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# A systematic review on interventions for children with dyslexia

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**ABSTRACT**

Dyslexia is often described as the most common learning disability among the students that affect their ability to read and write. Children with dyslexia persist to their reading difficulties into adolescence and adulthood if without effective intervention and instruction. Therefore, this paper aims to review on the current state of available interventions for children with dyslexia in Malaysia and compare the interventions conducted outside Malaysia instead of to identify the frequently used for assistive technology tools in improving literacy skills. A total of 30 articles published between 2009 and 2021 that met the inclusive criteria were downloaded from electronic databases such as Scopus, SpringerLink and ScienceDirect. The interventions were divided into two categories which are phonological-based and assistive technology-based. The findings indicated that most of the interventions are focused on assistive technology tools and mobile learning applications become the favorite choice in Malaysia to assist students with dyslexia in ameliorating their learning difficulties. However, the developed mobile learning applications are not focused on teaching phonics and combined all three language skills (reading, spelling, and writing) in an application. Hence, it is imperative that researchers in Malaysia take into account to develop more mobile learning applications that focus on English language phonics and encompass three language skills (reading, spelling and writing) in an application for students with dyslexia.



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## 1. INTRODUCTION

Literacy skills play a pivotal role in the success of the academic settings. Good readers have more chances in widening their mental horizons and achieving more success in the rapid advancement of the world [1]. Nevertheless, the substantial number of illiterates or struggling readers is distinct in Malaysia. The groups of literacy strugglers may encompass learners with dyslexia. Dyslexia has been described as a language-processing disability that is neurobiological in origin and characterized by inaccurate and/or fluent word recognition and by poor spelling abilities. Learners with dyslexia have difficulties in mapping letters with their corresponding sounds, blending and segmenting sounds of the words [2]. Typically, they more slowly articulate their words or sentences during the reading process as they have lower memory spans that lead to inefficiently in accessing phonological information [3]. According to, learners with these disabilities may impair in reception, recognition, organization, storage, retrieval, and reproduction of information.

According to international dyslexia association, dyslexia is being suffered by about 10%-15% of the world population. In Malaysia, there are estimated about 314,000 children are suffering from dyslexia in year 2010 and the number increased to 400,000 in year 2013 based on the statistics reported by Ministry of

Education Malaysia. Therefore, it is important to have an intervention program to curtail the amounts of students with dyslexia to cater the 4th industrial revolution challenge (4IR). Reading difficulties will persist throughout adolescence to adulthood [4] if without effective intervention and instruction. Since the level of severity of learners with dyslexia are different from one person to another, hence it is vital to have structured and flexible intervention plans to cater to their needs. Phonics approach is the most promising approach to increase the accuracy of word reading than reading fluency.

Snowling [5] suggested that effective interventions for learners with dyslexia in the early stage should emphasize on phoneme awareness and mapping letters and sounds via writing and reading from texts at the appropriate level to reinforce emergent skills. In view of this, Osman, Yahaya, and Ahmad [6] recommended that reading intervention for children with dyslexia not only be phonologically oriented, but should incorporate multisensory approach, which utilizes the children's auditory, visual, and kinaesthetic sensory components in the learning strategy.

Apart from that, recent research revealed that assistive technology has become the favorite choice among learners with dyslexia. Learners with dyslexia who exhibit poor decoding skills and low levels of fluency may use text-to-speech software to convert printed text documents into a natural-sounding voice [7]. Moreover, device such as word processors with spellcheckers can be used by learners with dyslexia who struggle with writing and spelling to improve their spelling and writing organization and structure. Remarkably, there have been claimed that mobile learning applications improve overall in reading ability for children with dyslexia [8] as it provides uniquely engaging manner such as touch-screens [9] instant-feedback functions [10], fun environment [11], and learning independently according to their own pace and ability [12].

There are varied types of interventions to assist children with dyslexia in alleviating their difficulties on literacy skills as the level of problems experienced by them are different. However, the existing reviews are more focused on the generalizability of interventions for children with dyslexia and were performed years ago [13], [14]. Hence, the purpose of this research is to review the literature on the available interventions for children with dyslexia in Malaysia and compare the interventions conducted outside Malaysia to identify the frequently assistive technology tools used by educators to assist children with dyslexia in mitigating their literacy difficulties.

## 2. RESEARCH METHOD

### 2.1. Search strategy

The review articles published between 2009 and 2021 were searched online via electronic databases such as SpringerLink, ScienceDirect, IEEE Xplore Digital Library, Scopus and ERIC. Google Scholar database was used to retrieve articles as well as to reduce other potentially relevant studies that may have been missed from the systematic database search. The papers were searched by using the keywords, namely "Dyslexia AND Intervention", "Reading difficulties AND Intervention", and "Dyslexia AND Intervention in Malaysia".

### 2.2. Inclusion and exclusion criteria

After identifying the keywords, inclusion and exclusion criteria were established to clarify the search more notable and useful nature in relation to the subject to be dealt with. The researchers set out the following inclusion criteria: i) Dyslexia intervention program must be the main condition of the study; ii) Participants in the study must be students with dyslexia in primary school or application evaluators; and iii) The articles must be in full-text English journal and published between 2009 and 2021. Then, researchers excluded studies that did not consider dyslexia as the main disorder for intervention program and interventions focused on medical contexts.

### 2.3. Extraction and analysis of data

The search produced a total of 193 potentially eligible studies of which 30 met the inclusion criteria. The 30 selected papers were reviewed systematically and data were extracted relating to the wide-ranging characteristics of the studies. These characteristics are comprised of: study; methodology; types of intervention; findings; and recommendation. A narrative synthesis was employed to summarize the findings of eligible studies included in this systematic review. Figure 1 presents the flow chart on the process of selecting dyslexia intervention for the systematic review.

## 3. RESULTS AND DISCUSSION

Table 1 and Table 2 are presented a summary of the characteristics of the eligible studies and their key findings. These eligible studies were conducted in very few on phonological-based interventions, namely

10 studies. Most of these studies were focuses on assistive technology-based intervention particularly on mobile learning applications namely 16 studies.

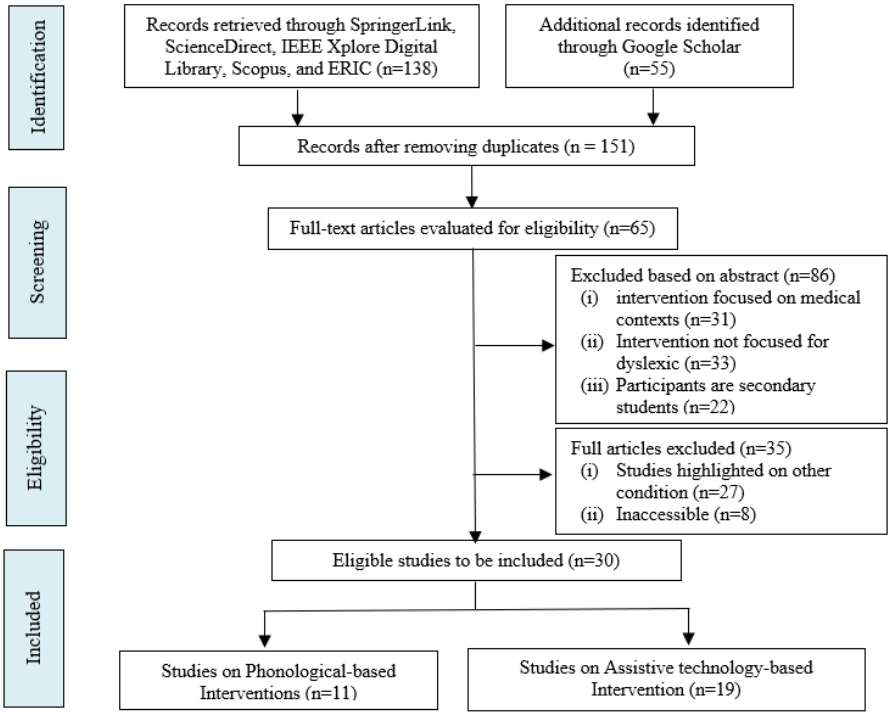


Figure 1. A flow diagram of dyslexia intervention selection for the systematic review

### 3.1. Phonological-based interventions

From 30 review articles, only 10 articles are focused phonological-based interventions [15]–[24], in which five phonological-based interventions are from Malaysia. Table 1 presents the 11 phonological-based interventions which comprise of *Kaedah Gabungan Bunyi Kata* method, multisensory therapies, Orton-Gillingham (OG) approach and Davis method. According to Abzol and Haron [15], *Kaedah Gabungan Bunyi Kata* (KGBK) taught students the three most important vowels (a, i and u) and one consonant to construct open syllables (CV) that form a word has meaning. KGBK was effective to increase their proficiency on reading and writing of Malay Language instead of improving their learning motivation to read and write. Similarly, reading performance of children with dyslexia was improved after following 10 sessions of phonological educational intervention [16], phonics through spelling intervention [17] and sensory-perceptual skills training [18].

On the other hand, Ziadat [19] adopted quasi-experimental approach to assess oral reading and reading comprehension levels of Arabic language basic skills using intervention Visual, Auditory, Kinesthetic, and Tactile (VAKT) strategy. The findings revealed that experimental group which adopts VAKT strategy showed a significant enhancement on comprehension reading and oral reading levels than control group. Likewise, children with dyslexia in Subramaniam and Nasir [20] study also enable to write letters that have similar shapes without any reversal after went through the 10 multisensory method therapies.

In addition, Lee [21] has designed and developed the *MyBaca* Malay word recognition intervention program for children with dyslexia. Educators adopted a few instructional strategies such as cut-outs of 2D letters made from carpet, trace-write worksheets, Bingo game cards, phoneme cards and using word strips during the implementation of this program. Subramaniam, Mallan, and Mat [22] also produced a learning module based on the use of multi-sense explication activities like VAKT, Gillingham and Fernald methods to trigger the active learning environment for children with dyslexia. Orton-Gillingham (OG) approach conducted by Lim and Oei [23] indicated OG approach was effective in remediating the literacy difficulties of students with dyslexia. Lee [24] also found that Davis Correction Program has helped children with dyslexia to correct visual perceptual problems, correct problems with reversals and in tracking while reading.

The findings indicated that phonological-based interventions have proved to yield a positive impact on rehabilitating literacy difficulties of children with dyslexia. These results are consistent with those of other studies [25]–[28]. A possible explanation for this might be that phonological-based intervention increased phonological awareness of children with dyslexia. Implementation of multisensory approach builds visual-auditory associations in learning reading via kinesthetic activities and thus develop attention span to the reading task [18].

Table 1. A summary of phonological-based interventions

| Study | Methodology | Type of intervention | Findings | Limitation/Recommendation |
|---|---|---|---|---|
| [14] | Sample: Five remedial students with dyslexia at one of the primary schools in Petaling Utama | Phonological based intervention (Assimilation from Linguistics (phonics) and Psychology Cognitive Development Perspectives (words with meaning) | KGBK approach improves reading sentences and writing skills instead of boosting their interest on reading and writing in Malay Language. | |
| [15] | Sample: 16 3rd-grade female dyslexic student | Phonological based intervention | Phonological educational intervention is effective on the reading performance of dyslexic children. | Limitation: Conducted on female students |
| [16] | Sample: 52 children with dyslexia | Phonological based intervention | Semantic stimulation could benefit the spelling development of children at risk for or with dyslexia. | |
| [17] | Sample: 60 dyslexic students | Phonological based intervention (Cognitive and Multisensory learning) | Sensory-perceptual skills training significantly increases performance of the students. | |
| [18] | Sample: 39 students with dyslexia in third-grade | Phonological based intervention (Multisensory learning) | VAKT is a sufficient approach to advance the comprehension reading and oral reading levels of students with dyslexia. | Limitation: Research data in categorical data type. Recommendation: i) Adopt continuous scale measurements; ii) Considering learning style and reading motivation |
| [19] | Sample: 10 students who are beginner dyslexics | Phonological based intervention (Multisensory learning) | All respondents were able to write letters that have similar shapes without any reversal. | |
| [20] | Instructional strategies based on: Orton-Gillingham approach; National Reading Panel review; Elements of Structured Literacy | Phonological based intervention (Orton Gillingham approach) | *MyBaca* was developed based on theoretical of dyslexia. | Limitation: Focus on Malay Language Recommendation: i) 3D physical letters with color hints were enhanced into a computer-based tangible reading system; ii) Generalized to word recognition in other languages |
| [21] | Sample: 5 children with dyslexia in age 8-9 years were selected in Malacca | Phonological based intervention (Multisensory learning) | Language learning games managed to attract dyslexic children in learning Malay Language. | Limitation: Focus on the words that have diphthongs in Malay Language |
| [22] | Sample: 39 students with dyslexia | Phonological based intervention (Orton Gillingham approach) | OG approach was effective in remediating literacy difficulties of students with dyslexia. | Limitation: Lack of a wait-list or no-intervention control group. |
| [23] | Sample: 1 dyslexic child | Phonological based intervention (Davis method) (Combination of cognitive and literacy) | Davis model enables correct visual perceptual and reversal problems and tracking words. | Limitation: A small sample (one person) |

### 3.2. Assistive technology-based intervention

Most of the review articles (20 out of 30) are highlighted assistive technology-based interventions which encompass mobile learning applications [8], [9], [11], [29]–[41], Tangible Interaction (TI) [42], [43], machine learning (ML) approach [44] and automatic speech recognition (ASR) technology [45]. The finding could be explained by assistive technology improves children with dyslexia on literacy skills as it has features that allow them to practice and repeat on the sound or word as many times without restrictions [43]. Table 2 presents a summary of assistive technology-based intervention.

Table 2. A summary of assistive technology-based intervention empirical studies

| Study | Methodology | Type of intervention | Findings | Limitation/Recommendation |
|---|---|---|---|---|
| [8] | Sample:<br>8 dyslexic children aged 7 to 12; Teachers and parents at Dyslexia Association of Sarawak | Assistive technology (Mobile application) | Participants were satisfied with user interface design, color, and images and improved in spelling and sounding out words. | Recommendation<br>Add more interactive learning features (audio recording of users' voices) and a variety of stories into the story module |
| [9] | Sample:<br>5 students with dyslexia | Assistive technology (Mobile application) | Showed progress in their overall game performance over a short period of time usage. | Recommendation:<br>Testing the application's effectiveness over an extended period of time |
| [30] | Sample:<br>11 dyslexic children from 2nd to 7th grade | Assistive technology (Mobile application) | Half of the children could improve their performance in reading as well as in spelling. | Recommendation:<br>i) Prolong the time training;<br>ii) Effect of the therapeutic approach on reading and writing |
| [31] | Sample:<br>5 dyslexia caretakers (the teachers or parents) | Assistive technology (Mobile application) | Most of them agree that Leady can help dyslexic students to learn how to read. | Recommendation:<br>Provide learning features for reading a word, and add writing assessments to measure the students' writing abilities. |
| [32] | Sample:<br>Seven evaluators | Assistive technology (Mobile application) | Agreed that *Dyslexia Baca* is well designed in aspects of content and multimedia elements. | Limitation:<br>Focus on Malay Language |
| [33] | Sample:<br>10 children with dyslexia | Assistive technology (Mobile application) | The games fulfilled the activity objective of the three pre-established areas. | |
| [34] | Sample:<br>5 teachers of the Dyslexia Association Kuching, Malaysia. | Assistive technology (Mobile application) | WRIDY is helpful and useful in learning writing alphabets for kids with dyslexia. | Recommendation:<br>Add more modules in pronunciation of the letters, lower case letters and scoring system |
| [35] | Sample:<br>Dyslexic students aged 5 | Assistive technology (Mobile application) | Developed application improved handwriting skills of children with dyslexia. | Recommendation:<br>Build on other platforms (iOS and Windows); Include the writing assessment of two and three-lettered sight words |
| [36] | Instrument:<br>i) Observation<br>ii) Interview | Assistive technology (Mobile application) | 90% could focus because attracted to the background, suitable voice, clear instruction. | Limitation:<br>Focus on Malay Language<br>Recommendation:<br>Prefers to use an adult voice |
| [37] | Sample:<br>5 dysgraphic children aged 7 to 12 | Assistive technology (Mobile application) | Participants' handwriting was improved over the course. | |
| [38] | Sample:<br>Three evaluators | Assistive technology (Mobile application) | *FunLexia* has the potential benefits to help children to learn Arabic. | Recommendation:<br>Larger number of participants |
| [39] | Sample:<br>25 children with dyslexia | Assistive technology (Mobile application) | The apps improved the learning processes of children with dyslexia through games with easy-to-use tools. | Recommendation:<br>Designing an app for dyscalculia |
| [40] | Sample:<br>10 teachers who teach in specialized education | Assistive technology (Mobile application) | Participants strongly agreed to all usability dimensions. | |
| [41] | Sample:<br>40 dyslexic children with age 5-8 years old. | Assistive technology (Mobile application) | Children enjoy and engage in playing the application and agree to use it again the apps. | |
| [42] | Sample:<br>Malay primary school. | Assistive technology [Tangible Interaction (TI)] | TI enables to assist children with dyslexia in reading, spelling, and phonology. | |
| [43] | Sample:<br>9 children with dyslexia, aged 6–9 years old at the Dyslexic Association of Malaysia | Assistive technology [Tangible Interaction (TI)] | Increase engagement with the program and enabled to learn some words from the phonics-based reading program. | Recommendation:<br>Revise uppercase letters to small letters and have homophone exercises |
| [44] | Sample:<br>Students aged between 8-12 years old | Assistive technology [machine learning (ML) approach] | Students with dyslexia learn in ways that suit a specific individual. | Limitation:<br>Focus on Malay Language |
| [45] | Sample:<br>10 dyslexic children in two public schools | Assistive technology [Automatic Speech Recognition (ASR)] | The pronunciation models help determine the recognition process accuracy. | Limitation:<br>Focus on Malay Language<br>Recommendation:<br>For faster recognition and improved recognition accuracy. |

In relation to the mobile learning application, Mr Read V2.0 was developed by Borhan *et al.* [8] to assist children with dyslexia ages 7 to 12 to increase their vocabulary size by using the sight words approach. The findings revealed that Mr Read V2.0 is an effective learning platform to improve reading skills of children with dyslexia. In addition, Bigueras *et al.* [29] developed LaroLexia mobile application that is written in Filipino language on the Android platform to assist children with dyslexia to read. Based on the findings, reading performance for both categories (letter category and word categories) of children with dyslexia improved after using LaroLexia mobile application. Likewise, Prosodiya developed by Holz *et al.* [30] also revealed that children enjoy spending time playing the game and their performance on spelling and reading comprehension was improved.

Another mobile learning application, Leady was developed by Hidayati *et al.* [31] for children with dyslexia in the first grade of elementary school to learn how to read by recognizing the letters and connecting each letter with their corresponding sounds instead of letter writing. All respondents agree that Leady can assist children with dyslexia to learn how to read. Moreover, Daud and Abas [32] developed Dyslexia Baca to assist children with dyslexia to recognize and distinguish letters 'p, q, b, d, m, and w' by matching the letter presented with the letter shown in the balloon. Similarly, Dyslexia Aide which consists of alphabet learning and memorizing skills enhancement also developed by Mohamad and Samsudin [11]. Bittencourt and other researchers [33] developed a mobile application to assist Brazilian children with dyslexia in counting the number of syllables and consolidating their working memory.

In overcoming the writing difficulties among children with dyslexia, WRIDY mobile learning developed by Wee *et al.* [34] was useful to support children with dyslexia in learning writing alphabets. Likewise, handwriting skills of children with dyslexia were improved after using the application developed by Tariq and Latif [35]. Further, CinTA mobile application has been developed by Azmi *et al.* [36] to assist children who have problems on writing and recognizing characters. CinTA applies the letter 'C' and letter 'l' as a base in writing another character to teach children with dyslexia. Children with dyslexia are required to play an interactive quiz in a game mode to evaluate their learning performance. Similarly, Rahim and Jamaludin [37] developed Write-Rite application to support them in practicing writing at different levels of difficulty via activities and exercises. The findings revealed that Write-Rite improved writing proficiency among children with dysgraphia.

The preliminary research of FunLexia which was developed by Ouherrou *et al.* [38] indicated that FunLexia offers an enjoyable environment for children with dyslexia instead of improving their fundamental skills in Arabic language such as reading, writing, comprehension, Arabic orthography, short-term memory and concentration. Likewise, Skiada *et al.* [9] developed a mobile application known as Easylexia for children with dyslexia to improve their elementary skills such as reading comprehension, orthographic coding, short-term memory and mathematical problem-solving. The evaluation of this application revealed that the application engages the attention of children with dyslexia in learning and keeps them in focus on the device's touch screen.

On the other hand, Larco *et al.* [39] developed Helpdys App to support children with dyslexia in word recognition, spelling, vocabulary, and photographic memory. Similarly, Burac and Cruz [40] build-up the IREAD, a mobile assistive application using unity 3D, in teaching reading and writing lessons for children with dyslexia. IREAD consists of three modules, learning module, evaluation module and history/reports module. Apart from that, Saputra [41] found that children are engaged and enjoyed using LexiPal application which incorporates story/theme, clear goals, levels, points, rewards, feedback, and achievements/badges.

Additionally, TI Model is another assistive technology tool that can employ to support children with dyslexia in learning. For instance, Jamali *et al.* [42] proposed TI Model to teach children with dyslexia in learning letter-sound correspondence, word recognition, single sound values, and reading comprehension by using 3D tangible letters for Malay language. The kids with dyslexia grasp the 3D tangible letters and arrange it on the platform that holds the letters by using their body movements. The system will give audio and visual feedback by providing the sound of the letter and recognizing the word correctly on the screen. In response to this demand, Teh, Ng, and Parhizkar [43] developed Trace it for children with dyslexia to air trace alphabets using graspable physical objects of a specific color to interact with the phonics-based reading program. By using color-based recognition system to detect the hand motion via the tracked colored object, the children enable to see and trace alphabets on the screen and hear the alphabet or word sounds.

A computer-based learning model using machine learning (ML) approach was proposed by Hamid, Admodisastro, and Ghani [44] to improve learning of the Malay language among students with dyslexia. The computer-based learning model provides teaching support based on cognitive difficulties and improves the student's learning via specifying individual teaching. On the other hand, Husni and Jamaludin [45] provide such immediate reading intervention by using ASR technology to remediate reading among children with dyslexia. When the user makes a mistake during the reading process, the immediate intervention module is invoked, allowing for feedback that informs the user of the mistake.

Based on the article's findings, mobile learning application is the most frequently used among assistive technology tools in the intervention studies as it is portable, inexpensive and easy downloading [46], [47]. This finding is supported by Quick [48] which addressed mobile application which has touch screen manner that is easier to use than a mouse and a computer for children who have trouble with fine motor skills such as children with dyslexia. Besides, children adapt more easily to use mobile applications since they start to use mobile devices at the early age of their life [49], [50]. Moreover, the learning process can occur inside and outside the classroom via mobile devices and mobile networks [51]. The findings in this study also indicated that there are limited mobile learning applications (6 out of 15) in Malaysia compared with other countries. Moreover, the developed mobile learning applications are not focused on teaching English Language phonics and combined all three language skills (reading, spelling, and writing) in an application.

## 4. CONCLUSION

The review highlights the various interventions which include phonological-based and assistive technology-based to improve the literacy skills of children with dyslexia. Interventions conducted in Malaysia propensity to employ assistive technology tools than phonological-based intervention. The review of the literature indicated that Malaysia still lacks of a mobile learning application that focuses on English Language phonics and comprises all three language skills (reading, spelling and writing). Therefore, it is imperative that researchers in Malaysia develop 3 in 1 mobile learning application in learning phonics to alleviate their difficulties on literacy skills.

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