International Journal of Engineering & Technology, 7 (4.31) (2018) 175-181

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Cognitive-Behaviour Intervention in Developing an Adaptive Learning Model for Students with Dyslexia

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Abstract

Cognitive-Behaviour Intervention (CBI) is designed as a suitable intervention for students by identifying cognitive as well as behaviour conditions. Through CBI, the students' learning goals are easier to establish, and the skills related to particular conditions can be developed. Current dyslexia's learning interventions were mostly developed to tackle cognitive or behaviour conditions separately. Whereas, the students with dyslexia suffer from cognitive deficiencies as well as behaviour challenges, both the conditions are interrelatedly. As a result, students with dyslexia reportedly underperform, lazy, ignorance and stupid due to the inappropriate learning style. In addition, there are very limited works that allow for adaptability in addressing the dynamic states of the student's learning process such as engagement. A study has shown that students' engagement could be a predictor of good academic performance. Therefore, in this paper, we present the approach to combine both cognitive and behaviour conditions of the students with dyslexia as well as the intervention in our proposed adaptive learning model. The cognitive model senses the student's difficulties through exercise given while the behaviour model utilises the machine learning model to address the engagement states of the students. Finally, the model intervene by praising effort, hints and changing activity based on the student's state. The results showed that a promising new way to assists students with dyslexia in their learning.

Keywords: *Cognitive; Behaviour; Intervention, Dyslexia; Adaptive; Learning Model.*

1. Introduction

Cognitive-behaviour intervention (CBI) represents an interrelating perspective between cognitive and behaviour in an education setting [1]. The combination of these perspective aims to understand the students and to develop the intervention by addressing the difficulties faced by the students [2]. The implementation of CBI for students with learning disability especially for students with dyslexia becomes an alternative for learning improvement [1].
Students with dyslexia typically suffer from difficulties associated with cognitive abilities, inaccurate/fluent word recognition, poor spelling and decoding abilities [3]. Aside from that, the students also deal with behaviour issues which affect the learning experience. Those behaviours include refusal in learning, feeling a dislike of school, suffering from inferiority and sensitivity due to failure to achieve the required performance [4]. Without appropriate intervention, these students will continually be left behind compared to the rest of the students.
Current approaches proposed that the intervention for students with dyslexia be addressed separately. The approach relatively focuses on the cognitive aspect. To name a few, the development of computer applications such as 'Dyseggxia', 'LexiPal' and 'MyLexic' meet their aim to help a student with dyslexia to improve their cognitive deficiency [5]–[7]. However, these interventions are not intelligent enough to adapt to the variety of deficiencies that the students suffer from. It is merely a game-based approach that emphasizes repetition. Additionally, the interventions exploit the use of multimedia elements, gamification, and interactive design to create engagement, enjoyment and finally motivation to solve behaviour issues [8]. However, the application only functions as an evaluation tool. It is unable to tackle behaviour issues in parallel with cognitive deficiency.
Current approaches have limited ability to address behaviour problems such as engagement, and the approaches are usually being performed manually. For example, the engagement states were usually acquired using observation and self-reporting [9], [10]. However, these methods often failed to cover all the complexity of the engagement [11], [12]. Whereas the technology-based approach applies log files and eye tracker [13], [14]. Unfortunately, the eye tracker itself is considered an expensive and invasive device [15]. The existing studies also address their solutions generally despite critical needs of students with learning difficulties like dyslexia.
Therefore, in this study, we develop a learning model that considers both cognitive and behavioural aspects by providing intervention for students with dyslexia. In addition, the learning model incorporates machine learning approach to capture dynamic behaviour states. The rest of this paper is organized as follows. In the second section, we explain the background of the studies related to dyslexia and the difficulties in cognitive and behaviour issues. The third section describes methodology conducted, and the fourth section provides the result of cognitive-behaviour identification and the proposed intervention used in this work. Finally, we deliberate on the findings and concludes this study.

2. Background

In this section, we explain the background of dyslexia, challenges and deficiency faced by the students from cognitive and behaviour perspective as well as current intervention.

2.1. Knowing Dyslexia

Dyslexia International organization reported that 10% of the world's population suffer from dyslexia [16]. In 2016, 8.5 million students in America or 1 out of 6 were reported to have dyslexia. These findings were clearly stated in the Research Excellence and Advancements for Dyslexia Act (READ) [17]. While in Malaysia, the prevalence of dyslexia is estimated to affect 314 000 students [18]. The number is unfortunately expected to increase every year due to the extensive Literacy and Numeracy (LINUS) screening programme [19]. Dyslexia has a relatively genetic basis that is inherited from family members. Dyslexia is identified as a specific learning disability that affects the brain by processing information related to language differently [2]. The affecting skills include word recognition, phonological awareness, spelling, reading as well as writing. These skills are part of their cognitive abilities.

2.2. Cognitive Deficiency and Behaviour Challenges

In this section, we explain the cognitive and behaviour conditions from the perspective of dyslexia.

2.2.1 Cognitive Deficiency

Cognitive is a process of perceiving knowledge that includes thinking, reading, remembering, learning and paying attention [20]. The acquisition of language is a crucial part of cognitive development [21] . In particular, the development of reading relies heavily on the certain cognitive processes such as phonological awareness, orthographic processing, lexical access and working memory [22].
Phonological awareness is the ability to separate the sound (phoneme) of every letter in a word [23]. For example, to read the word 'bat', the reader must (i) aware and (ii) able to separate the word into three phonemes namely 'b', 'a' and 't'[24]. Unfortunately, most of the students with dyslexia are reported to have a deficiency in this process which resulted in reading difficulties. Some of the students are found to be confused and forgot the link between the letters with their phonemes such as 'a' and 'u', the letter 'm' and 'n' and also letter 'h' and 'l' [25]. As a result, not only do they take time to read but they also make mistakes in reading [26]. Therefore, the weakness in terms of phonological awareness reflects the language acquisition of individual student.
rthographic processing involves the visual perception in recognizing the pattern of the letter and retrieve the pronunciation from memory [22]. The word recognition difficulties are attributed to poor processing skill [27]. Some of the researchers claimed that students with dyslexia confused the orthographic representation such as between 'b' and 'd', 'p' and 'q' which obstruct them to connect with letter-sound correctly [4], [26]. Consequently, the students take some time to utter the word, experience a hard time to read a sentence, have a high tendency to do a mirror writing and misspell the word [4].
While lexical access refers to a process of obtaining a meaning of a written word from stored memory [22]. There are a few techniques to obtain the meaning of the words which are (i) through graphical representation and (ii) transforming the graphical sign into sound then use the sound to access the meaning [22]. The second process reflects the severity of the dyslexia difficulties [28].
Another cognitive deficiency that hinders dyslexic students is a poor working memory. Despite their average to above average intelligence, the students are found to have a limitation in retaining information such as decoding and word recognition [29], [30]. This condition is sometimes caused by poor phonological awareness and orthography representation [22]. The students are reported to make mistakes in arranging word, combining syllabus, skipped sentences and some of them were adding and deleting letters and word anonymously [4], [26].

2.2.2 Behaviour Challenges

In dealing with cognitive deficiency, there are two personalities displayed by the students. The students appeared to be either an articulated class clown or too quiet and isolated themselves [4]. Their behaviour in the classroom is either extremely noise or extremely quiet. This may be the way they express themselves to compensate for not being able to grasp the lessons in the classroom. Furthermore, the students with dyslexia experience a mass of negative emotions like embarrassment, frustration, regret, fear, upset, inferior and many more [18]. They also become a subject of dyslexic misconception by calling them retarded, besides being subjected to punishment. Unfortunately, these feelings are part of the student's life experience as a dyslexic student.
Studies have shown that behaviour challenges suffered by the students with dyslexia have a major impact and may lead to learning refusal. Therefore, to help the students with dyslexia, both cognitive deficiency and behaviour issues specifically engagement behaviour are inclusively considered. Based on the findings, a strong engagement can be a predictor of good academic performance. Therefore, we incorporate the engagement behaviour with the cognitive deficiency in the dyslexia learning model [31].

2.2.3 Cognitive-Behaviour Intervention (CBI)

Cognitive is a process of perceiving knowledge. For this paper, the cognitive process is being related to language [3]. The cognitive component in CBI comprises of cognitive distortion that involves misinterpretation and cognitive deficiency that relate to the students' cognitive-processing abilities. The behaviour component describes the environmental influences such as past trauma and a reflection of the deficits skills [2]. Intervention in the CBI should be able to determine a suitable combination of the aspects of cognitive and behaviour based on the students' needs and level.
The first step to perform CBI is to assess the students' specific needs (weakness) and strengths [1]. The assessment is important to identify the individual current performance using a standard test based on the up-to-date curriculum. It is encouraging to give feedback to the students on their assessment results. At the same time, the students' emotions and behaviours need to be recorded to enable the factor that may affect the cognitive performance be examined. A few methods have been suggested that includes in-depth interview, rating-scales, self-reporting techniques as well as observation recording [1].
Several intervention techniques have been recommended for underachievers which include the modelling of steps (hints), periodic check of learning progress to meet the goal, breaking the task down into smaller units with the time frames set for each task [1]. Besides, self-monitoring gives the opportunity to the students to build their confidence and to get their attention. Finally, rewarding the students' their current performance using positive reinforcement approaches like praising and grading [32].
There are many commercialised as well as research-based CBI that help students with dyslexia for the English language such as iLearnRW [33], PoliSpell [34] and Read-Aid [35]. iLearnRW is a game-based solution to help dyslexic children overcome their reading and writing difficulties [33]. The intervention proposed in this work is an adaptation mechanism based on the student's model and the lesson planner. Both game and adaptation mechanisms are aimed at maintaining the students' learning engagement.
PoliSpell, on the other hand, is an adaptive spellchecker that helps people with dyslexia to predict their word [34]. The system adapts the needs of their user based on their behaviour as one of the in-

tervention techniques. The adaptation comprises typical errors made and the interface they choose. Another intervention for the English language is Read-Aid. It is an assisting tool to help students with dyslexia to read [35]. The tool measures the reading speed, the reading errors, and the reading comprehension.

For the Malay language, there are several interventions introduced such as MyLexics [7], Dyslexia Baca [11] and BacaMAX [12]. MyLexics is the first Malay language intervention that focuses on helping students with dyslexia to read and write. It prioritises the alphabets introduction, syllables combination and word construction. The work includes intervention approaches such as providing hints using video approach, multimedia elements with interactivity and self-learning environment to capture the students' interest.

Dyslexia Baca is a mobile application that focuses on alphabets recognition especially the most confusing letters [11]. Those are letters ‘p’, ‘q’, ‘b’, ‘d’, ‘m’ and ‘w’. While, BacaMAX has been developed to facilitate the reading difficulties faced by students with dyslexia [12]. The intervention offered in this app involves three levels of words reading and phrases namely – easy, medium and difficult vocabularies. The difference between each level is based on the complexities of the consonant and vowels pairs. The app applied interactive design to capture the students' attention. Besides that, the app applied CBI by using rewards approach of congratulation pages together with clapping’s sounds [11] and provided help when clicked on the cartoon icon [12].

The findings from previous studies have shown that cognitive deficiency is significance mediation. However, there is still a gap when it comes to behaviour intervention particularly the engagement behaviour. Most of the research use gamification as an engagement element to trigger curiosity and interest [13]. Not to forget, the use of multimedia elements to attract, interest and to support the students. These solutions were measured using either a questionnaire or an interview to obtain feedbacks from the interventions. None of these interventions closely measured the engagement behaviour in relation to cognitive deficiency.

3. Methodology

This study is wanted to understand the cognitive difficulties faced by the students with dyslexia as well as to identify the engagement states while doing the exercises given. Therefore, a study has been conducted at Dyslexia Association Malaysia (DAM) with 30 participants. This study involves observation to the students with age between 6 to 12 years old. There are four phases in conducting this work which involve identifying the cognitive deficiency, cognitive evaluation, eliciting engagement behaviour and predicting engagement behaviour. In this section, these phases will be explained in detail.

3.1. Cognitive Identification

In this phase, the observation is conducted to observe the difficulties faced by the dyslexic students in learning the Malay language. This phase is conducted at the Dyslexia Association Malaysia (DAM), Ampang and it involved dyslexic students with the Malay language learning difficulties. DAM is a recognised and established a centre in Malaysia. The students aged between 6 -12 years old. Approval to conduct the observation at the centre was obtained by requesting permission through letters and phone calls. Before the study begins, the consent forms were distributed to the parents to obtain their permission for the children to participate in the study. This study took place in a quiet room provided at the centre. It is known as the audio room that is equipped with an air-conditioner, tables, chairs and electric socket. It is a suitable place to conduct an individual experiment as the student needs a high level of concentration while answering the exercise.

The session started with a self-introduction session by asking the student his/her name and age. This is to make the student feel comfortable with the surrounding and the facilitator. Next, the objectives of the session were explained, instruments were provided, and instructions about what they were required to do were given. All the students were required to complete the (a) phonology, (b) spelling, (c) reading and (d) writing instruments consecutively. In each instrument, the instructions were read to the students and time was recorded as soon as they began to answer.

In the phonology instrument, there was one activity that needed the student to verbally vocalise the phoneme of the given alphabets. Here, an audio recorder together with a video camera were used to get a clear recording data of the sound of the alphabets. While in other activities, only a video camera was used to capture the session. While the student answers the question, the starting and finishing times on each sub-topic were recorded.

Besides that, the student’s behaviour and difficulties when answering the exercise were observed using an observation checklist. Once the student completed the phonology instrument, he/she was asked to do self-reporting by rating the exercise given as agreeing or disagreeing based on easiness, enjoyment, fear and their willingness to answer the questions again.

After completing the first instrument, the student was asked to answer the spelling instrument. Similar to the first instrument, a video camera was used to observe the entire session while the student answers the questions. When the student asked for some hints like how to spell a word or when he/she does not know the vocabulary of the object (illustrated on the picture) in the Malay language, then help was given and recorded. However, when the student was unable to do most of the exercise and idle for a longer time, it was suggested that s/he skips the exercise to avoid spending too much time on one exercise and being demotivated. Once again, the student needs to do self-reporting for the spelling instrument.

In the reading instrument, the student was asked to perform a reading exercise which comprises reading short and long stories. An audio recorder was used to record the reading sessions. There were several questions to be answered related to the stories. The rationale of this activity was to check whether the student understands what he/she had read. At the end of the session, the student needed to report his/her perceptions about answering the instrument.

The last instrument was the writing exercise where the student needed to copy an alphabet displayed on a flash card that was shown for 6 seconds. The student was also asked to copy a sentence in a blank space provided. Besides that, to test the student knowledge of his/her background, the student needs to type his/her name, father’s name, mother’s name, and hobby. Finally, the student was tested on sentence construction based on a given word. Similar to the previous instrument, the student was required to do self-reporting at the end of the session.

3.2. Cognitive Evaluation

In the cognitive evaluation, there were three independent variables namely the total number of errors, the time taken and a total number of hints requested. The variables were used to classify the student’s level into two categories (i) mastery level and (ii) non-mastery level. To classify the student’s level, a rule-based algorithm of if…then... rules were used based on condition shown in the flowchart in Figure 1.

According to Arroyo and colleagues [36], a student who has fewer errors and requested less to zero hints within a minimal time taken constitute mastery. In addition, the guidelines from LINUS evaluation also characterizes mastery as low error that allows for only 1 error for every 5 questions. Therefore, based on these guidelines, we determine the rules that ‘mastery student is allowed to make only 1 mistakes for every 5 questions in each section of the instruments’.

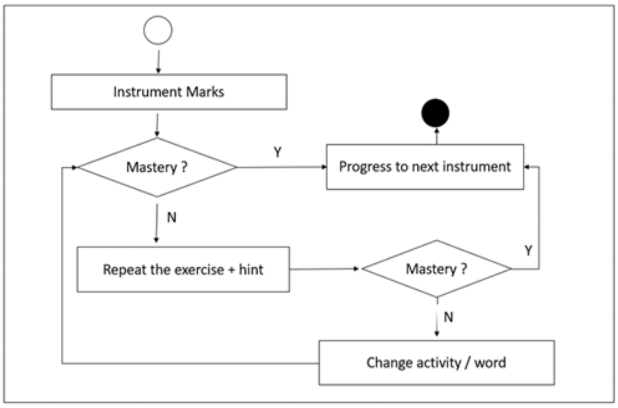

Fig. 1: Rule-based for the cognitive evaluation flowchart

3.3. Engagement Behaviour Elicitation

Engagement behaviour in this work was derived from Whitehill et al. and Hernandez et al.[15], [37]. We used the frontal face to predict the student's engagement behaviour. The setting included the use of video camera to capture the student's behaviour based on the student's face. Video camera with a tripod was placed on the table facing the subject to capture the entire face. Image classification was applied to utilise the student's face and classify the images as engaged or disengaged. Predicting engagement was difficult when using common systematic programming due to the uncertainty that involved vast image patterns. Therefore, machine learning approach was used to ease the engagement prediction. Machine learning is an artificial intelligence that provides the system with the ability to learn and predict without being structurally programmed. It can be automatically modified when exposed to a new data after learning from a large data input [38].

3.4. Engagement Behaviour Prediction

MATLAB R2016 was used for features extraction and classified in the WEKA version 3.81. As shown in Figure 2, the process of engagement prediction is presented. The steps include the data input acquisition, pre-processing techniques, clustering, and classification. For data input acquisition, we gather the data in the form of images extracted from video data. With the help of human coder who is an expert in teaching students with dyslexia, more than 900 images from 30 students managed to be compiled. The images come from a total of 450 images for engaged image and another 450 images of disengaged images. Refers to Table 2 for the features included in the labelling of the images.

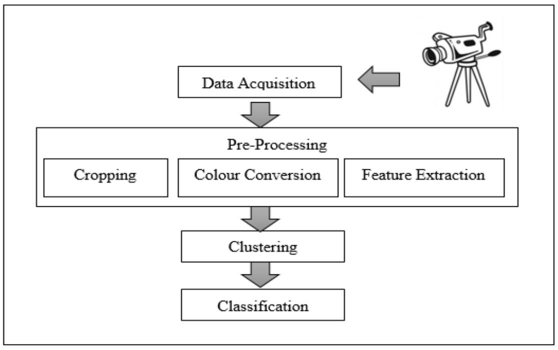

Fig. 2: The engagement prediction process

Table 1: Engagement Representation

Types	Situation	Features
Engage	Looking at the computer screen	-Frontal face detected - Eyes open
Disengage	Looking away from the screen	-Undetected frontal face -Eyes close

In the pre-processing techniques, we crop the images into an average of 600x700 pixels dimension. After that, the images are converted from the Red-Green-Blue (RGB) format to the Grey-scale format. This is to reduce the size of the images. Next, a specific feature called Speed-Up Robust Features (SURF) is used to detect the key interest point from the images. SURF works only on the grey scale images [39]. SURF then identifies and extracts the key interest point based on the features given in Table 1.

In the clustering process, the extracted features in the form of the vectors are clustered using k-means algorithm to find a fixed number of representations in this vector [40]. This set of representation is called a codebook. In this work, a codebook with the size 500 is used [41]. Finally, the images are classified using the SVM classifier.

SVM is a widely used classifier among researchers in image classification. This is due to the classifier's ability to handle non-linear problems like the human face [42]. Our main focus for the classification process is to look for the highest accuracy result that is able to correctly distinguish between engaged and disengaged images. Therefore, we compare the two classifications using two SVM approaches that are using RBF kernel or linear kernel.

4. Result

In this section, we discuss the results gathered related to cognitive, engagement behaviour and cognitive-behaviour intervention.

4.1 Cognitive

The results show that most of the students with dyslexia are having difficulties in all the instruments, as shown in Table 2. For the phonology instrument, 18 students are reported to achieve the level of 'mastery', and only 12 students are reported with 'non-mastery'. Non-mastery students do not only have issues with the number of errors but they also take a long time to answer the questions. The shortest time answered is 6 minutes while the longest time answered is 36 minutes. Phonology is the basic knowledge in language processing skills. Therefore, the student with severe dyslexia condition commits more errors.

Spelling instrument is also impacted due to the decrease in the number of 'mastery' students. The difficulties in the spelling acquisition are closely related with a weak foundation of the phonological awareness [43]. Five students are unable to finish the spelling exercise due to their limited skills. In terms of time, the shortest is 8 minutes, and the longest is 20 minutes.

The most problematic difficulties faced by the students in the reading skill. Only three students are able to answers with at least 1 error for every exercise they encounter. In the reading instrument, seven students are unable to finish the reading due to their reading difficulties. For the students who achieve the 'mastery' level, they are not only able to read but also comprehend the passage by answering the questions correctly. The maximum time taken by the students to finish their reading instruments is 40 minutes while the minimum time taken is only 8 minutes.

In the writing session, a higher number of 'non-mastery' students (22 students) are found. Only eight students are able to write their details, copy sentences and create a simple sentence. The majority of their errors are due to mirror writing problems and the inability to spell the words. The maximum time taken is only 17 minutes and the minimum time is 9 minutes. Six students are unable to finish their writing instruments due to poor phonological skills background.

Table 2: Cognitive Result

Types	Phonology	Spelling	Reading	Writing
Mastery	18	10	3	8
Not Mastery	12	20	27	22

4.2 Engagement Behaviour

Given the 900 images, local features are detected in the areas of the interest points. In this work, our interest point is related to the frontal face, e.g.: eyes region and whole face area. Refer to Figure 3 for the sample of the key interest point detected from both the engaged and disengaged faces. The detection is solely based on the SURF descriptor that is able to provide a significant speed-up while improving the performance of the detection [44].

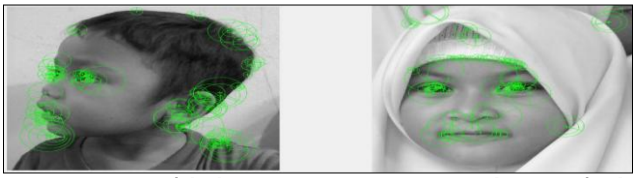

Fig. 3: Detection of the key interest point using SURF descriptor for disengaged (left) and engaged (right) faces

Once the vector of each feature has been acquired, the vector based on the 500 codebook sizes is clustered. The results will then undergo the classification process using the SVM classifier with 10-folds cross-validation. The reason we used the cross-validation is to avoid overfitting issues [45]. LIBSVM or Library Support for Support Vector Machines is chosen as the SVM classifier in the WEKA platform with an adjustment of the kernel using Linear and RBF.
Based on the results shown in Figure 4, the highest accuracy for the engagement behaviour prediction is when the classification uses the LIBSVM Linear with 96% accuracy. The linear kernel performs better in this data because the data has a linear decision boundary. However, the accuracy reported with LIBSVM RBF is still acceptable with almost 88% accuracy. The results prove that LIBSVM is able to distinguish between the engaged and disengaged faces when we apply the SURF descriptor as well as the k-means algorithm.

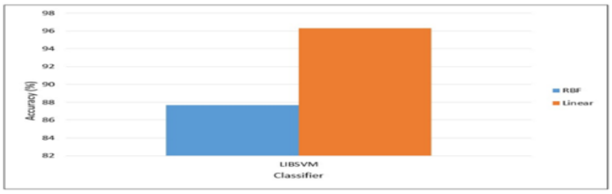

Fig. 4: The accuracy results for engagement behaviour prediction

4.3 Cognitive and Behaviour Intervention

Once we got both inputs from the cognitive and engagement behaviour, the next phase is making a decision for the Expert Model in the Adaptive Learning Model. Refer to Table 3 for the details of the decision rules. In this phase, we divide the decisions into two decisions, i.e. academic decision for cognitive intervention and affective decision for behaviour intervention. These two decisions will be concurrently provided to the student.

Table 3: Cognitive Result

Cognitive	Behaviour	Academic Decision	Affective Decision
Mastery	Engage	Increase problem difficulty	Show learning progress
Mastery	Disengage	Maintain problem difficulty	Praise effort & change activity
Not Mastery	Engage	Maintain problem difficulty	Offer hints
Not Mastery	Disengage	Reduce problem difficulty	Change activity

In the academic decision, the student who has mastery and reported to have been engaged with the learning, will be intervened with increasing difficult tasks. This is to challenge the cognitive knowledge of the student so their performance can be improved [12]. As an affective decision, his/her learning progress will be shown to the student in order to motivate him/her [46].
While for the student who is identified to have achieved mastery but is disengaged with the learning contents, the intervention for the academic decision will only involve maintaining the problems' difficulty. However, at the same time, the system will praise his/her efforts and change the activity by adding visual aids such as pictures and sounds as extra support [46].
The student who has not achieved mastery but is engaged with the content will be treated by maintaining the current level of problem difficulty. The intervention could include offering hints. Hints were reported to be successful in creating persistency for the engagement in learning [47].
Finally, students who are reported to be disengaged and have not achieved mastery will be intervened by reducing the difficulty level of the problem. To attract the student, the system will change the activity with the use of supplementary visual aids which comprises of pictures and sounds as an extra aid. Besides that, the system will praise the students with positive, encouraging words.

5. The Proposed Adaptive Learning Model

Hence, in this section, we present a proposed learning model that considers both cognitive and behaviour conditions of the students with dyslexia. The Adaptive Learning Model consists of five components: exercise model, behaviour processing model, student model, expert model and teacher model [48].
The cognitive deficiency faced by the students is identified in the Exercise Model. While for student's behaviour, his/her engagement states are continuously tracked and processed in the Behaviour Processing Model. Finally, the Student Model aggregating the cognitive and behaviour input from the Exercise Model and Behaviour Processing Model includes the student's demographic background to construct the student's profile. The model is shown in Figure 5.

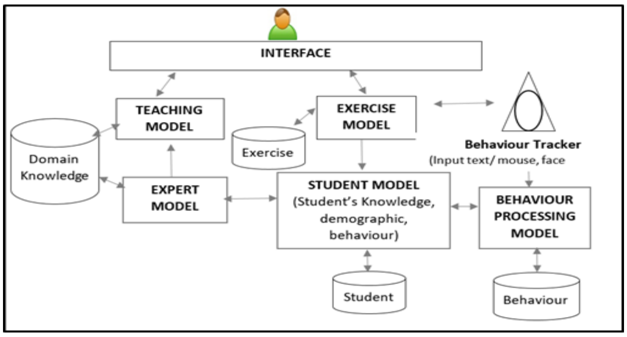

Fig. 5: Adaptive Learning Model for students with dyslexia

5.1 Exercise Model

The exercise model comprised an instrument of four exercises related to language processing difficulties. This includes phonology, spelling, reading and writing instrument. The phonology instrument tests the sounds of the alphabets, vowels, consonant and simple syllables.
Whereas, in the spelling instrument, the test is related to the complexity of consonants and vowels in a word. The reading instrument assesses the reading fluency of the student in short and long passage. Finally, the writing instrument aims to measure the error in writing.
The instruments are created and evaluated based on the LINUS syllabus programme. There are five questions for each sub-topic specifically linked to each instrument. However, the students are

only allowed to make one error out of the five questions to be labelled as achieving the Mastery level. This is considering the fact that some students may accidentally answer it correctly. Two errors and above will be labelled as Non-Mastery. Refer to Table 4 for details of the Exercise Model.

Table 4: Exercise Model Content Syllables

Instruments	Topic	Total Questions	Total Marks
Phonology	-alphabets and phonemes	5	20
	-vowels (V)	5	
	-consonant (C)	5	
	-simple syllables	5	
Spelling	-VCV and CVC	5	20
	-CV+CV	5	
	-CVC VC	5	
	-CVCVCV	5	
Reading	-short passage	5	20
	-comprehension	5	
	-long passage	5	
	- comprehension	5	
Writing	-copying	5	20
	-fill up details	5	
	-create short sentence	5	
	-create long sentence	5	

5.2 Behaviour Processing Model

While the student answers the exercise, a video camera is used to record the student's frontal face. The face is used to classify the student's engagement while answering the exercise in the Behaviour Processing Model. The classification is based on the learning classifier machine such as the Support Vector Machine (SVM) to classify the displayed behaviour as being engaged or disengaged with the learning content. The results of the model are used as an input for the Student Model.

5.3 Student Model

The Student Model aims to identify the individual learning style gathered from the student's cognitive deficiency, his/her demographic details, and engagement behaviour. For demographic information, data such as the student's age, gender and race are used to create the student's profile, and it is later stored in the database. The cognitive input of the student in each instrument is classified into the category of mastery or non-mastery. For the engagement behaviour, the result will be either the student is engaged or disengaged. All the output will be transferred to the Expert Model for further analysis.

5.4 Expert Model

The Expert Model aims to suggest adaptive learning based on the student's cognitive performance and engagement behaviour. The model requires prior data to come up with suggestions on the affective and cognitive decisions. For cognitive decision, the model will increase the problem difficulty when the student has already mastered the skill and engaged with the learning contents. The affective decision is made to capture the student's attention by showing his/her learning progress when he/she succeed in completing each task. It is also used to praise the student's efforts.

5.5 Teaching Model

The domain knowledge database filters the student's activity-based language modules which consist of phonology, spelling, reading, and writing. The teaching model acts as a teacher to provide a suitable intervention based on the student's performance and behaviour. There are four elements that needed to be taken into accounts such as affective decision, academic decision, audio and written instruction, and colour or character preferences. Finally, the Teaching Model provides the student with activities based on the current learning performance and acts as an intervention. The intervention addresses the cognitive difficulties and improves the student's learning through specifying individual teaching activity.

6. Conclusion

This paper has presented an in-depth discussion of the cognitive deficiency and behaviour challenges experienced by the students with dyslexia. The results show that students with dyslexia require inclusive intervention that takes into consideration both the cognitive and behaviour conditions. An automatic detection via the frontal face may help to detect the students' engagement behaviour when they not engaged with the learning content. From the observation conducted, the students are also recorded to be easily demotivated and they tend to lose focus easily. There is a definite characteristic for the cognitive deficiency for students with dyslexia in all the four instruments. Whereas, the behaviour displayed is considered similar to students without dyslexia. Therefore, in the work, the behaviour component is not solely used for students with dyslexia but also for students with other types of learning difficulties or even students without the learning difficulties.

In our study, incorporating cognitive and behavioural conditions in learning intervention gives a positive solution to the students with dyslexia. Through the adaptation intervention in the Expert Model, it gives the students options to independently learn in more positive and encouraging ways. The Adaptive Learning Model also intends to reduce teacher's dependency and promote self-learning.

In conclusion, research pertaining to students with dyslexia is still scarce, especially in Malaysia. The inadequacy of data related to the numbers of dyslexics in Malaysia, dyslexia difficulties in language processing, engagement behaviour as well as eliciting sufficient students' face images become a challenge in our research. The use of machine learning itself has a great potential for the learning about dyslexia. However, without enough data, we could not utilise it to explore the maximum potential of dyslexic students. For that reason, in the next phase of the work, we will focus on developing a complete intervention prototype that not only adopts the Expert Model but also intervenes using the Teaching Model.

Acknowledgement

Special thanks to Dyslexia Association Malaysia (DAM) for great assistance in this research. We would also like to thank the university's ethics committee who approved our application to conduct this study, along with the GP-IPS/2016/9479000 grant awarded who fund the research work.

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