Mobile Dyslexia Screening Test: A New Approach through (Multiple-Deficit) Model Mobile Game to Screen Developmental Dyslexia Children

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Abstract— Dyslexia is a global phenomenon, it is reported that around 70% of children with learning disability is dyslexic. It is estimated around 314,000 Malaysian school going children are dyslexic and few of them received proper and suitable teaching method. With this huge number of school population percentage are at risk of dyslexia an intervention program are in serious needs. Presently there is no Malaysian standardized instrument to screen children with developmental dyslexia in the school environment especially for the preschool children. Teachers experience is the sole attribute that initiate the process of screening dyslexic in the school environment. It is understandable that early detection would lead to a proper treatment and remedial program. It is a great necessity to develop a simple screening test that could help teachers and parents to diagnose dyslexia symptom in a child based on multiple deficit theories. We propose the idea of a single series of game that would be able to screen dyslexia through mobile approach to cope with the problem of non-standardized screening method, untrained teacher to recognize the symptom of dyslexia, and ill awareness of the dyslexia problem which incorporate Multiple-deficit theories of dyslexia and mobile game.

Keywords – Learning Disabilities, Dyslexia, Dyslexia Screening, Multiple-deficit Theories, Mobile Game.

I. INTRODUCTION

Dyslexia is a global phenomenon, it is reported that around 15% to 20% of world population has a learning disability [1] and most of them is dyslexia (70%-80%) [1]. In the U.S.A the figure is around 10%-17% [1], while in France and Czech the number is around 2%- 5% [2][3]. With this alarming figure many researcher has conducted various of research on this topic focusing broadly from what cause dyslexia, the screening process of dyslexic and the remedial process that they should proceed.

Malaysia is as knowledge based society that which most of the time using the exam oriented method of classification [4]. It is estimated around 314,000 school going children are dyslexic[5]–[8] and few of them received proper and suitable teaching method for the remedial [9]. A research conducted by [10] in the state of Penang, Malaysia identified that 9.4% of grade 1 student has learning disability and most of them (92.3%) had severe reading problem.

In 2003 it is estimated that around 9.1% and in 2004 is around 7.7% of school population are dyslexia [11]. These numbers are quite lower than the estimated figure which is 10% of the school population[6], [7], [9]. A study conducted to a random group of preschool children shows that 27.5% of the samples are at risk of dyslexia and 15% are highly at risk [12]. With this huge number of school population percentage are at risk of dyslexia an intervention program are in serious needs [5], [13]. But what happen is that the help for dyslexic children are isolated and misguided [13]since many of dyslexic student are not properly identified.

Presently there is no Malaysian standardized instrument to screen children with dyslexia in the school environment [8], [11], [14]. Teachers experience are the sole attribute that institute the process of screening dyslexic in the school environment [14], what happen to a new teacher that have lack of experience and knowledge of dyslexic student.

Early intervention is the key to help dyslexic children successful on their study and later in life [8], [15]. In order to have early intervention and remedial program, early detection has to be made possible. [12] also suggested that the screening process should be done at the preschool level.

II. DYSLEXIA

In Malaysia the definition of dyslexia is still not clearly understood [10] some says it is a type of disabilities [5], [6], [10], [16], [1] while others suggest that it should be viewed as different rather than disable[8]. Among others the definition of
Dyslexia can be best explain as disorder because of the difficulties in spelling, reading, and writing skills [4]. There are several symptoms of dyslexic which puzzles most of the researchers which are:

- Difficulties/disabilities in spelling, reading and writing [6], [7], [13],[4], [1].
- The main reason of dyslexia is not fully understood but it runs in families, which indicate a genetic influence [3], [11].
- The dyslexic have similar or higher intelligence compared to the non-dyslexia children [7], [9], [11], [18], [15].
- It is more common among boys rather that girls [12], [19].
- The socio cultural opportunities are not causing dyslexia [13].

By looking at these aspects one could tell that dyslexia could be recognized if proper measurements are undertaken at proper time. It is stated that in Malaysia there is no such standardize method to screen dyslexic at the early stage of their age [8], [11], [14]. [12] suggest that the screening process should be done a preschool level since many of the children are showing the developmental dyslexia symptom. In the other hands many had suggest that early intervention could help them successful in life [8], [15].

In Malaysia dyslexic is unrecognized population due to ill awareness [8] of these problem and lacking of standardized screening instrument [8], [11] which leads to difficult experience faced by them [8]. Most of dyslexic, mastering a skill is a tremendous challenge and yet the common teaching method used in Malaysian school, when dealing with them is using the reading skills just like the non-dyslexic[6], [9]. Developing a screening instrument (in Malay) is not an easy task [11], the main reason for this statement lies in these two factors

- There is no standardized screening test in school environment [8], [11], [14].
- Different kind of test is needed to screen dyslexia to avoid misdiagnose [11].

It is a great necessity to develop a screening test that could help teachers and parents to diagnose dyslexia symptom in a child based on multiple deficit theories. It is understandable that early detection will give them a change for proper treatment and remedial program [3].

III. MULTIPLE DYSLEXIA DEFICIT THEORIES

There are many research conducted in order to uncover the main theories behind the cause of dyslexia deficit in reading, spelling and writing. These deficit are multifactor [20], it may fall under speed of processing, short term memory [18], sequencing and organizing [15], [18] auditory and visual perception, spoken language (phonological deficit) [20] and motor skills deficit [14], [20]. The main deficit theories are.

A. Phonological Core Deficit

Phonological decoding is the ability to read unfamiliar words (and/or non words) and translating them into a sound [21]. It is widely accepted that the main reason behind the difficulties in reading are lies in phonological processing [9], [22]. These theories stated that dyslexic have difficulties in using and manipulating phoneme because of the deficit in phoneme representation [22]. This is why most of the dyslexia test will include the phonological test [21].

There are also some reasons that phonological core deficit is not the only theories [23] since other theories also exhibit the same consequences.

B. Working Memory Deficit

Working memory is our ability to hold and manipulation information over a brief period of time [16]. The working memory deficit theories suggest that the dyslexic have problem to use the working memory [18]. The working memory problem is identified as the reason behind the reading difficulties, language impairment, attentional problem [16] and ability to learn mathematic [5]. A study conducted by [16] also suggested that dyslexic do have short term and working memory difficulties compared to the non-dyslexic.

C. Auditory Deficit

Auditory deficit theory claims that the dyslexic have problem in rapid naming [21]. The deficiency in auditory could disturb the ability of the children to learn orthographic and reading cause by the phonological problems [2], [21], [24]. [24] quoted that if there is a damage to the early auditory pathway, the quality of phonemic sound will be degraded and it will disturb the reading development.

D. Visual Attention Deficit

The process of visual stimuli not only about the visual perception but also include the involvement of attention system [25]. The dyslexic children show slower response pattern compared to the non-dyslexic. Some suggest that dyslexic have difficulties in processing letter visually [21].

The theories also suggest that it is the reason why the dyslexic seeing distort, shimmering or floating letters [23] while reading. The recognition system somehow unable to process all the letter correctly at the same time and some of the letters are left unprocessed [23].
E. Cerebellar Deficit

The cerebellar deficit theory assume that the cerebellum does not functioning well [21]. This theory suggests that problems with learning occur because of the timing difficulties. The cerebellum is supposedly play important role in timing and in motor and sequence learning [22].

This theory also explains why the dyslexics are slower and more prone to error when using keyboard [22]. The sluggish attentional shifting (SAS) suggest those dyslexics are difficult to disengage once their attention is engaged [22], [26]is part of the cerebellar deficit theory.

IV. THE DYSLEXIA SCREENING

Currently there are numbers of research focusing on screening dyslexia. Most of the research is trying to incorporate the knowledge of dyslexia symptom and computer technology. Different approaches have been suggested in order to remedy a fast and accurate screening instrument.

An interactive multimedia approach for the early screening of dyslexia was introduced by [17] to enhance the traditional method of screening dyslexia. This application focuses on three main aspects which is identifying letter, identifying number and identifying direction. The idea of dyslexia screening incorporates some of the theories of deficit such as directional confusion [17].

Another interesting work was done by [14] to discriminate between dyslexia and autism using an expert system. It is not a multimedia approach since the data had to be inserted for the qualifier to develop a result. The development of this application was done using Incremental Expert System prototyping. This system is based on the observation data inserted by the teacher from time to time.

Eye movement is one of the indications of visual stress [27]. A computerized screening was conducted by a series of questionnaire question that focuses on the aspect of visual stress inserted into the system to get the result. As stated by [3] that the brain dysfunction can be determine by the eye movement and therefore it could be used to detect dyslexia. In order to manifest this idea [28] uses eye movement analysis to screen dyslexic based on assumption that the dyslexic will exhibited longer fixation on specific reading material. The main issue is how to determine which text will reveal the dyslexic difficulties and which is not.

Lucid Rapid dyslexia screening is computerized assessment software to screen dyslexic student. The tests involved in this software are phonological processing, auditory sequential memory and phonic decoding and visual verbal integration memory. [29] conducted a test in Singapore (which is an example of multilingual society) using Lucid Rapid confirms that the result is accurate if it could overcome the issue of false positive and false negative. The result is also influence by the children’s proficiency in English.

A serious game was developed by [30] to predict the risk of developmental dyslexia in pre- readers children. It is a new concept where the test was conducted in series of game. The games are Paths game, Fence letters game and the Wizard game. The main idea behind the game is to test the visual processing and auditory processing. The Temporal Order Judgment (TOJ) is one of the elements being evaluated in this game. The game also presented as a training tool for the child to treat dyslexic children.

Another game approach were presented by [19] with the aim of 100% children independently. The set were made of six different games with mainly to evaluate the student word production, syllabic memory capacity, verbal work memory, auditory memory syllable and word reading capacity. It is basically a web based application which used the client server architecture. The children will play the game and at the end they will get the statistical result.

Some of these software were develop with the understanding that dyslexia symptom can be recognized through certain means. The idea of using computer also caught the attention of fuzzy expert to underlines the different between dyslexia, dysgrafia and dyscalculia [31]. They suggest the use of soft computing methodology to differentiate these three group of learning disabilities. The aims of this project to get accurate result while with a mass population. Since most of the previous dyslexia screening software were focus on a specific small group [19], [27], [30] with the exception of Lucid Rapid [29]. The parameter being used are essay, reading, comprehension, spelling, perception, solving problem, word problem, mental sums, time, calendar and money. These parameter represent various theories [1], [7], [15], [17], [32]of the dyslexia symptoms, but teachers observation and insertion of data is still the main ingredient.

Brazilian researcher also present a computational approach for screening dyslexia using DysDTool architecture based on neural networks model [33]. This system consist of several layer which are the web layer to collect information, layer processing data, neural network layer process data and screening module. Their result indicates the robustness of neural network as the computational technology suitable to diagnose dyslexia.

With all these research, one might think the importance and the urgencies of a dyslexia screen system to be develop with these criterions

- A system that can provide instant early result.
- A system which support mass population.
- A system that able to screen dyslexic at their very early stage including the pre-reader and pre-school children.
- A system that utilize the self learning concept and exclude the phonological barrier of a language.
V. MOBILE GAME APPROACH TO SCREEN DYSLEXIC

In recent years the advancement of mobile technology (mobile phone and tablet PC) has offer support for many students with dyslexia [34]. The utilization of human computer interaction (which is an interdisciplinary field) offers a new capacity of mobile technology as a assistive cognitive tool in education [30], [34], [35].

Multimedia approach which is the core in the mobile dyslexia screening test is a proven approach [5], [13] and the dyslexic student use the information technology because they never failed before [5]. Multimedia also has the potential to remove and/or reduce the problem faced by the dyslexic [17]. Because it offer the multi sensory teaching approach [4], [5], [7], [9], [13], [18] suggested the use of proper teaching method for the dyslexic or else they will fell disappointed and lost interest in the learning process. In contrast the dyslexic shows positive attitude toward the of multimedia courseware[17] and it has the capacity to motivate the dyslexic student. The observation done by [17] demonstrate that the dyslexic are eager to explore the courseware and even tried further module, this clearly indicate certain the sign of dyslexic which has difficulties in reading material but exhibit the average IQ or above average IQ [16].

The multimedia approach offer the Attention, Relevance, Confidence and Satisfaction (ARCS) model that can sustain and stimulate the motivation of the dyslexic student [5]. These learning model also support the teaching principle for the dyslexic which is multisensory, over-learning, automaticity, structure and practice [5], [13].

According to [5] multisensory incorporate the visual, auditory, kinesthetic (motor skill) and tactile elements. While over-learning focuses on the range of teaching approaches so that the same information is being taught in different situation.

Based on previous study boys are more likely to be dyslexic [12], [19] but by the use of multimedia, the boys are more eager to explore and actively involved in the learning process [18]. At the same time [18] also stated that not many multimedia courseware, games and web side were design specifically for those who have learning disability, especially in Malay language[6], [7].

These elements which have been discussed before can be used as the screening characteristic for the development of mobile dyslexia screening test which incorporate the mobile technology, the multi-deficit theories of dyslexia origin and the effectiveness of interactive multimedia in communicating with them.

VI. MULTIPLE DEFICIT DYSLEXIA SCREENING MOBILE GAME

The dyslexic children share certain specific symptoms which can be test using a specific game. These games were design to compare dyslexic and non-dyslexic respondent achievement. The idea of using game as the classification tool has been introduce by [19], [30]. They proposed set of games that focuses on several deficit theories of dyslexia such as visual-spatial attention and speech segmentation [30] and phonological ability [19].

We propose the (Multiple-Deficit) Dyslexia Screening Mobile Game Model to screen the developmental dyslexia children using mobile game approach. This model incorporated 3 different elements which are the knowledge of multiple deficit theories, the development of mobile application mini-games and the users which will receive the expected result from this application.

A. Knowledge of the multiple deficit theories

The information derived from knowledge of multiple deficit theories is summarized by some of these researches.

[17] suggested that the dyslexic have difficulties in understanding specific and long instruction. They also have problems to stay focus, to stack information in sequence and directional confusion such as determining left or right. Another known area is poor short term memory compared to the non dyslexic children.

![Fig. 1. (Multiple-Deficit)Dyslexia Screening Mobile Game Model](image-url)

[5] concluded that due to the poor short term memory the dyslexic also experience problem in mathematic especially the multiplication concept.

[7], [16], [36] explain the most obvious traits of dyslexic is the poor ability to decode association between the letter and its sound. It can be depicted by the poor naming of these letter b-d, p-q, n-u and m-w.
[18] state that the dyslexic are least patience rather that the non dyslexic. They are likely to easy to give up and lost the fundamental knowledge. They also show a lot of guessing rather than finding the actual result.

[37] explain the relationship between the lack of motor skill and well timing of the dyslexic with the poor ability in automaticity (quick enough to understand). This also explain why most of the current screening process include the rapid naming process.

B. Development of mobile application mini-games

This game comprise of 2 modules which are the Data Collection module and the Data Analysis module. Both of these modules were incorporated in a single application so that it would generate immediate reporting to the user (parent, teacher, and practitioner).

The Data Collection module starts when the respondent plays the series of mobile mini-games. These games were design in 9 different stages which depicting 9 different domain (derived from the knowledge of dyslexia deficit theories). The domains in this game that the respondents have go through are:-

1. Domain to test the difficulties in understanding instruction.
2. Domain to test the directional confusion.
3. Domain to test the problem in mathematic.
4. Domain to test the short term memory capability.
5. Domain to test the problem in arranging sequence.
6. Domain to test the problem in decoding the sound-letter association.
7. Domain to test the lack of patience.
8. Domain to test the difficulty to stay focus.
9. Domain to test the lack of motor skill and well-timed.

Data Analysis module starts after the Data Collection module end. All variable data will be analyzed by the Decision Tree Classifier to classify the data and produce result. The decision tree induction (general conclusion) is design prior to the game development using a sample test data. We also propose the use of clustering technique to simplify the decision tree to adapt the mobile application environment.

Three categorical respond will be generated by the game which are risk, high risk and no risk of dyslexia. The result will help the parent and teacher to take further action in determining future test and/or proper remedial program.

C. User

The current practice the dyslexia screening in Malaysian school is done through series of observation by the class teacher especially by the Malay Language teacher [38]. The screening processes are:-

1. The teacher will suggest the suspected dyslexic student to undergo the dyslexia screening.
2. The Malay Language teacher/ coordinator will perform the observation and fill out the screening form consist of question about student reading ability, behavioral strength and weaknesses.
3. The complete form will then be analyzed using specific scoring mechanism to determine the probability that the student is dyslexic.
4. A report will be provided by the school to be given to the medical practitioner for the further test.

These process are highly dependent on teacher’s observation in order to initiate the screening process. Currently there are no screening process for developmental dyslexia and the preschool children.

The Dyslexia Association of Malaysia adapt different screening process strategy where the parent will sent their children for the screening process. There are several test including reading/comprehension, numbers, sentences construction, handwriting, spelling, perception, listening skills and visualization.
The proposed (Multiple-Deficit) Dyslexia Screening Mobile Game Model is suggested to avoid the initial process of teacher or parent misdiagnose the children. If no body initiate the screening process most likely the children will left in their school environment with out remedy program. Our purpose model will reduce the human dependency to screen dyslexia especially at the innitial state. It also able to focus on mass respondent.

The user of the propose model are likely teacher, parent and practitioner which will use the initial result to further invetigate the probability of a child being dyslexic.

### TABLE 1. (MULTIPLE-DEFICIT)DYSLEXIA SCREENING MOBILE GAME DOMAIN

<table>
<thead>
<tr>
<th>No</th>
<th>Game Domain</th>
<th>Mobile Game</th>
<th>Related Dyslexia Deficit Theories</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Difficulties in understanding instructions</td>
<td>- Choosing icons that resemble specific task.  - Find the missing part</td>
<td>- Visual Attention deficit theory</td>
</tr>
<tr>
<td>B</td>
<td>Directional confusion</td>
<td>- Left and right instruction</td>
<td>- Visual Attention deficit theory</td>
</tr>
<tr>
<td>C</td>
<td>Problem in mathematics</td>
<td>- Multiplication concept</td>
<td>- Working memory deficit theory</td>
</tr>
<tr>
<td>D</td>
<td>Short term memory</td>
<td>- Matching game</td>
<td>- Working memory deficit theory</td>
</tr>
<tr>
<td>E</td>
<td>Problem in arranging sequence</td>
<td>- The order of the letter and number</td>
<td>- Visual Attention deficit theory</td>
</tr>
</tbody>
</table>

### A. Difficulties in carrying out instruction[17].

To test this difficulties a series of game such as choosing objects that similar to the given instruction such the tapping image based on sequence of instruction. Another technique is by asking the children to perform specific task such as ‘choosing icons that resemble specific task’. Finding ‘missing part’ can be a challenging method to screen for the difficulties in carrying out instructions

### B. Directional confusion [17]

To test this element a series of game such as hide and seek can be apply. In order to get to a specific location a player should be able to use the ‘left and right instruction’. Another way is to find a ‘path from one location to another location’. Confusion can be added to the game design so that the true and false answer won’t be easily recognized by the player so that they will continue playing despite of false answer. This is to avoid lack persistence and patient theory of the dyslexic [18]. The numbers of error will be used to determine the stage of awareness in directional confusion which one of the key element of the dyslexic children.

### C. Problem in mathematic [5]

Mathematical problem sometimes referred as dyscalculia [31]. On the other hands most of the dyslexic also suffer mathematical disability [6], [15]. A series of game that include ‘multiplication concept’ can be added to the game. A simple multiplication of two is profound difficult for the dyslexic [5].

### D. Short term memory, [17]

A simple ‘matching game’ between related object can be used to test the short term memory and/or ‘memory game’ which used familiar item from their own environment.
E. Problem in arranging sequence [17]

This type of game focuses the element of sequencing such as ‘the order of the letter and number’, the ‘sequence of shape mix up symbols with color’ such or by ‘figuring the missing part of an object’. The sequence of numbers is also very challenging for the dyslexic children.

F. Problem in decoding the sound-letter association [7], [16], [36]

The game also should be able to test auditory deficit by giving sound of a letter and the student need to identify the letter. [18] stated that the dyslexic much prefer the audio instruction rather than written instruction.

G. Problem in decoding the sound-letter association [7], [16], [36]

This is the fundamental phonological deficit theories and the most common screening procedure for dyslexia [19]. The letter sound will be pronounced and the children have to ‘find the correct letter’. To add so more confusion several mix up letter with different color and background shape will be added to test whether the children focus on the detail or only surface of shape and color only- ‘color and shape classify’. The most confuse letter are b, d, p, q and the lease confuse letter also will be examined to screen for the dyslexic. The game also will ask the child to spell confuse words and non words.

H. Lack of patience [18]

A series of ‘skip button option’ is represented to give option to the children to skip or continue the specific game. There are also screen without auditory instruction where the children need to read in order to play the game.

I. Difficult to stay focus [17]

To stay focus a dyslexic need something interesting as suggested in the ARCS model [5], without this kind of amusement their focus will decay and might skip these screen. The are other type of games such as ‘finding detail of an objects’, ‘reading maps’, ‘finding places’ and ‘judging time’ that will used intensive focus [16]. Another suggestion is to find hidden item or ‘compare differences between 2 images’.

J. Lack of motor skill and well-timed [37]

The most common screening technique is rapid naming but there are other method of gaming such as puzzle game, ‘pathway game’ where the children must follow specific path, the number of children strayed away will be evaluated to screen the deficit in motor skill. ‘Rapid tapping’ on a specific object also can exhibit the ability in the motor skill of the children. Another type of game is like ‘hit the moving rabbit game’, where the children need to tap the screen on specific timing.

VII. CONCLUSION AND FUTURE WORK

The idea of a single series of mini-game that would be able to screen dyslexia through mobile approach is suggested to cope with the problem of non-standardized screening method [8], [10] untrained teacher to recognized the symptom of dyslexia [12], and ill awareness of the dyslexia problem [6], [8], [10].

The different kind of dyslexia deficit theories which were exploited in the mobile game design are Visual Attention deficit theory, Working memory deficit theory, Auditory deficit theory, Phonological core deficit theory and Cerebellar deficit theory.

The proposed mobile game is at its initial phase, the number difficulties related to specific deficit theories can be expanded accordingly. This research could be extended to identify the specific remedial program for specific dyslexic children (should undertake) based on the game result. Furthermore as a mobile application, vast data collection (of dyslexic population) can be made possible over time.

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