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AN EXPLORATORY STUDY ON BLIND USERS' MENTAL MODEL IN COMPUTER ACCESSIBILITY

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ABSTRACT

The growing needs in the area of HCI has led to many new researches focusing on user-centric design, investigating the problems faced by a computer user and ways to produce an effective yet efficient design. Often, designers need to acquire the knowledge and the experience of the users to produce a good interface design. This can be referred as a wise exploitation of user's mental model. The paper serves as a preliminary study which explores the mental model of blind users as a contribution in improving the accessibility of computer applications. Based on the blind user's perception, imagination and interpretation, the study indicates that touch sensation plays an important role in improving the representation of a computer application to them. Associating touch sensation with information familiar to the blind users enhances the learning process.

Keywords: blind, avalanche photodiode (APDs), III-V materials, guard ring, optical communication.

INTRODUCTION

The term "computer accessibility" in human-computer interaction spells out clearly the accessibility of computer system to all people, regardless of disability or severity of impairment [1]. The user interface of a computer should be accessible by anyone, independent of their physical, perceptual-motor, social and cultural capabilities [2]. In [3], it is stated that blind users usually use software known as "screen readers" which works with all the programs installed in a computer to read out the interface and details of an application to them. However, not all can be read by the screen readers. Braille devices able to produce the output on the computer display however, some important information such as application names and pop-ups are not displayed by the Braille device.

World Health Organization (WHO) recorded the estimated visually impaired population as 285 million; with the blind holding the record of 39 million and the rest occupied by the low vision category [4]. Eweek.com did address an important question on why the blind community is being ignored when they are able to create a big market [5]. The challenges in life and acquiring a new skill especially on IT field seem to be an issue to the blind. It is important to allow the blind to further venture into the IT equipped world by providing an easy learning platform for them. As a start, this paper presents a study that identifies the usability problems based on users' experience when interacting with a computer application. The intention is to understand the blind users' mental model. The study further investigates the extent in which touch sensation could be used in accessing the application.

LITERATURE

Designers tend to address a user's mental model as a valuable piece of information due to the ability of these users to formulate the mental model using their experience and expectations. In order to design a user's preferred system, one need to utilize the user's mental model as this information is found to be greatly contributing during the development stage. Every designer considers a mental model to be an absolutely necessary element as it helps them to understand a user's view on system content [6, 7]. Usually, when a user interacts with an existing or familiar environment, they tend to use the previously developed mental model and if they come across an unfamiliar or a new environment then they will create a new mental model altogether [6].

Familiarity can be achieved when a user's mental model is analyzed and some of the important questions are answered such as (1) how a system should look alike? Or (2) how a system supposedly should behave? Or (3) how a user expects a system to respond? Mental model of a blind can be in any form, such as a diagram, an image, a theory, a set of concepts, some guidelines or etc [8]. This representation is said to be a great help in enhancing the understanding of usability of any system [9, 10]. Usually, a system is build according to a designers' view. In another word, the developed system is based on a designer's mental model. In this study, mental model of blind users refers to the representation formed by the blind when they use computer application.

According to [2], usability issues highlight the easy use of an interface which is measured through the interaction between a user and the system. In [11], it was addressed the need of assistive technology when a blind computer user accesses a computer application. And that it is important for the designer to design a system or an application which is "software" friendly for the screen readers to be able to read the presented content.

Often the blind users' mental models are not taken into account and the developed applications are tested without considering the fact that blind users have the tendency to navigate through an application instead of listening carefully the information that is being read [12]. A developed computer application must be oriented to usability and accessibility for the users from any

background. Referring to Table-1, usability or also referred to as accessibility of an application is defined in terms of five quality components [13]. Usually, an application is designed by a designer having these five components in their mind as a benchmark to ensure good applications with great accessibility level is produced for the users. Current computer applications do not address the issues face by the blind. It can be due to the fact that, the availability of screen reader is believed to perform it's' duty. And another reason can be due to the lack of awareness among the developers and also visually impaired are not even considered as a heavy computer user but research has proven that a large number of blind users are now very independent and learning new skills for survival.

Table-1. The Five Quality Components [16].

Components	Description
Learnability	How easy is it for users to accomplish basic tasks the first time they encounter the design?
Efficiency	Once users have learned the design, how quickly can they perform tasks?
Memorability	When users return to the design after a period of not using it, how easily can they reestablish proficiency?
Errors	How many errors do users make, how severe are these errors and how easily can they recover from the errors?
Satisfaction	How pleasant is it to use the design?

RELATED WORK

Mental model and blind internet users

In [14], the two-dimensional mental model created by the blind people when they are using touch screen with audio feedback was discovered. These authors have agreed that little work has been done on mental model for blind people. Mental model of blind people created from surfing a two-dimensional web page is investigated using two ways: firstly, is by using a touch screen display with audio feedback and the other using a screen-reader only. Users were given 10 to 15 minutes training on the each of this web page before the actual test was conducted. Five users are required to surf the pages twice using screen reader for the first time and using touch screen with audio feedback for the second time.

And another five did the same but using the touch screen with audio feedback for the first time and screen reader for the second time. After that, all users are given a set of foam blocks containing rough and smooth surface to construct the diagrammatic representation of the pages. Rough surfaced blocks represent the headings while smooth surfaced blocks represent the data. After the analysis of these diagrammatic representation, it shows that previously (using screen reader) the mental model of a blind user are in single column structure as quite a number of the representation stacked up the headings foam blocks in one column or both headings foam and data foam blocks in one column.

The same users had two dimensional mental model after using the touch screen with audio feedback which shows that these assistive technology able to deliver the content of a layout better than a screen reader. As these users, tend to stack up the headings foam and data foam blocks in two-dimensional (Table) format. However, their research also shows that the theory is applicable better if the layout is simple and not much different can be seen if the layout is complex. Therefore, it can be concluded that the two-dimensional mental model of the blind people is highly influenced by the complexity of a web page.

In [15], it was highlighted the issues faced by the blind society when navigating web pages. They assess the web pages based on one important accessibility point which is "Ease of navigation". They have also highlighted that "information scent" plays an important role whereby related information are grouped or arranged together and if a blind user skips their targeted topic, they will know it by realizing the scent of the current topic which is different from the previous topic. Though the research used a systematic evaluation process, the final outcome of this research was merely an identification of the accessibility level among the e-commerce sites in three different countries.

Difficulties faced by the blind users involving the sighted individuals

A study by Fernando Alonso *et al*. focuses on the development of dual graphical user interfaces for both visually impaired and sighted communities. They concentrated on how to come up with a design that will be able to satisfy both types of users [16]. The main concern of this project was to deliver a set of guidelines that can be used in the dual interface development in accordance with design for all principle. Even though these authors did take into consideration for the blind users, but the crossed checked guidelines had to drop out some issues that exist only in the visually impaired environment since those issues does not co-exist in the sighted user environment.

A research on the application of various stimuli to produce an effective pattern which is believed to increase the effectiveness of represented information to the user was conducted in [17]. The study suggested a design principle defining the stimulus pattern. It was a good study; however, the authors have failed to provide the

same experiment for all the users which are essential in deriving a conclusion. To eliminate biasness during the evaluation, a change in the sequence of the tactile pattern should be done instead of not giving certain patterns at all for some users. Therefore, this shows that it is not right to conclude if the actual test subject is differs for all the users.

Audio metaphors for the blind users

A conversational metaphor was proposed in [18], in which the metaphor focuses on the environment of 3D aural to allow the visually impaired for easy access of information. The proposed hypermedial model contains direct graph nodes and links which is used to map to certain speakers. Documents are represented by the nodes and the semantic relationships between the documents are represented using the links. A speaker is used to explain the detail of the nodes and links to the user. Many samples of real people were used to generate the 3D voice of speakers using an off-line way [18]. The authors have developed a metaphor for the visually impaired, the proposed idea focused only in audio environment and did not address the problems relating to computer accessibility or other usability issues related to blind users.

General improvement of the surrounding objects for the visually impaired

A study was focused on improving the interactions between a blind and everyday technological manmade object such as hand phones, software applications and etc. In this article, interviews and observations were used to address the obstacles faced by the blind in using the technological gadgets [19]. In order to improve the gadgets, it is important to know the obstacles faced by the blind community while using the surrounding objects. In another review, Gregory Petit *et al*. has generated tactile graphics by translating the illustrations in the schoolbook to be accessed by the visually impaired students. Two types of tactile hardware were used to generate the three different tactile rendering of an illustration [20]. A significant result was shown in displaying the tactile illustration by applying a workable methodology; however, they did not propose any framework that can be used by others at the end of the project.

MOTIVATION OF THE STUDY

Previous researches focuses on the problems faced by the blind in using a screen reader thus not highlighting the inaccessibility of computer application to them [14, 18]. Some other findings relating to touch sensation were lacking of empirical study, hence not supporting the contribution of touch sensation in learning computer application [14, 17, 20]. Our initial investigation reveals that in order for a blind user to select and to open an application such as Microsoft Word, the user need to depend on the screen reader to read the file name or the name of the application. This entire process takes plenty of time as user need to wait and listen to the entire icon description to be read. Based on our findings, blind users possess rich tactile sensation in dealing with their daily life. There is a need to conduct an exploratory study on blind users to address their problems in accessing computer applications and to evident the presence of the touch sensation as an important factor that contributes effectively in improving the accessibility of computer applications.

THE STUDY

The objectives of this study are twofold:

a) To examine blind user's experience on computer accessibility.

A thorough study will be conducted to identify the issues faced by the blind in accessing computer applications.

To examine how touch feedback may assist in accessing computer applications.

b) Touch sensation is known to work well with blind, however, in this study, it will highlight to what extent touch can contribute in accessing computer applications.

Personal interviews and in-depth interviews

Several informal interviews and four in depth interviews were conducted with seven blind users. One of them is the chairman, two of them are the instructors and four of them are the students. The age group of the interviewees is above 18 and their occupation varies tremendously. Interviews were chosen due to the nature of this method which has a very high response rate and also the method encourages the collection of true and correct responses addressing the nature of a problem [21]. The section below describes some of the questions asked during the interview session:

- Can you easily open a Microsoft word application?
- How do you know that you are opening a word document instead of an excel sheet?
- Have you ever made a mistake of opening other documents instead of the intended document?

The questions somehow addressing the same issue which is on the users' accessibility level when accessing an application during the learning process. The main objective of the researcher for asking the similar questions is to ensure the respondent's response is consistent and correct directing to the main problem of this research. Four in-depth interviews were also conducted to get the respondents to further open up about their concern and dissatisfactions when dealing with computer applications. In-depth interviews are useful when detailed information about a person's thoughts and imagination is required [21]. The section below highlights two of the questions asked during the in-depth interview:

- In your imagination, how flexible do you want/prefer the existing computer applications to be presented?

- In your opinion, what kind of senses seems appeals the most for a blind user?

These questions are designed to trigger the user to communicate their thoughts and expectations. When a user describes their thoughts and expectations in detail, it allows the researcher to identify the issues with the current application which does not satisfy the user's need.

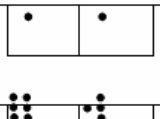
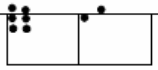
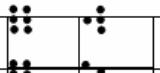
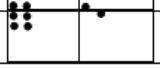
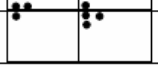
Observation

Apart from interviews, observation was also done for the entire period of Braille class and computer literacy class with the same set of participants from the interview session except for the chairman. The observation was also video recorded for multiple reviews. Observation was conducted due to the ability of this technique recording the actual users' behaviour. Observation eliminates the tendency of a respondent being bias or exaggerates their problems, captures the latest happenings and only actual behaviour is being captured [21]. The facial reactions and eagerness or lack of interest and irritations when a user encounters an issue while working with computer applications is studied to identify the negative emotions of a user and the factors which cause this negative emotion during their learning process. By identifying a users' emotion and factors which cause this emotion, more accurate information is obtained by the researcher to support the research questions of this research.

Hand-on activities

Hands-on activities in the form of two simple games were conducted with four participants to learn more about a blind person's habit in applying their existing experience on discovering knowledge. The experiment was performed with the intention to explore and to identify the effect of touch sensation to the blind users. Polystyrene blocks resembling the Braille cells are created and referring to Table-2, blocks were used to represent some of the frequently used applications. The representations are new patterns and are not represented in Braille code. The pattern of pop-up blocker and pattern of applications (apps) is a new creation due to no suitable Braille code is available for the representation while the combination of application (apps) code and alphabets referring to the first word of an application is used for the complete representation. These inventions are used to test the touch sensitivity level among the participants to explore the mental model of the blind users to show that touch sensation able to contribute in improving the accessibility of computer applications.

Table-2. Patterns of the blocks to represent applications.

Applications /Description	Block Pattern	Applications /Description	Block Pattern
1) Pop-up Blocker (new)		4) Internet Explorer (apps + i)	
2) Ms.Word (apps + w)		5) File (f + e)	
3) Ms. Excel (apps + e)		6) Folder (f + r)	

RESULT AND DICUSSIONS

Results of interviews

The information presented in Table-3, highlights the views of each key person in terms of issues faced by the blinds in accessing computer applications. Referring to the feedback, they have admitted that almost all of their students are unable to open a simple application such as ms.word. This simple application needed repetitive actions even with the aid of a screen reader such as listening and clicking repetitively.

Results of observation

The below analysis was done based on the observation of these selected group of participants and instructors. The video recorded observations were reviewed few times in order to ensure that only real issues are captured for analysis purpose. The second presented information in Table-4, points out the observed nature or characteristics of the key persons during both interview session and observation session.

The facial reaction and the body language of the participants were analyzed carefully to derive the below emotions as stated in the Table-4. The observation reveals that the instructor's emotion is divided into both positive and negative while the emotions of the students is mainly negative. This can be due to the reason that the instructor is an advanced user while the students are just the beginners. Based on Table-3 and Table-4, the main factors contributing to the "inaccessible" elements for the blinds are identified.

The main factors contributing more to the "inaccessible" elements for the blinds are arranged to the most frequently encountered to the less frequently encountered by the users and also according to the most frustrating to the less frustrating emotion felt by the users:

- Inability to open the right application.

- Blocks by the pop-up blocker.
- Having to listen repetitively the same information when missed out for the first time.
- Inability to know the actual content of a graphic.
- Inability to understand the foreign accent.

Table-3. Issues and views of key person on the blinds.

Role	Issues and views
Chairman	▪ The difficulty of the participants in following the entire program and some abandoned half way due to the complex learning process.
Instructors	**General issues faced by the students:** ▪ Totally helpless when a pop up blocker pops out and inability to understand the displayed graphics as the screen reader reads it out as "graphics". Expressed the need for additional assistive technology. **Issues faced by the beginner students:** ▪ Inability to open a simple application such as Ms. Word and inability to understand the words read by the screen reader due to the foreign accent
Participants/ Students	▪ Inability to understand the word read by the screen reader, especially when a word spelled using local language (Malay language) is read. ▪ Unable to figure out a pop-up blocker and inability to open some simple applications. Express the need of some other additional technology.

Table-4. Observed analysis of key person.

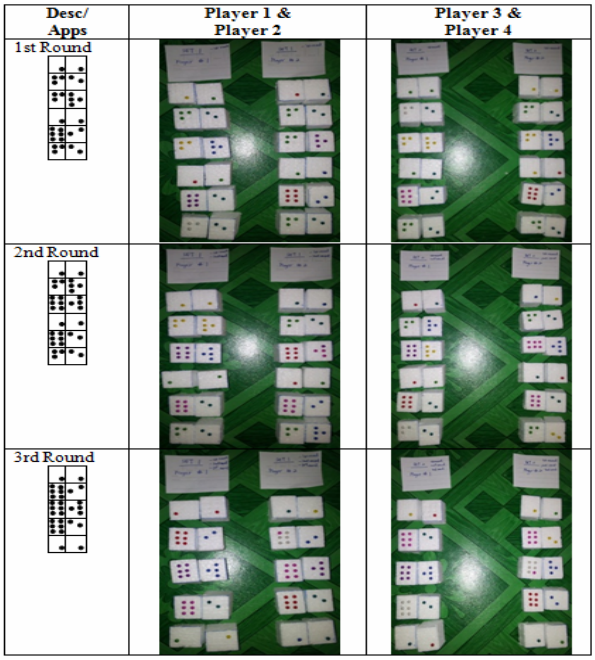
Role	Observed nature
Instructors	▪ Appears calm and confident in moving around the applications and able to confidently open some computer application and demo the class activities. ▪ Seems a little impatient while waiting for the screen reader to read each app and seems unhappy when a screen reader reads out a displayed graphic as "graphic". Appears not happy when a pop up blocker blocks their input.
Participants /Students	▪ Appears nervous and diffident when trying to open an app and appears frustrated when unable to open the right apps or when there is a pop blocker block the screen. Appears blank when a screen reader reads out a displayed graphic as "graphic" ▪ Looks annoyed when unable to understand the word read by the screen reader and having to listen again the same word in the attempt to understand.

Results of Hands-on activities

Two types of hands on activities were conducted with four players. Each player was given about 50 blocks of polystyrene. For the first hands-on activity (arrange the blocks activity), a list of applications names was read out and the players find the blocks that represent the particular application and arranged it in front of them. The second hands-on activity (Guess the blocks activity), blocks representing an application are presented in front of the players and they feel the blocks and guessed the application names. All the participants were given only 5 to 10 minutes to learn the representation of blocks pattern for each application.

Referring to Table-5, three rounds of arranging the blocks activity were conducted. At each round, five to six applications' names were read out and the players searched through the blocks given to them and arranged the correct representation of the apps. Comparison between the arranged blocks by the players and the actual blocks (as shown in Table-5) shows that the players are able to arrange most of the blocks correctly.

Table-5. Arrange the blocks activity.



Referring to Table-6, player 1 and player 3 are presented with blocks of description (a) and player 2 and player 4 is presented with blocks of description (b). Based on the observed result, all players are able to correctly guess the presented blocks except for player 2 as player 2 is someone who has become blind just recently and trying to adapt to blindness. Throughout this activity, the players expressed their opinion by pointing out that having Braille blocks to represent applications and pop-up blockers truly facilitates them in learning computer skills.

Table-6. Guess the blocks activity.

Desc / Apps & Icon Names	Player 1 (a)	Player 2 (b)	Player 3 (a)	Player 4 (b)
(a) Internet Explorer *(b) Pop-up Blocker*	√	√	√	√
(a) File *(b) Ms.Word*	√	√	√	√
(a) Pop-up Blocker *(b) File*	√	√	√	√
(a) Ms.Word *(b) Internet Explorer*	√	√	√	√
(a) Folder *(b) Ms.Excel*	√	X	√	√
(a) Ms.Excel *(b) Pop-up Blocker*	√	√	√	√
(a) Pop-up Blocker *(b) Folder*	√	X	√	√
(a) Internet Explorer *(b) Ms.Word*	√	√	√	√
(a) Ms.Word *(b) File*	√	X	√	√
(a) File *(b) Internet Explorer*	√	X	√	√

√ Able to guess correctly X Unable to guess correctly

Most of the previous research on assistive technologies is focused on the problems faced by the blind in using a screen reader thus not highlighting the inaccessibility of computer application to them [14, 18]. Some other findings relating to touch sensation were lacking of empirical study, hence not supporting the contribution of touch sensation in learning computer application [14, 17, 20]. Throughout this activity, the players or better known as the blind participants seems more confident and excited in using the blocks to represent computer applications. They have also expressed their opinion by pointing out that having braille blocks to represent applications and pop-up blockers truly facilitates them in learning computer skills. Having only screen readers as their assistive technology in learning computer seems complex for the blinds. Combination of screen reader and braille blocks will definitely help the blinds in learning the applications faster and in an easier manner.

CONCLUSION AND FUTURE WORK

This exploratory research investigated the issues and problems faced by the blinds society by conducting a series of interviews, recorded observations and hands on activities. Challenges faced by the blinds in performing a simple task such as opening an application in the computer has been highlighted. Views from various key personnel such as chairman, instructors and blind participants from the blind association has taken into consideration in concluding the problems of the blinds which shows that the usual representation of computer accessibility is not suitable for the blind IT users. And the analysis of the collected result has shown that the touch sensation of a blind can be used in identification of an object. In this case, braille blocks were used as the object. Thus, representation of a computer application using a braille blocks improves the learning process of a blind person. The hands on activity has also evident that touch sensation is an effective alert mechanism for the blinds in navigating through computer applications.

Hence, this study discovers the mental model of a blind user as an important contribution in improving the accessibility of computer applications. As a future work, the formulation of a usable model representing the mental model of the blind users will be focused onto. This model will be established to overcome the identified factors which contribute to the "inaccessible" element of an application for the blind. It is foreseen that a developer may use the model as a system development guide and as well as a system assessment guide in future.

REFERENCES

[1] http://en.wikipedia.org/wiki/Computer _accessibility - Accessed 30/09/2013/.

[2] Simon Bacellar Leal Ferreira, Ricardo Rodrigues Nunes, Denis Silva da Silveira, "Aligning Usability Requirements with the Accessibility Guideline focusing on the Visually-Impaired", in 4th International Conference on Software Development for Enhancing Accessibility and Fighting Info-exclusion (DSAI 2012), Elsevier, 2012.

[3] Queiroz, M.A. – Bengala Legal - http://www.bengalalegal.com/ - Access 2/4/2008.

[4] World Health Organization, "Global data on visual impairments 2010", WHO/NMH/PBD/12.01.

[5] Vaas, L. (2000, April 16). Web Blind Spots. eWeek.com. Retrieved October 24, 2012, from http://www.eweek.com/c/a/Web-Services-Web-20-and-SOA/Web-Blind-Spots/1/.

[6] Siti Nur Syazana Mat Saei, Suziah Sulaiman and Halabi Hasbullah, "Mental Model of Blind Users to Assist Designers in System Development", in ITSim, 2010.

[7] K. Potosnak. , "Human Factor: Mental Model: Helping Users Understand Software", September 1989.

[8] Mental Models and Usability, Retrieved on December 20, 2011 from:
http://www.lauradove.info/reports/mental%20models.htm.

[9] Sandra P. Roth *, Peter Schmutz, Stefan L. Pauwels, Javier A. Bargas-Avila, Klaus Opwis, "Mental models for web objects: Where do users expect to find the most frequent objects in online shops, news portals, and company web pages?", Elsevier, 2009.

[10] S.H. Kurniawan and A.G. Sutcliffe, "Mental Models of Blind Users in the Windows Environment", in Proc. ICCHP, 2002, pp. 568-574.

[11] Moloney, K.P., Jacko, J.A., Vidakovic, B., Sainfort, F., Leonard, V.K. E Shi, B., "Leveraging data complexity: Pupillary behavior of older adults with visual impairment during HCI", in ACM Transaction on Computer-Human Interaction, pp.376-402, 2006.

[12] Takagi, H., Asakawa, C., Fukuda K. and Maeda J, "Accessibility designer: visualizing usability for the blinds", in Proceedings of the ACM SIGACCESS conference on computers and accessibility, pp.22-26, Atlanta, 2004.

[13] Jakob Nielsen, "Usability 101: Introduction to Usability", by Nielsen Norman Group, http://www.nngroup.com, 4th Jan 2012-Accessed 02/10/2013.

[14] Ahmad Hisham Zainal Abidin, Hong Xie, Kok Wai Wong, "Blind Users' Mental Model of Web Page Using Touch Screen Augmented With Audio Feedback", 2012 International Conference on Computer and Information Science (ICCIS).

[15] Takagi, H., Saito, S., Fukuda K., and Asakawa, C., "Analysis of Navigability of Web Applications for Improving Blind Usability", in ACM Transaction on Computer-Human Interaction Vol 14, Sep 2007.

[16] Fernando Alonso, José L. Fuertes, Ángel L. González, and Loïc Martínez, "A framework for blind user interfacing", in ICCHP, 2006, pp. 1031-1038.

[17] Hiroaki Nishino, Ryotaro Goto, Tsuneo Kagawa, Kazuyuki Yoshida, Kouichi Utsumiya, Junji Hirooka, Toshihiko Osada, Nobuhiro Nagatomo and Eiji Aoki, "A Touch Screen Interface Design with Tactile Feedback", International Conference on Complex, Intelligent, and Software Intensive Systems, IEEE, 2011.

[18] Mauricio Lumbreras, Gustavo Rossi, "A metaphor for the visually impaired: Browsing Information in a 3D auditory environment", in CHI'95, 1995.

[19] Kristen Shinohara, "Designing Assistive Technology for Blind Users", in ASSETS, 2006.

[20] Gregory Petit, Aude Dufresne, Vincent Levesque, Vincent Hayward, Nicole Trudeau, "Refreshable Tactile Graphics Applied to Schoolbook Illustration for Students with Visual Impairment", in ASSETS'08, 13th-15th Oct 2008.

[21] Mukesh Kumar, Salim Abdul Talib and T.Ramayah, "Business Research Methods", Oxford University Press, 2012.