ARPN Journal of Engineering and Applied Sciences

BacaMAX: ADDRESSING VISUAL DEFICIT TO FACILITATE READING FOR DYSLEXIC CHILDREN

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ABSTRACT

This paper proposes BacaMAX, an educational technology application to ease reading and text processing for dyslexic children. Being diagnosed as dyslexics, children (adults too) are facing greater challenge to learn to read. One of the main theories of dyslexia is due to visual impairment, which is not referring to the problems with the eyes but with the information processing that took place inside the brain. Apparently, those who are facing this problem trigger the wrong part of the brain to process text thus creating difficulties in reading. Aiming to reduce this issue, a specific design is proposed mainly for interactive applications to support reading for dyslexics. The design is tailored to meet the dyslexic children's requirement and need, taking into account the three dimensions of Interaction Design (IxD) and minimalist concept. To prove the concept, a high fidelity prototype, called BacaMAX, has been developed. The prototype was developed using the six steps of Goal Directed Design (GDD) method. Currently, BacaMAX is being tested in a primary school that runs special dyslexia classes. The application's effect to children's interest and learning experience has been positive.

Keywords: dyslexic children, interactive reading application, educational technology, BacaMAX prototype.

INTRODUCTION

Dyslexia has been well known for its effect on reading difficulties among children as well as adults. It is however, can be cured as mentioned in (Singleton, 2006). Methods to cure however, remain a challenge since researchers and teachers must find ways to best allow dyslexic children to develop links between what a word looks like, sounds, and means.

One of the potential way, as we see it, is to use computers to remediate the difficulties or at the very least, increase the interest to learn to read for dyslexic children. Not only that, computers or more specifically ICT, could transform teaching and learning (Sutherland, 2006). Thus, our aim is to build specific design suitable to help ease the difficulties that dyslexic children face when reading. It is important that these children are given the specific tool tailored to their difficulties so that we can help increase their interest, self-esteem, and motivation to learn to read.

The good news on dyslexia is that it can be 'treated', or perhaps the dyslexics are using alternative brain pathways to read correctly, but slowly, as have been mentioned. Since reading is an important skill to be acquired, methods have been proposed and used to teach them to read such as the multi-sensory method (Handler & Fierson, 2011; Birsh, 2011). Although the conventional method works well, the use of computers are seen promising as it provides a more interesting, fun environment for the children thus enabling them to be more motivated and less intimidated to learn to read (Southeast Comprehensive Center, 2008; Lerner, 1997). Therefore, based on our encounters with dyslexic children, we proposed a minimalist interface design to accommodate the eight colours proposed by Irlen (2005). The eight colours of Irlen are depicted in Figure-2. The colours are used as background for text to ease reading for dyslexic children. They are potentially effective in reducing the reading difficulties among the children.

DYSLEXIA AND IxD

The motivation behind the research and development of BacaMAX lies in our personal experience dealing with dyslexic children during data collection. We have found that these children can read, although with much difficulties, using certain font colours and background colours. For example, one dyslexic child can read fluently when text is printed on blue coloured paper. This triggers the need to investigate more on reading with suitable colours and how can these elements be designed together to leverage their reading ability and so reducing their difficulties, visually. The following subsections explain the study further.

Dyslexia and reading by the colours

Researches have witnessed that dyslexics are using somewhat different pathways in the brain to read using MRI images (Singleton, 2006; Shaywitz, 2003). There are three parts of the brain that make up the system for reading: 1) inferior frontal gyrus, which is located on the anterior part, for articulation and word analysis; 2) parieto-temporal, which is located somewhat in the middle part, for word analysis; and 3) occipito-temporal, which is located on the posterior part, for word form. Apparently, dyslexics are under activating the parieto-temporal and the occipito temporal pathways (the areas are not activated at all) as shown in Figure-1 (images are from Singleton (2006)). This is why reading is such a difficult task for them.

Figure-1 illustrates the difference of activated pathways in nonimpaired and dyslexic (a). The nonimpaired reader activated areas on the left of the brain, whereas dyslexic reader (fluent, but slow reader) created an alternative pathway that trigger activation of the anterior and posterior parts of the brain (b) (Singleton, 2006).

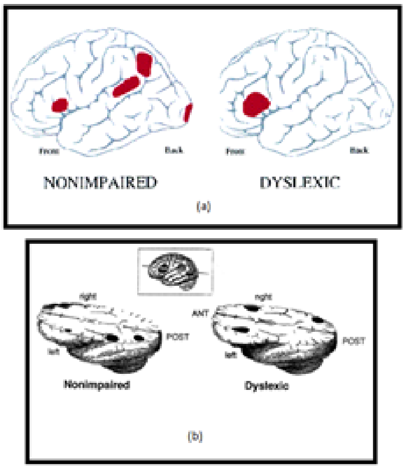

Figure-1. The difference between nonimpaired and dyslexics's brains (source: Singleton, 2006) .

For some accurate but slow dyslexic readers, research have shown that they are using a slightly different pathway to read, i.e. activating the other secondary systems for reading – on the right posterior part as well as on the frontal area on the right. Why such conditions occurs? Table-1 briefly describes the theories and the effects to dyslexic children.

Visual impairments that are mainly caused by visual deficits and low working memory can be potentially reduced by providing a carefully designed reading interface to minimize the difficulties. Temporal or timing difficulties also cause dyslexic children to have problems in visual information processing. However, this argument does not conflict with the established statement that visual impairment, particularly referring to the physical problems of the eyes and vision, do not contribute to reading difficulties (Stein & Walsh, 1997). Our intention is to focus the reading interface design such that it could ease, somehow, the text information submitted by the visual cues to the brain. In other words, it is aimed so that the proposed design could ease the information processing ability sent from the eye to the brain.

Table-1. Major theories underlying dyslexia and the effects on dyslexic children (source: Beneventi, Tonessen, Ersland, & Hugdahl, 2010; Paulesu, 1996; Ramus et al., 2003; Paulesu et al., 1996).

Theory	Main cause	Description	Effects to DC
Phonological deficit	· genetic/brain difference - perisylvian part of left hemisphere - serebral deficits	· phonological coding can be referred to as systematic relationship between an alphabet and its sound.	· difficulties in identifying sequence and sounding out words. · problems with rhyme, mix of sounds, noneword repetitions. · confused with similar sounds (e.g. *paku*, *pasu*).
Low working memory	Deficits in short term memory in the front lobus of the brain, right hemisphere (video), and left hemisphere (audio).	Memory processing involving 4 main components: 1)audio memory (including phonology); 2)visual memory (including orthography or the shape of words); 3)procedural or movement memory (a.k.a. habit memory, e.g. riding a bicycle); 4)semantic memory.	· inefficient use of working memory. · problems in translating visual information to phonological representation, thus limiting the ability to learn new words when reading.
Visual deficits	deficits in visual magnocellular system (a group of neurons as path for transferring electrical signals from eyes to the brain).	Dyslexics failed or have difficulties to process information sent from the eyes.	· unstable and vibrating binocular vision. · confusing the sequence of letters and causing weak memory for visual information.
Temporal or timing difficulties	· magnocellular differences (audio or visual). · only effects temporary processing.	Deficits in the part of the brain that controls sounds and rapid visual information.	· DC have difficulties in processing rapid sounds and visual information. · DC need more time to learn, process information, and give response.
Automaticity	Deficits in cerebral parts of the brain.	Most tasks are performed using a combination of various skills. If all skills need to be performed in parallel, they have to be done spontaneously (automatically).	· DC will use too much load when asked to perform new tasks or complex tasks. · DC normally are lacking automaticity especially in reading, calculation, and motor skills.

VOL. 10, NO. 3, FEBRUARY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

As colours play important role to ease reading for them, so as the interaction between the reading application (computers) and the users (dyslexic children). Thus, the eight colours are chosen and the child-computer interaction is also taken into serious consideration towards a reading application that really helps. The following subsection discusses how these two are put together to formulate the proposed design.

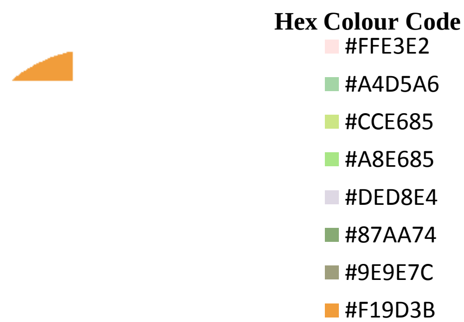

Figure-2. The eight colours proposed by Irlen (2005) with the corresponding hexadecimal colour codes.

Interaction design

Interaction design (IxD) emphasizes on design for positive user experience, especially for interactive devices or computer applications such as a reading application. Three dimensions are considered in coming up with a suitable design that include form, content, and behaviour. A form represents the physical layout of the interface such as colours, fonts, buttons, labels, and contrast. Content refers to what is being presented to user, in this case the text (in Malay language). Behaviour denotes how the content is presented to user and thus concerns with user experience when using an application. Thus, the eight colours of Irlen are fit into the form design to promote positive experience (ease of reading) that an application should present while presenting its content.

The form dimension also includes suitable font type, suggested to be any font from the sans-serif family, and suitable colours for font face (Fakhrul, Husniza, & Zulikha, 2013). Interestingly, we have discovered that the children read better when asked to customize their own font colours. Hence, the font colours (different colours for different syllables) are made flexible where each of them could have their own preferences. The behaviour of the application, on the other hand, is somewhat straightforward and simple. The reading application displays the words, phrases, or simple sentences on screen so that the children can read them, record their reading, playback the recording, or click for help. Such behaviour is important to triggers more than one senses while they are reading, i.e. using their vision and hearing to read and to listen to the correct reading to allow them to correct their mistakes. The translation of the design into the actual reading application, BacaMax, is discussed in more details in Irlen (2005).

In a nutshell, BacaMAX encapsulates the design such that the difficulties associated with visual deficits, again not referring to the physical problems of the eye, can be potentially reduced for two reasons: 1) the IxD design of all three dimensions could reduce their difficulties in reading, which also indicates reducing their cognitive load to process text and thus read better; and 2) the child-friendly design could trigger interest and pull their attention as well as motivation to read and at the same time be engaged in the reading process.

BacaMAX: THE PROTOTYPE DEVELOPMENT

BacaMAX is developed using rapid prototyping where the IxD dimensions are translated into the physical design of the application. It is constructed to accommodate three levels of word reading and simple phrases, all in Malay, where every vocabulary are randomly selected from the primary school syllabus, mainly coming from Buku Panduan Pelaksaan Program Pemulihan Khas (Masalah Penguasaan 3M) (Jabatan Pendidikan Khas, 1999). This book is being used by teachers to introduce words to the children and teach them to read correctly.

The vocabulary of BacaMAX is separated into three levels – easy, medium, difficult, based on the consonant (C)-vocal (V) patterns in a particular word. The CV patterns are important as Malay is a syllable-based language, i.e. they are constructed based on combinations of syllable. For example, the word 'ibu' (mother) and 'bapa' (father) are constructed using two syllables (i-bu and ba-pa) but are categorized into two different CV pair: 'ibu' falls under the V+CV pattern whereas 'bapa' falls under CV+CV pattern. BacaMAX's levels are divided based on the complexities of CV pair in a word. The vocabulary also includes ten sentences with mixed syllable patterns. The CV patterns are those syllable patterns listed in the syllabus as carefully outlined in the above mentioned book. Table-2 listed example of words for each syllable patterns grouped in the three levels of difficulties in BacaMAX.

Table-2. Example of words outlined in their respective syllable patterns with different level of complexities. The more complex the pattern is, the more difficult it is to dyslexic children.

Easy		Medium		Difficult	
Word	Syllable pattern	Word	Syllable pattern	Word	Syllable pattern
Ibu	V+CV	kereta	CV+CV+CV	cendawan	CVC+CV+CVC
bapa	CV+CV	menara	CV+CV+CV	terowong	CV+CV+CVCC
bunga	CV+CV with diagraph	telinga	CV+CV+CCV	memancing	CV+CVC+CVCC with diagraph
wad	CVC	kangkung	CVC+CVC with diagraph	merangkak	CV+CVCC+CVC
udang	V+CVCC	serunai	CV+CV+CVV	bungkusan	CVCC+CV+CVC

In the difficult level, sentences are also included to enhance reading performance to dyslexic children and introduce them to a more challenging reading – sentence level. Although the sentences are constructed based on a variety of syllable patterns, which also include simple words such as 'itu' and 'beli', they are treated as difficult as they would require the dyslexic children to process more text in order to read the whole sentence. Thus, these make up for the design of the content dimension of IxD.

The content dimension is incorporated together with the form and behaviour dimensions in an exclusive design specifically tailored to meet their need. The proposed design is translated into actual implementation of BacaMAX using Adobe Flash CS6 as a tool to develop the reading application. BacaMAX performs a simple behaviour in that it allows the children to customize their font colour and background colour preferences, as have been discussed. Functions as voice record and replay are also included to enhance the reading experience. The minimalist concept is transformed into a child-friendly interface, with very minimum text, to reduce their cognitive load while trying to read the word on screen. The interface design is kept simple but yet still attractive so that every child is not distracted with other elements on the screen and thus could focus more on the word or sentence that they are supposed to read aloud. Help is also provided should they are not sure how to read the words. To get help, just click on the green dinosaur, we call it Dino, and it will read the sentence for them. Figure-3 presents a few samples of BacaMAX's screen shots.

As illustrated in Figure-3, notice that the interface presents very mininal text – the name of the application, i.e. BacaMAX with a small copyright notice printed at the bottom; the target text, which is displayed on the stone-like frame that Dino is holding; the functions (record, replay, save, colour customization buttons for foreground, i.e. for each syllable in a word, and background) are not at all labelled. This is the minimalist concept that we try to put forward so that the children are more focused on the word/sentence that they are supposed to read and not any other text. It is promising that this design could somehow result in a more dyslexic-friendly child-computer interface that would leverage their reading ability thus reducing their difficulties.

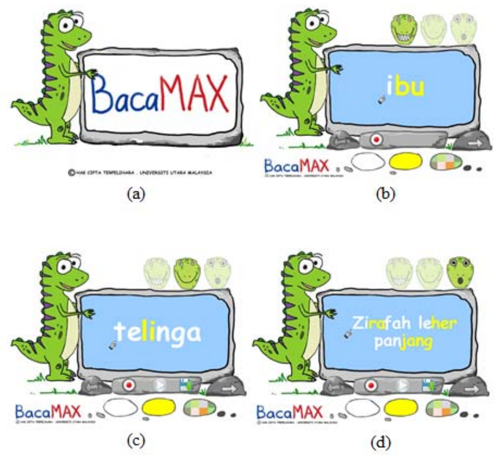

Figure-3. A few example of BacaMAX's interfaces: (a) denotes the main interface; (b) presents level easy (c) shows a medium level word; and (d) displays a sentence with combinations of syllable patterns. The three Dino heads each represents a level.

RESULTS AND DISCUSSION

An integrated model of BacaMAX has been developed since 2009. The model intent to integrate impairment and its related remedial interface. We have successfully developed the first version of BacaMAX prototype a year later and the prototype was tested by students from Sekolah Kebangsaan Jalan Dato' Kumbar (SKJDK). Responses, feedback in terms of its usefulness and suggestions for improvement were obtained from students and teachers. Taking the feedback as input, we have also successfully developed the second version of BacaMAX such as the one shown in Figure 3. This version has also been packaged into an Android apps where it is available for free and can be downloaded from Google Play Store (search: BacaMAX). We also observed that students prefer the Android version running on tablets/smartphones as compared to the prototype available on PCs/laptops. Indeed, it is another evidence that using a device with minimal control buttons are more preferable by the dyslexic children.

Version 2 of BacaMAX is a much more efficient alternative where the students response can be transformed into voice replay to produce a real student-centered learning experience. The students are encouraged to take the challenge and improved on their own. No one there to blame them if they make mistake, because no one knows. This is very crucial for dyslexic children because they do not want others to know that they make mistake, and also they are tired of being reminded of their slips in reading.

However, such a challenge need careful monitoring by teachers, as authoritative evaluator on the students' achievement, from time to time. For this specific purpose, we are working on the speech synthesis component of BacaMAX to better enable teachers to monitor the students' progress. This component is supposed to provide feedback on the percentage of accuracy of the verbal reading, where teachers can monitor the progress periodically (weekly or monthly manner).

Currently, BacaMAX is being tested in SKJDK. Early observation indicated that in terms of colours, the students prefer white fonts on the pastel coloured background (i.e. Irlen background colours, Figure-4). For normal students including us, such combination are very subtle and does not highlight the text much but it allows them better view of the text. Thus, it is however works well for the dyslexic students.

Figure-4. Dyslexic children who used BacaMAX prefer these combinations of foreground and background colours.

CONCLUSIONS

It is undeniable that the conventional method works reasonably well to address the reading problem faced by the dyslexic children. However, the advancement of computer technology specifically in dealing with speech input, voice replay, rich visualization features, and seamless user controls made reading more interesting, fun and meaningful for the children. As such the children are seem to be more motivated and less intimidated to learn to read, at least as experimented in this study. By no means is this study to replace the conventional approach but BacaMAX can complement the 'treatment'. For that reason BacaMAX is made available on multiple platforms such as an Android apps running on tablets/smartphones as well as an application running on PCs and laptops. Future improvements include extending the function in which teachers can input their selected words into BacaMAX so as to enrich its vocabulary and thus enable the children to try reading different words. More features are expected to be incorporated for the enhancement of BacaMAX.

ACKNOWLEDGEMENTS

This research is financially supported by the Fundamental Research Grant Scheme of Ministry of Higher Education Malaysia (MoHE).

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