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ISSN: 0193-4120 Page No. 3094- 3100

Design Guidelines of Tangible Interaction Learning Model for Children with Dyslexia

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Article Info
Volume 81
Page Number: 3094- 3100
Publication Issue:
November-December 2019

Article History
Article Received: *5 March 2019*
Revised: *18 May 2019*
Accepted: *24 September 2019*
Publication: *14 December 2019*

Abstract:
Children with dyslexia are synonymous with having difficulties in learning to read. Dyslexic children commonly encounter visual, auditory and kinesthetic deficits which cause aninability to process the information in their brain despite no visual, hearing and motor impairments. The current teaching approach used is through traditional instruction such as books, flashcards, boards and many more. However, children with dyslexia require a multisensory approach which allows them to utilize all their senses, be it eyes, ears, voice, and tactile, in learning. Tangible interaction has gained a reputation as an alternative approach to bring richness and intuitiveness of a multimodal using physical tangible objects while interacting with a digital space. In order to provide the appropriate tools for dyslexic children in learning, design guidelines of tangible interaction learning model are established and supported by theories and other related works in the dyslexia domain. In regards to the design guidelines, an initial tangible interaction prototype called Disleksia Belajar 3dT is going to be developed for children with dyslexia. The prototype may serve as an interactive and supportive tool for dyslexic children to learn Malay language.

Keywords: *design guidelines, tangible interaction, dyslexia children*

1. INTRODUCTION

Children with dyslexia are found to have difficulties in learning, specifically in language. They struggle in reading skills, word recognition, differentiating the sound of letters, recognizing mirror letters, and forming syllables in sentences. Other challenges that dyslexic children may encounter are with spelling, writing and speaking. Currently, the traditional study materials such as flash cards do not provide any interactive and automated feedback. In addition, these materials have multisensory limitations, for example using alphabet blocks only allows the children to recognize the shapes (Abdul Hamid et al., 2017). Dyslexic children substantially use multisensory that allows them to use various senses such as touch, see, hear and kinesthetic movements in learning to read, correctly sounding out letters, and recognizing as well as distinguishing mirror letters.

In order to improve the dyslexics' learning approach, an appropriate TI learning model is required to promote interactive and engaging learning experiences. One technique in learning for dyslexic children that has created a greater interest is using tangible interaction (TI). TI offers various efficacy to provide an enjoyable collaboration and support in learning for children with dyslexia (Fan et al., 2016;Falcão and Price, 2010). Basically, TI allows users to use physical objects called tangible objects to interact with digital information in virtual space that encompasses spatial interaction and embodied facilitation.

In this paper, we present the design guidelines to develop a TI learning model and

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its prototype called Disleksia Belajar 3dT. The guidelines are derived from the theories of dyslexia and existing related works. The following sections are organized as follows; the second section presents the background study, while the third section describes the design guidelines for a TI learning model, and the fourth section explains the prototype. Finally, the paper ends with a conclusion and future work.

2. BACKGROUND STUDY

In this section, we describe the background study of dyslexia, theories of learning for dyslexia and TI in learning for children with dyslexia.

2.1 Dyslexia& Learning Theories

Dyslexia is a language disability, affecting reading and writing, speaking and listening. This section presents the common learning theories in teaching children with dyslexia and how we could applyTI design guidelines based on these theories which will be implemented in our work. Learning theories are conceptual frameworks describing how knowledge is absorbed, processed, and retained during learning. The following are the related learning theories which generally have been used for children with dyslexia. The first theory is the Orton Gillingham (OG)method that suggested using a multisensory approach in teaching the children. OG also suggested providing a kinesthetic-tactile support of visual and auditory associations that could help to correct the tendency of confusing similar letters and rearranging the sequence of letters while reading and writing (Reid and G, 2016).

The second theory is a dual coding theory that emphasizes the association between the symbolic system and sensory motor system. For example, in the visual modality, there are printed words and pictures. In auditory modality, there will be spoken words and sound events. For example, dyslexic children can associate between a picture of a tiger and also can relate to the spelling of the word ‘tiger’. Verbal and non-verbal events will function independently. According to Clark and Paivio (1991), verbal will process information such as text and audio while non-verbal will process visual information such as diagrams, animations and photographs. Finally, the kinesthetic or tactile learning theory allows children to perform tasks such as manipulate, organize and interpret the information that they have experienced through tactile (touch) or kinesthetic (movement) (Kinesthetic Learning Strategies,2017). Dyslexic children typically learn best when they can perform body movements, or use their hands and provide various senses of touch. One common kinesthetic teaching method used with dyslexia students is 'air writing', where students say a letter out loud while simultaneously writing it in the air(Teh et al., 2015).

2.3 Tangible Interaction in Learning for Dyslexia

There are a few TI systems developed for learning which have provided remarkable achievements to children’s learning (Marshall, 2007;Falcão and Price, 2010). These systems are moving the digital interface to the physical world which provide multimodality interfaces using various sensory means (Price et al., 2003, Antle et al., 2015). Most of the researchers such as Ndombo et al.(2013), Tittarelli et al. (2014), and Scruggs and Mastropieri (1994) recommended a teaching method for children with learning difficulties which must include visual, auditory and kinesthetic approaches. Based on the theories and research works, TI has a greater acceptance to support learning activities(Fan et al., 2016;Teh et al., 2015). TI also supports children with dyslexia in providing suitable learning material i.e. tangible objects, giving concrete examples such as concrete objects, as well as promoting learning by doing. The work by Zuckerman et al.(2005)stated that TI is more accessible to children, as well as a more intuitive interface for children with learning difficulties.

There are several attempts in TI which emphasize on the language processing disorder which is considered to improve letter

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sound correspondence, phonological awareness, alphabet recognition, distinguish mirror letters, writing alphabets, vowel and consonant recognition, and learning syllables (Abdullah et al., 2009; Husni and Jamaludin, 2013;Daud and Abas, 2014). These works have tremendously focused on the learning language for dyslexic children. For example, the work in Traceit (Teh et al., 2015) explained about the development of letter sequence using hands-on activity in real space for dyslexic children. The dyslexic children practice on letter tracing activities and perceive physical affordance like moving, manipulating and feeling the physical letters. TI is beneficial to dyslexic children as it encourages the children to perform on their own as well as increase their confidence and rely lesser on others when learning(Scruggs and Mastropieri, 1994). As a result, it is importantto include auditory and graphical representation as well as tactile feedback when designing TI for children with dyslexia. Another advantage thatTI canoffer isexploratory learning which is learning by doing. The children usually have low confidence, are easily distracted and rely heavily onthe teacher or parent during their learning process(Ahmad et al., 2012). Therefore, TI encouragesthe childrento examine and explore the task that they are unfamiliar with and createindependence in learning. It is also suggested that exploratory learning provides significant effectiveness and is an attractive strategy for learning, specifically for children with dyslexia (Marshall, 2007).

3. DESIGN GUIDELINES FOR TANGIBLE INTERACTION LEARNING MODEL

This section describesthe tangible design guidelines which are derived from the theories and related works that addresschildren with dyslexia. The specified design guidelines are considered to act as an outline when developing the tangible learning model system. The detailed design of the tangible learning model comprises of four main components (*1) presentation styles, (2) TI system requirements, (3) learning conditions*, and *(4) types of learning*(Figure 1).

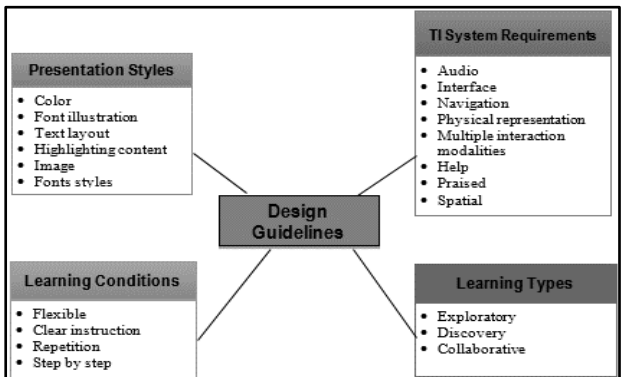

Figure 1.The Design Guidelines of Tangible Learning Model for Children with Dyslexia

1.***Presentation styles*** describe the way the information and content will be presented in the TI system. The style is specifically addressed towards the physical attributes such as sight, feel and emotion.Itis suggested to use sans serif fonts for dyslexic children asthe fonts areclear and do not have decorative strokeswhich may causeconfusionas well asprovide ashorter reading time (Rello et al., 2013). Besides that, Abdul Hamid et al. (2017)reportedthat font types using 'Comic SansMS' and 'Century Gothic'were introduced to Malaysian primary school students with dyslexia. Next,the background colour should make the text distinguishable and easy to read. Rello and Bigham (2017) proposed 10 different types of Irlencolours for dyslexia. Peach colour had the shortest mean reading time followed by orange and yellow. The use of warm background colours like

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peach, orange, and cream were used to stimulate their brain in reading. Other than that, the use of cool background colours such as green, blue and blue grey cancalm and relax the reader whilereading. The use of green and red colours should be avoided as these areconfusing and may bedifficult for colour blind users to read (Kriss and Evans, 2005; Madeira et al., 2015). In Rello et al. (2013), font illustration must be presented in large size with a minimum of 18 points and also avoid theunnecessary use of capital letters as childrenare morefamiliar with lowercase letters for sentence construction. Husni and Jamaludin (2013) mentioned avoiding using bold letters and use letters that haveno mirror effects. Aziz et al. (2013) suggestedto use a left justified layout and provide extra spacing between each text to avoid text crowding. The sentences must be short and simple in 15- 20 words per sentence as suggested by Madeira et al. (2015). Bullet points or a numbering technique is usedrather than long wordy paragraphs. The syllables can be shown using black and red coloursto identify the words.Besides that, underlines and italics of the text should be avoided as this will make the text seem to run together (Madeira et al., 2015).Moreover, the text should be highlighted and changed to green colourafter the whole sentence isread by the system. Lastly, useimagesthat are clear and colourful. Clark and Paivio (1991) described dyslexic children as needing verbal and non-verbal representation that will process through visual information like diagrams, animations and photographs in dual coding theory.

2.***TI system requirements*** comprise of components that will be included in a tangible user interface. Aziz et al. (2013) suggested to include audio feedback like a narration technique which will help to read out instructions. Also, an audio icon could be used to replay the sound of the letters and use a clear voice to recognize various letter sounds. Aziz et al. (2013) also suggested that the interface must display a simple design and the contents should not be cramped in a page. Ahmad et al. (2012) suggested to provide a smooth navigation to every picture as well as use pointing devices to identify particular words for future reference in learning. Spatiality characteristics refer to the detail of TI which is embedded in real space and users can make movement in real space when interacting in the space environment. The design of the tangible object needs to be considered, such as position and placement that interact with the system. Marshall (2007) mentioned spatial properties of TI which can be applied to allow dyslexic children to perform using the 2D or 3D object and interact in their space environment which supports reading activity. Next, the usage of tactile, video and audio will enable children with dyslexia to have the option of multiple interactions during learning. Minogue and Jones (2006) reported the use of tactile and kinesthetic approach which can enhance children's attention and memory in learning. This approach adopted the theory of kinesthetic that requires children to manipulate, organize and interpret the letters and flashcards through tactile or kinesthetic. Next, physical representation of tangible objects using 3D objects such as tactile letters can incorporate the use of textures to the physical objects. Fan et al. (2016) explained that dyslexic children require a multisensory approach to stimulate their brain and improve learning by having textures to enhance their learning. Next, praising which provides feedback or response to the activity that the dyslexic children performed will motivate them to recognize the next level of activity. According to Daud and Abas (2014), the sound of clapping or use of words will motivate them in learning. Finally, the help function could be in the form of audio that is embedded in the TI system. Dyslexic children need to be provided with short and simple help, and support using clear pictures.

3. ***Learning conditions*** include flexible learning style, clear instructions, step-by-step, and repetition. The flexible learning style allows dyslexic children to apply learning based on the need of the individual learners. The style also includes different levels of achievements and let others take part according to their own capability when using

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the system. Clear, simple and unambiguous instructions should be used to encourage dyslexic children to perform a task. Pontual and Falc (2014) stated that repetitive activities could strengthen the children's memory in executing at ask. Besides that, a step-by-step action allows them to perform certain activities such as arranging letters or constructing words. Dyslexic children could be guided to do reading activities, for example first displaying the word, and then the children will read it out loud. Next, ask them to say the letters in the word. Then, ask what vowels they see. Next, identify the letter at the beginning, middle and end of the word. This will help the children analyze the word and process it in detail (Abdullah et al.,2009). Lastly, dyslexic children may have difficulty memorizing information such as remembering the date, month and year in order and they really need the repetition method to aid them in remembering the sound of the letters. For example, in a learning activity using flashcards, the teacher may repeat the letters many times and pronounce the sound of the letter clearly to the dyslexic children (Pontual and Falc, 2014).

4. ***Types of learning*** that are supported by TI comprises of three types of learning namely exploratory, collaborative, and discovery. The exploratory learning encourages dyslexic children to examine and investigate the information and knowledge they received by exploring on their own. This technique promotes learning by allowing the dyslexic children to learn by doing (Izzah et al., 2008). Next, collaborative learning offers dyslexic children to work together in a group to solve a problem as well as to accomplish certain activities. Usually, the children work in a small group with 3 to 5 members to search for the answers, solutions and understanding of the activity (Dillenbourg, 2007). TI also supports collaborative learning by encouraging dyslexic children to exchange tangible objects with each other. Thus, this helps to improve their social interaction by having access to shared tangible objects to perform activities of solving problems together. The work in Abdul Hamid et al. (2017) reported a group of children using tricky shape dominoes to find the right pattern of the shapes and the children worked together to match the dominoes shape correctly. This technique develops their ability to see the similarities and differences also while improving their social interaction skill. Finally, discovery learning encourages dyslexic children to participate in active engagement. Dyslexic children can find solutions or answers on their own. Besides that, discovery learning provides high motivation to dyslexic children because they will have the opportunity to perform the activities independently (Abdullah et al.,2009).

4. THE PROTOTYPE

In this study, we have developed an initial tangible interaction prototype called Disleksia Belajar 3dT for children with dyslexia. The prototype is an initial version of the system which provides an interactive and supportive tool for dyslexic children to learn Malay language. This prototype was built based on the design guidelines. The prototype comprises of five types of learning modules focusing on Malay language. The first module is to identify letters which include vowel and consonant letters. This module will adopt the learning theories of OG and dual coding whereby dyslexic children will identify the letters and associate with the picture while reading. The second module focuses on spelling which teaches dyslexic children the spelling of consonant vowels in two syllables (CV+CV). In this module, dyslexic children will adopt the OG theories in which they need to recognize the syllables based on the sound of the letters. The third module focuses on syllables where dyslexic children will learn the syllables of the consonant, vowel, diphthong and diagraph words. Here, dyslexic children can categorize the syllable which allowing them to adopt OG and dual coding theories. The fourth module consists of matching letters where dyslexic children will match the initial letter based on the picture hint on the screen. This module allows dyslexic children to grasp the tangible letter

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and match correctly with the picture shown to them. This involve kinesthetic learning theories which require them to use their body movement to perform the learning activity. The final module is reading which allows dyslexic children to listen to the reading of a short paragraph in which applied OG, dual coding and kinesthetic learning theories. The module allows the children to arrange and manipulate the tangible letter using different senses. Then, they will interact with the tangible letters in their own space environment which they connect with the digital representation in the prototype system. The prototype system provides feedback to dyslexic children which offers intuitive audio narration, sound of the letters and 3D images when performing the 5 learning modules.

5. CONCLUSION AND FUTURE WORK

In this paper, we presented the TI design guidelines which are adopted in the learning model for dyslexic children. The guidelines consist of four components which are presentation styles, TI system requirements, learning conditions, and types of learning. The guidelines are also used to develop the Disleksia Belajar 3dTprototype that serves as a tangible learning application for dyslexic children to learn Malay language specifically in reading, spelling, and phonology skills.

6. ACKNOWLEDGMENT

Special thanks to Dyslexia Association Malaysia (DAM) for the great support in this research.We would also like to thank the University for funding the research to conduct this study.

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