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Detecting Dyslexia in Children Using a Computer-Aided Diagnosis System
Detecting Dyslexia in Children Using a Computer-Aided Diagnosis System

Abstract

Early detection is important for dyslexics to receive early and proper treatment. This paper presents a study on the use of a computer-aided system, MyAddyXia, to diagnose dyslexia among children. It uses five simple tests – Alphabet, Pattern, Arithmetic, Direction and Word Tests. Data were collected from 39 dyslexic children of the Dyslexia Association of Malaysia (DAM). These tests diagnose the presence of reading and writing disabilities. The results of the study showed that the Alphabet, Arithmetic, and Word Tests were most effective. The computer literacy of the dyslexic children and the feedback from the teachers of DAM were also highlighted.

Key words: MyAddyXia, dyslexia, alphabet test, arithmetic test, word test.

Introduction

Dyslexia is classified as a type of learning disabilities, and is manifested as difficulty in learning with respect to reading (Jain et al., 2009). It is caused by deficits in the brain, but it does not necessarily imply that the dyslexic child is of low intelligence (What is Dyslexia, 2009). Dyslexic children can have problems with reading, listening, speaking, writing, calculating, memorising, and doing things quickly. Additionally, problems such as depression, anxiety, dysgraphia (a handwriting problem) and attention-deficit/hyperactivity disorder (ADHD) may co-occur with dyslexia (Hultquist, 2006). Some dyslexics are gifted with special talents in arts, music, problem-solving skills, and intuitive people skills (Sharing the latest
research results with those who need to know, 1998). Dyslexia is a specific learning disability, which also includes autism, Down’s syndrome, cerebral palsy, mental retardation, and slowness in learning (Suet, 2007a).

According to the Ministry of Education of Malaysia, about 314,000 school-going children (about 5% to 10%) are dyslexic (Wong, 2009; Suet, 2007b). Early detection makes it more likely that dyslexics will receive early and proper treatment for the disability (Mico-Tormos et al., 2002). Dyslexia is a neurological deficit, hence, brain imaging methods such as PET scans, and functional Magnetic Resonance Imaging (fMRI) scan will normally be used in diagnosis (Paulesu et al., 1996, Temple et al., 2003; Lyttinen et al., 2005). Other diagnostic methods include eye movement patterns tests (Pavlidis, 1989), handwriting pattern recognition (Reitano, 2001), and genotyping (using DNA samples of children to detect dyslexia) (Paracchini, et al., 2008). These methods are very costly, and hence, MyAddyXia was developed as a cheaper alternative.

**Method**

This study aims to develop a computer-aided system that can diagnose dyslexia in children. The accuracy of the diagnosis is highly dependent on well-designed tests. To achieve this, interviews were conducted with teachers of the Dyslexia Association of Malaysia (DAM), who are very familiar with the behaviours of dyslexic children as well as the problems they encounter in the learning process. Information was also gathered through interviews with a few teachers, parents of dyslexic children, and from the literature review pertaining to some common difficulties observed in dyslexic children. These include difficulties in differentiating some letters of the alphabet such as b, d, p, n and u; identifying patterns or shapes and directions (i.e. facing left, right, up or down); solving simple arithmetic problems such as addition and subtraction.

**Dyslexia Diagnosis Tests**

Five tests – alphabet, pattern, arithmetic, direction, and word tests, were formulated to identify dyslexic children or those who have reading and learning difficulties. The alphabet test consists of eight questions, while the arithmetic, pattern and direction tests each have five questions. The word test consists of thirty-five questions. Each question is a single word having not more than eight characters.
Students were asked to write down the word they had read. All the questions were first compiled for a paper-based test, which was used in a pilot test with students in a kindergarten, a primary school, and the Titiwangsa centre of DAM. Most non-dyslexic students of at least six years of age from the kindergarten and primary school were able to answer the questions correctly. This indicated that the questions were not difficult, and at a level suitable for that age group. This also implied that students of the same age or older, who could not answer the questions, must have some learning deficits.

Research Design

The Dyslexia Association of Malaysia (DAM) was chosen for this study. DAM has three centres, which are located in Ampang, Subang Jaya in Selangor state, and Titiwangsa in Kuala Lumpur. The two latter centres have four classes, each class has about five students. The Ampang centre has three classes. DAM offers three-month courses in the Malay Language, English and Mathematics. There are four levels – pre-school, beginner, intermediate and advanced. Students can continue to study in DAM after they have completed each level, or completed all four levels. They can also join the normal schools after they have completed any level of the courses.

Three paper-based pilot tests were conducted. The results of the pilot test provided useful information on the desired features and functionalities to be built into MyAddyXia. Generally, kindergarten textbooks contain fewer words, have bigger font size, and have colourful pictures. These features were considered in the design of the graphical user interface (GUI) of MyAddyXia. To prevent students from memorising the correct answers, all the answer options provided in the multiple choice questions were randomly generated. Also, to prevent students from answering questions without thinking, a sound feature is incorporated in MyAddyXia, and the questions are asked verbally. As dyslexic students have difficulties in reading, all instructions are kept short and simple, and read out to allow the students to fully understand the instructions of a test before answering.

The first prototype of MyAddyXia was released and reviewed by the teachers of DAM. A pilot test was conducted on a batch of dyslexic students of the Ampang centre of DAM. Data collected from the pilot test were analysed and used to improve MyAddyXia.

A new version of MyAddyXia, which included some minor changes, was released. The updated system incorporates the five tests as in the previous version. The flow of each test is simple, straightforward, and it requires minimum user input. Most of
the questions can be answered by a mouse click, except for the arithmetic test that requires the dyslexic students to key in numbers using the keyboard. Each test has either five or ten questions, and the time needed to answer each test is recorded.

A survey was carried out in the DAM centres to evaluate MyAddyXia. To verify that the tests are effective, data collection was carried out at the beginning of a course, when the dyslexic children first enrolled in the DAM centres, and they have not yet undergone any ‘treatment’ (guidance by the teachers) to overcome their disability. The dyslexic students, ranging in age from 6–15, used MyAddyXia, individually. The following section reports the effectiveness of the five tests and some comments from the teachers.

Results

Forty-two students from all three DAM centres participated in the study using the updated version of MyAddyXia. The data from the five tests (alphabet, pattern, arithmetic, direction, and word) were analysed. Before analysis was carried out, the responses from the students were checked to verify that they had answered all questions. Three sets of test data were rejected as some of the questions were not answered.

Of the 39 respondents, 12 (30.8%) were male and 27 (69.2%) were female students. Among those respondents, there were 13 (33.3%), 13 (33.3%), 6 (15.4%), 5 (12.8%), and 2 (5.2%) respondents from the age groups of 6–7, 8–9, 10–11, 12–13, and 14–15, respectively.

Alphabet Test

The alphabet test had ten questions. In this test, the instruction was given verbally. The students were asked to choose a distorted image (a letter) from four given options. The four options comprised an image which was shown in its original form, flipped horizontally, vertically, and both horizontally and vertically, as illustrated in Figure 1. This was aimed at detecting signs of confusion associated with dyslexia.

Figure 2 shows that the majority of the dyslexic students got the letter p wrong (15 students, 38.5%), and made the fewest mistakes with letter m and letter w (5 students, 12.8%). They made 93 mistakes with the first 8 letters (b, d, p, j, u, g, n, and q). In addition, 70 (75.3%), 12 (12.9%) and 11 (11.8%) of the mistakes made were
due to horizontal, vertical, and both horizontal and vertical confusion, respectively. This implies that the majority of the students tend to view a letter horizontally. Five students made mistakes with the letters m and w, when the letters were rotated 90 degrees or 180 degrees.

**Pattern Test**

The pattern test consisted of five questions, to test the students’ ability to map five shapes. As shown in Figure 3, the same design and interface were used.

As shown in Figure 4, 33 students (84.6%) answered five questions correctly, except for one student (2.6%) who answered only one question correctly. The design of this test needs to be improved so that the students could understand the question clearly.
The Arithmetic Test consists of five questions – two questions involving single-digit addition (Addition 1 and 2), two questions involving single-digit subtraction (Subtraction 1 and 2), and one question involving subtraction between two-digit integers and a single-digit integer (Subtraction 3). The questions are displayed vertically, as shown in Figure 5.

Table 1 shows that of the 39 students, 27 (69.2%) and 28 (71.8%) students did the single-digit addition 1 and addition 2 correctly, respectively. Seventeen (43.6%) students did the single-digit subtraction correctly, and 11 (28.2%) students did the double-digit subtraction correctly. The majority of the students used their fingers
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It is clear that the majority of them could not answer Question 5 (Subtraction 3), which involves a number greater than 10. A few students were able to find the answers using mental calculation.

Figure 5. Arithmetic Test (Addition and Subtraction)

Table 1. Arithmetic Test Results

<table>
<thead>
<tr>
<th>Question</th>
<th>No. of Students with Correct Answer (%)</th>
<th>No. of Students with Wrong Answer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition 1</td>
<td>28 (71.8)</td>
<td>11 (28.2)</td>
</tr>
<tr>
<td>Addition 2</td>
<td>27 (69.2)</td>
<td>12 (30.8)</td>
</tr>
<tr>
<td>Subtraction 1</td>
<td>16 (41.0)</td>
<td>23 (59.0)</td>
</tr>
<tr>
<td>Subtraction 2</td>
<td>18 (46.2)</td>
<td>21 (53.8)</td>
</tr>
<tr>
<td>Subtraction 3</td>
<td>11 (28.2)</td>
<td>28 (71.8)</td>
</tr>
</tbody>
</table>

Direction Test

In the direction test, the students were given five shapes: arrow, heart, trapezoid, polygon, and pentagon. Instead of clicking on the shape to colour it, they were requested to click on the clockwise or anti-clockwise arrow to rotate the shape (Figure 6).
As shown in Figure 7, the overall results of the Direction Test were slightly poorer than those obtained for the Pattern Test. Of the five shapes, the students made most mistakes with the polygon shape, with 7 (18.0%) students giving the wrong answer. This was due to the different GUI used in both tests. The students could easily identify the differences in the four options of the Pattern Test (Figure 3). This was not possible with the Direction Test (Figure 6), as the students had to click on the arrow to see the shape from only one direction, at any time.

**Figure 6. Direction Test**
Clic and rotate the shape to get the same pattern

As shown in Figure 7, the overall results of the Direction Test were slightly poorer than those obtained for the Pattern Test. Of the five shapes, the students made most mistakes with the polygon shape, with 7 (18.0%) students giving the wrong answer. This was due to the different GUI used in both tests. The students could easily identify the differences in the four options of the Pattern Test (Figure 3). This was not possible with the Direction Test (Figure 6), as the students had to click on the arrow to see the shape from only one direction, at any time.

**Figure 7. Comparison of Pattern Test and Direction Test Results**

Comparison between Pattern Test and Direction Test

<table>
<thead>
<tr>
<th>Pattern Test</th>
<th>Direction Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrow</td>
<td>36</td>
</tr>
<tr>
<td>Heart</td>
<td>37</td>
</tr>
<tr>
<td>Trapezoid</td>
<td>35</td>
</tr>
<tr>
<td>Polygon</td>
<td>36</td>
</tr>
<tr>
<td>Pentagon</td>
<td>37</td>
</tr>
</tbody>
</table>

**Word Test**

In the pilot test, the students had many problems with the word test. As a result, multiple choice questions were introduced. The test was aimed at identifying problems that the students might have in recognising a vowel or a consonant within
a word, and whether this happens with the beginning, middle or ending letters of a word. For example, to test problems with the front vowel, students were given verbal instruction to choose the word “i... n... k... ink...,” and the four options given were “unk,” “ank,” “onk,” and “ink” as illustrated in Figure 8. Another aim was to find out whether the students had problems with words containing repeated vowels (e.g. moon), repeated consonants (e.g. puppy) and a combination (e.g. eat, ring). The three most common mistakes were with the mix consonants (13 students, 33.3%), repeated consonants (12 students, 30.8%), and mix vowels (9 students, 23.1%), as shown in Figure 9.

![Figure 8. User Interface Design of Word Test](image)

![Figure 9. Word Test Results](image)
Findings of the Tests

The results of the five tests show that the majority of the dyslexic students can perform well if they understand the questions clearly. They should be given more time, more explanations and more help when using MyAddyXia. The three centres of DAM enrol dyslexic children four times per year in January, April, July and September. Hence, data collection should be conducted during the first two weeks of each enrolment period so that the tests can be administered on the children before treatment (training).

The results of the tests also revealed that the majority of the dyslexic students had problems with the Alphabet Test, Arithmetic Test, and the Word Test. These five tests are considered simple, sufficient and easy to conduct as the goal of this research is to develop a computer-aided system to diagnose dyslexia among the children. More studies need to be carried out based on these tests as well as other simple tests relating to dyslexia, to produce a more accurate method of detecting dyslexia.

Conclusion

Dyslexic children, generally, are unable to stay focused and are often distracted by the surroundings. They lose concentration easily, and hence, a test should not have more than 10 questions. They also have difficulty in reading, and instructions are best given verbally and in a simple and clear manner. Texts displayed on the computer screen should be of appropriate font size and should reflect good choice of colours. These are important to attract children's attention. The contents of the Direction Test and Pattern Test must be simple, interesting and unique.

It is also important to understand the methods and approaches that the teachers used in teaching the dyslexic children. This can help in the design of a system simulating a learning environment that the dyslexic children are familiar with. The teachers must be invited to review the first prototype of the system, and a few dyslexic children should be selected to use the prototype. This will uncover any weaknesses and errors in the system so that modifications could be made on the prototype. The modification to the prototype might require a few iterations before the prototype could finally be released for use.

As the DAM centres have three intakes, it is important to have information on the enrolment dates; class structure; time-table; school activities, and the teaching and learning environments. This information is needed for requirements elicitation
and also to ensure that data are collected at the right juncture of time. The test could be repeated at the beginning of each enrolment to investigate the effectiveness of the five simple tests for diagnosing dyslexia. Data collected two weeks after the term has started would be counter-productive to the objective of the study as the dyslexic children might have learned enough to overcome their difficulties in reading, writing and simple calculations.

This research also shows that parents are unsure whether their child is dyslexic. Most parents admitted that they were not aware of the symptoms of dyslexia. They did not know that their child was suffering from dyslexia until much later. In a worst case scenario, a child is diagnosed as dyslexic only when he/she is in secondary school. The teachers of DAM indicated that the later a child is diagnosed as dyslexic, the more difficult it will be for the teacher to correct the child’s disabilities. In this regard, MyAddyXia is a very useful and accurate alternative that even parents can use to diagnose dyslexia.

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