Let's Play with Colours: BacaMAX User Interface for Dyslexic Children

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Abstract. Reading difficulties are synonymous with dyslexic children, whose unique condition is due to dyslexia. One of the major theories of dyslexia is visual deficits which are not caused by the problems with the eyes but with the information processing that took place inside the brain. Hence, to assist dyslexic children reading we propose BacaMAX, a visually stimulating voice replay application designed carefully to ease them reading. The application is a result of years of study on dyslexic children and their colour choices. Bedside experiment with the children was carried out on a systematic background and a foreground colour scheme, specifically on syllables, words, and short sentences. This paper aims to deliberately discuss BacaMAX interface design that started with our beta version to the current improved version. Rapid application development is employed as the methodology to develop prototypes and user acceptance test is employed to test the prototypes on real users. As the result, all versions are presented and discussed.

Keywords: Interface design for dyslexic, reading application, visual stimuli and colours, dyslexia and reading.

1 Introduction

Dyslexia's secret that impedes reading abilities has been unveiled through research that shows pertinent deactivation in the parts of the brain that are normally used for reading. This unique condition can be clearly visualized through *functional magnetic resonance images* (fMRI) images, which also reveal that dyslexics are using a different pathway in the brain in order to read [1, 2].

Normally, three parts of the brain are activated for reading: the inferior frontal gyrus, the parieto-temporal, and the occipito-temporal. These three parts are located on the left side of the brain where the frontal gyrus sits on the anterior part (the front), the parieto-temporal is located somewhat in the middle part, and the occipito-temporal occupies the posterior part of the brain. The three parts combine together to form a system for reading where each of the parts play roles such as articulation and word analysis, and word form.

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Dyslexics, however, did not activate the aforementioned brain parts for reading but rather activated a different route as illustrated in Fig. 1 (source from [1]). The fMRI images reveal that dyslexics are under activating the parieto-temporal and the occipito-temporal pathways where these two areas fail to be activated at all when dyslexics were asked to read. Therefore, due to the under activated reading areas of the brain that dyslexics have the difficulties to read and process text information.

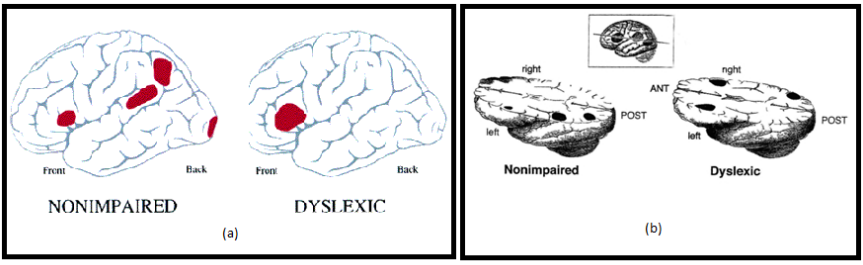

Fig. 1. The different activated reading pathways between normal reader and dyslexic reader (a). The normal reader activated areas on the left of the brain whereas dyslexic reader uses alternative pathways to read (b) [1].

The question is – what makes such conditions occur? What can technology offers to help them read and how? Therefore, this paper presents theories underlying dyslexia and deliberately discusses them in relation to BacaMAX, an application with its design specifically tailored to dyslexic children's requirements that aims to reduce their difficulties in reading.

2 Dyslexia and 'Twisted' Visual Cues

The universal theory of dyslexia is the phonological deficit theory [3-8], which says that the difficulties to read amongst dyslexics are caused by the impairment of the brain to process phonological input, as evidenced by the fMRI images. One of the causes for reading difficulties is due to problems with visual processing. It is important to note that the visual problems here do not refer to the physical problems of the eyes but instead, they are referring to the processing of visual cues sent by the eyes to the brain that supposedly targeting the reading pathways to be activated. Unfortunately for dyslexics, it didn't.

A number of theories have been put forward in relation with visual impairments namely visual deficits, temporal and timing difficulties, and low working memory. Table 1 highlights and briefly describes the three visual-related theories of dyslexia [9-11]. The theories presented in Table 1 serve as fundamental idea for designing a suitable interface for dyslexic children so that, somehow, their difficulties in reading can be reduced and thus, provide them a better means for reading.

Table 1. Visual-related theories that affect dyslexic children (DC)'s ability to read

Theories	Main cause	Description	Effects
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.

Referring to Table 1, the difficulties to read that are caused by visual impairments, i.e. visual deficits and low working memory which can be potentially reduced by providing a specifically designed reading interface for them. Note that, temporal or timing difficulties also cause dyslexic children to have problems in visual information processing. Nevertheless, this theory 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 [12]. After all, the theories here suggest that phonological deficits occur due to the problems in processing visual information sent to the brain for reading. For some unique reasons, the information is sent to the wrong parts of the brain creating either a different pathway for reading or no activation at all.

Inspired by the nature of the visual-related problems for dyslexics, we therefore intend to focus the reading interface design such that it could ease, somehow, the visual cues (of text) submitted to the brain. The design is aimed to ease the

information processing ability sent from the eye to the brain by providing stimulating visual presentation of text on screen for them read. This includes a set of identified requirements as depicted in Fig.2.

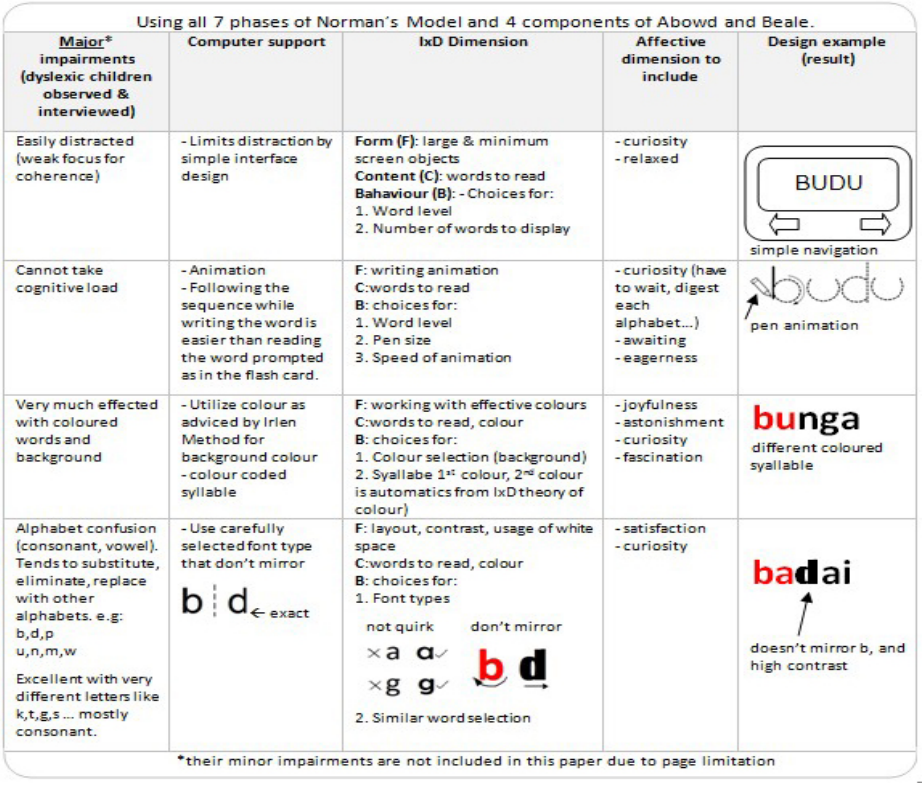

Fig. 2. A design specification for dyslexic children's reading application [13]. The specification outlines the dyslexic children's impairments and suggested some computer supports. Some of the examples are also presented.

As illustrated in Fig. 2, special consideration on their need to have suitable and adjustable background colours, different coloured fonts to highlight syllable boundaries in a word, as well as adjustable font types and sizes, for example, would ease the learning process. The suggestions for computer support mainly focusing on the interface design and presentation of text on screen for dyslexics to read are indeed important for developing reading application for them. Therefore as depicted in Fig. 2, the interaction design dimensions – forms, content, and behavior – are emphasized together with certain sample of design that would create positive affect on dyslexic children. Nevertheless, the design leads us to 'play' with colours to design an effective and affective reading application.

3 Playing with Colours

With the unique reading pathways for dyslexic children, experimenting with colours might result in an optimal design to increase the potential for these children to read thus easing the process of reading. After all, the good news about dyslexia is that it can be remedied. If not, the dyslexics can actually read by activating 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 [14, 15].

Although the conventional methods do wonders in teaching them skills they need to read, using computers seems both potential and promising as it facilitate a more interesting, fun environment allowing them to be more motivated and less intimidated to learn to read [16, 17]. Since using colours is important to create ease of reading, thus facilitating the visual cues, we chose to select colour schemes based on the Irlen method [18] for text background colours (see Fig. 3). As for the text colours, we opt to allow the children to select their own colour preferences that they feel most comfortable with. Interestingly, from our observation we have discovered that the children read better when using their own choice of favourite colours for the text.

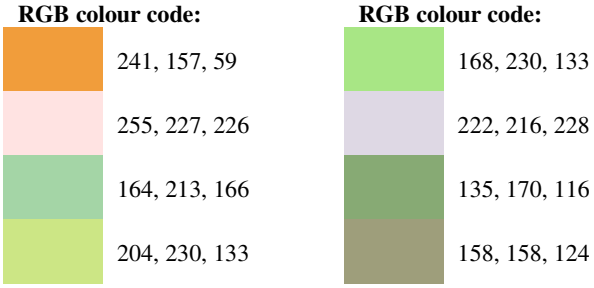

Fig. 3. The eight colours proposed by Irlen method [18] to be used as a way of 'treating' visual problems for dyslexics. The colours are presented together with their respective RGB colour code.

Since 2009, we have worked with dyslexic children of age 9 to 14. Their condition ranges from mild to severe dyslexia. We opt for personal bedside coaching and experiment since the children tend to lose attention very quickly. Although most studies [19, 20, 21] discovered 10-15 minutes attention span, we found that their attention span in reading Bahasa Melayu words is between 5 to 15 minutes, at most. The 5-minute attention span, specifically to the visuals being presented to them, is observed in those hyperactive dyslexics. Changing the visual contents such as colours and fonts size, or adding animation to the related texts help extends the duration.

We begin with coloured pencils and coloured papers and a set of vocabulary ranging from one to three syllables of all 23 syllable patterns of Bahasa Melayu. The first goal of this experiment was to show that different child has a different colour choices and that their choice can be used to improve their attention span and thus their

reading ability. The second goal was to set an entry level in deciding on colours, fonts, and overall user interface for the computer prototype we intent to build.

4 BacaMAX

The experiments disclose problems that can easily be solved by colours. Of all the problems faced by the dyslexic children, seven problems with regards to reading can be mellowed. They are (1) syllable identification, (2) similar-sounding word confusion, (3) little interest in words and letters, (4) jumbling up letters or whole words, (5) reversal in reading words, (5) visually irritating glare from white paper or white background, and finally (7) their attention span.

Taking the results from our manual experiments with coloured pencils and coloured papers, we move on to developing the computer prototype, given a persona name, BacaMAX. Since 2009 we have had four versions of BacaMAX being tested by the children. Just like the experiments conducted on papers, experiments were conducted on a computer screen. With BacaMAX, the children have control over the background colour, syllable colour and font size. From each version, feedback from teachers and students were gathered in order to come out with improved versions. Figure 4, 5 and 6 elucidate the first three versions of BacaMAX.

4.1 BacaMAX: Beta Version, Version 1 and Version 2

Figure 4 illustrates the earliest version of BacaMAX (2009) that considers only one colour for the text, i.e. black, and eight colours for the background. The goal was to test on the types and sizes of fonts preferred by the children. We also wanted to confirm that Irlen colours [18] are still valid as background colours that are suitable in assisting reading among the dyslexics.

Fig. 4. The beta version of BacaMAX

Version 1 (2010) (illustrated in Fig. 5) is the modified version of BacaMAX that uses two distinct colours to represent each syllable in a word. The colours chosen are

black and red, while the background colours remain the same eight. Black and red is the colour used by most books in early readings for normal children. The feedback that we gather was that the children prefer to have control on their choice of colours not only on the background but also on the syllable colours.

Fig. 5. BacaMAX's version 1

The improvement is reflected in version 2 of BacaMAX. In this version, the background colours still remain to be eight in total, are chosen as suggested in [18]. Another feature was added, i.e. the 'teacher' who is supposed to assist the children in case they need any help with the word. This version is a total makeover from version 1 where the minimalist concept is used in designing the user interface.

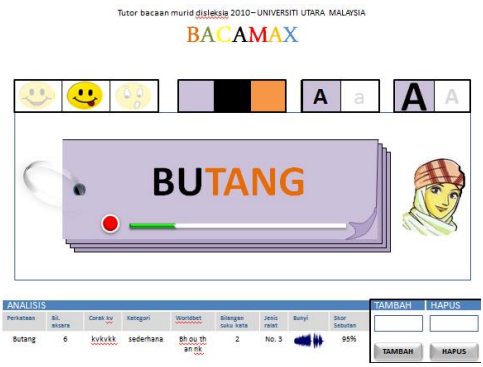

Fig. 6. The interface design for BacaMAX version 2. The smiley represents the difficulty level, the three colour represent the background and syllable colours, the A represents fonts size and fonts case (upper/lower).

4.2 BacaMAX: Version 3

In version 3, the concept designed for BacaMAX in version 2 is retained. However, the current version infused its design with a more child-friendly look. In version 3 a

cute, green dinosaur called Dino is introduced while maintaining the minimalist concept with minimum text presented on the screen (Fig. 7). Dino is replacing the 'teacher', which is featured in the previous version, to function more like a 'help' button where users can click on its body to hear the correct reading of the words and sentences. The interface is designed in such a way that there are no other texts to read other than the word required.

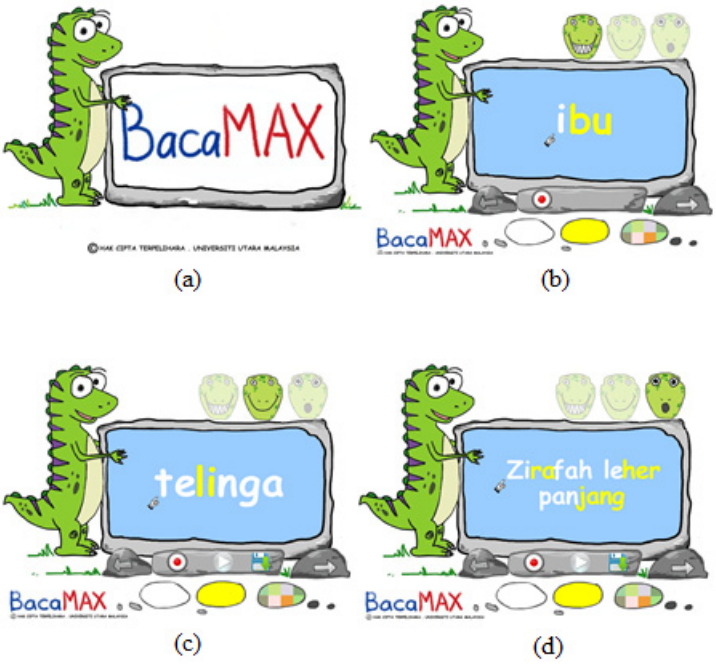

Fig. 7. Snapshots of BacaMAX's interfaces where (a) denotes the main interface; (b) presents level easy; (c) presents the medium level; and (d) presents the difficult level that involves words with complex syllable patterns and short sentences. The three dinosaur heads each represents a level.

5 BacaMAX's Achievements

Experiments with Version 3 of BacaMAX are still in progress at one of the schools in Kedah running a dyslexia class. Initial results of the experiment can be reported in terms of its general achievement in helping children reading words (and some sentences) in Bahasa Melayu. The achievement in terms of improvements in reading is clustered into seven problems mentioned earlier and listed in Table 2.

Table 2. Seven problems of which colour assistance facilitates some achievements

	Problems	Colour assistance	Achievement
1	Syllables identification	Different colour for different syllable (using their own colour choices)	*bu+nga* instead on *bun+ga*
2	Similar-sounding word confusion	Different colour for different syllable (using their own colour choices)	*duka, duga, buka*
3	Little interest in words and letters	Repeat same letter/word with different font colour/size/type	Increase attention span
4	Jumbling up letters or whole words	Use totally different syllable colour stroke and contrast for similar words	*kelapa* and *kepala* can be differentiated
5	Reversal in reading the words	Always use different colour for b/d/p when they appear in one word	Able to differentiate *b/d/p*
6	Glare from white paper or white background	Change paper colour/background on computer screen	Increase reading speed, with accuracy
7	Attention span	Combination of all the above	For hyper active dyslexic: from 5 to 10 minutes (100%) For normal dyslexics: no improvement in attention span

Yet to be observed specifically for readings are the (1) difficulties in acquiring phonic skills, (2) slow reading speed (with repetition in reading certain syllables), (3) inaccurate reading, in the case of omission of consonant/vowel/syllable/word, (4) frequent loss of the place when reading longer texts (an animation strategy would help), (5) an inability to skim through or scan over reading material, (6) a high degree of distractibility when reading, i.e. issues with gaining attention, (7) perceived distortion of text (this is for severe cases where words may seem to float off the page or run together)

Other than colour, animation is another viable strategy that can be ventured in order to assist dyslexic children in reading. Issues with frequent loss of the place when reading longer texts and distraction can be tackled with a smart animation strategy.

6 Conclusion

The design for BacaMAX's interface applies the concept of reading by colours proposed by Irlen for her exceptional effort to help people with reading disabilities to read. Since dyslexics are having difficulties, 'playing' with colours seems to be a potential solution that could leverage their reading, or at least ease their reading. The interface design, which emphasized on minimalist concept design, does indeed manage to ease reading for dyslexic children reading in Malay. Not only the interface has been designed exclusively for the children, the content and its presentation are designed specifically for them too. The words and simple sentences, which are grouped in three levels denoted by three dinosaur heads, are presented according to the syllable patterns. Here is where colours play their role – each syllable in a word is represented by a colour that is chosen by the children. BacaMAX has other features

such as recording and voice replay, however only features related to colours are discussed in this paper. While further research remains necessary to include other explanatory factors, this study provides strong evidence that poor reading performance in dyslexia stems from visual processing deficit where colours can be of valuable help.

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