has their own UCM; for User, Designer, Psychologist (Scientist) and the Device (System).

Other than these two papers, Sasse [11] in her PhD work has come out with comprehensive review about mental models that covers psychology, cognitive science and human-computer interaction disciplines.

Based on the literature, there are two ways to elicit the mental models. The first is by imposing appropriate models during training and trying to elicit users' mental model after they are exposed to the system. Another way is by just eliciting the mental model without prior training because some applications such as the Web is too complex to build a normative model for comparison [14].

Sasse evaluated different experimental scenarios for investigating user's mental model:

- **Task Scenario** – hands on
- **Teaching Back Scenario**
- **Advance Task Scenario** – verbal and hands on
- **Joint Exploration Scenario**

The first scenario which is Task Scenario requires users to perform a set of tasks using word processing application to derive performance data. The data which can be gathered under performance aspect are task completion, time to complete the task given and error. During the experiments, the users are prompted by the investigator to think aloud during the completion of tasks. However, user performance alone cannot be taken as an indicator of a specific users' mental model [11]. Sasse believes that verbalizing the reason for the errors done is a more natural way to extract verbal data. This is because user errors are systematic (happened because of the same reason) which should guide to user's actual mental model.

In the Teaching Back Scenario, the user is required to teach another person to use the application. This is to encourage users to verbalize their knowledge. However, this scenario is suitable if the users have been exposed to the system for a certain period prior to the experiment. In addition, the users seem to be dependent to the "learner" (investigator) when they face difficulties.

The third scenario is similar to the first one accept that it requires the user to answer several questions related to the application prior to the hands on task. Then, the user has to describe about the application before the experiment ends.

Another experimental scenario is Joint Exploration. Using this method, the user is required to work together with another person and explore the application. It is found that users were more involved and communicative. The disadvantage of this scenario is the less experienced users will be more passive since they lack confidence and are still expecting for guidance. Other than that, this method requires a lot of time for transcribing and analysis since the data gathered can only be analysed from recordings.

Sasse evaluated the scenarios in terms of:

- resources required to implement a scenario;
- amount of data on users' models elicited;
- quality of data on users' models elicited;
- effort required to analyze users' models.

Sasse also had discussed three types of data collection for mental model studies:

- **Performance data** - typically assesses user's task completion, time taken to complete the tasks and number of errors
- **Online protocols** - record user and system actions
- **Verbal data** - require users to verbalize during the interaction with the system

Sasse suggests alternative ways to elicit the mental models from the user including drawings, diagrammatic representations and schema-like representations. Schema-like representation is the extension description of the existing model including functions, components and properties of the extracted model. While, the subjects participated in the study were sighted people, the current study will involves participants accessing the web pages without visual ability. The data gathering procedure should be modified to suit with the participants. Obviously, it is not suitable to elicit mental model from the blind people using drawing. This study proposed foam blocks to be used by the blind people to represent the diagram.

3. BLIND PEOPLE'S MENTAL MODEL

It is found that at the moment there is still little work on mental model for blind people. Study by Murphy et al. [5] was conducted to understand the challenges faced by the blind users when accessing the Web using assistive technology. In terms of mental model, the study found that blind people attempt to remember the page structure when they scan for the desired information using screen-reader program. The study describes the mental model of the screen-reader users as a "vertical list", and they perceive all web pages to be in a single column-like structure. In this case, the screen-reader users will try to remember the sequence of the interested items.

It is a burden to mental load if screen-reader users have to memorize a large set of options. Furthermore, for wide-ranging and complex websites, the "vertical list" will be so extensive and impossible to be remembered. In addition, by collapsing the two–dimensional web page into a single list of items, many useful navigational hints would be lost, for example, the position of an item relative to other items (eg, on the left, on the right). Due to the above factors, the screen-reader users spent more time and needed more efforts to perform a task on the Internet [4] in comparison to their sighted counterparts [15].

Another work on the mental model of the blind was by Takagi et al. [3]. The focus of their study was to observe the interaction and strategies adopted by the blind when accessing online shopping web sites. Takagi et al. observed that the mental model used by screen-reader users to access the online shopping web sites is a vertical list. They found that the blind users had their own strategy to speed up the searching process. They also found that the screen-reader users focused on landing in the main content area by using gambling scanning or exhaustive scanning.

Kurniawan and Sutcliffe [16] investigated blind people mental models in dealing with a new Windows-based screen-reader program through interviews. Online protocol (video recording) was also used to observe participant's interaction.

One of the important remarks from the study is that the participants did not bother forming a mental model of a complex diagram/structure or a desktop layout because the screen-reader does not have the capability to describe it to them. This is one of the motivations for us to conduct this study.

4. PROPOSED METHOD TO ELICIT TWO-DIMENSIONAL MENTAL MODEL FROM THE BLIND PEOPLE

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 [6]. 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.

The availability of tablet computers such as Apple iPad and Google Android aPad which are designed to be controlled by bare fingers motivates us to study the potential of using them as an assisted technology for the blind. We hypothesized that by augmenting an assistive aid to have touch screen controls and audio feedback, a blind user would be able to create the mental model with the two-dimensional perspective from a web page. Hence the blind user would be able to obtain the overview of the web page and gain the sense of position in the web page more accurately.

Experiments will be carried out to elicit the mental models of the blind when browsing web pages using touch screen with audio feedback. Thirty sighted people will be blindfolded during the experiments. The involvement of sighted people is because of the difficulties to obtain the same number of blind participants. It was found that most experiments that are conducted using blind participants usually have only four to six participants [3]. The same experiments will be conducted with at least 10 blind people (late blind and congenitally blind) to reveal underlying patterns.

From the literature, it is found that previous researches on mental model of the blind people focus on performance data, verbal protocol and on-line protocol. However, this study will extend the previous works with another protocol which is diagrammatic representation (Figure 1).

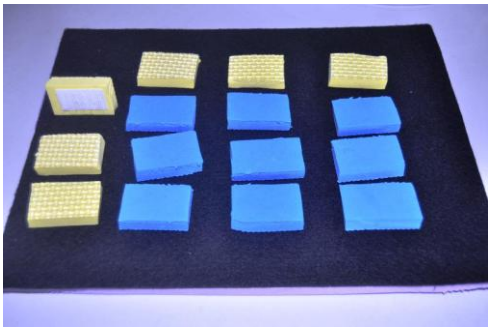

Figure 1: Diagrammatic Representation

After exploring the experimental page using touch screen with audio feedback, the participant is required to construct the layout

for the experimental pages using foam blocks and describe the layout. Blocks with different types of surfaces (rough and smooth) will be used to represent different web elements. However, only two elements will be asked; headings (rough blocks) and data (smooth blocks).

5. CONCLUSIONS

This study aims to discover in detail the blind people mental model of two-dimensional perspective by using touch screen with audio feedback. Empirical evidence about overview and sense of position using touch screen with audio feedback should benefit assistive technologies developer in the future.

This study also proposed a protocol to elicit mental model from the blind people using diagrammatic representation.

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