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DYSCALCULIA, CAUSES, INTERVENTIONS AND MALAYSIAN SCENARIO

Mohammad Amimul Ihsan Aquil [1]; Mazeyanti Mohd. Ariffin [1]

[1] Department of Computer and Information Sciences, Universiti Teknologi Petronas, Malaysia

Correspondence: Mohammad Amimul Ihsan Aquil (email: aihsan.aquil@gmail.com)

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Abstract

Dyscalculia has negative consequences for the children, youth and society at large. While Dyslexia is a well-known illness, Dyscalculia, on the other hand, is less known. Dyscalculia, although a relatively newly recognised learning need, has significant implications. About 5%-8% of children in primary schools are affected. Educational research and interventions evidence to alleviate Dyscalculia are very scarce in Malaysia. While Dyscalculia is a relatively newly recognised learning need, it has significant implication on society. It is essential, therefore, that educators in Malaysia are aware of this learning need and considers strategies for supporting children with it. Clearly, more research is required for the current situation, diagnosis and intervention in Malaysia to aid the Malaysian children suffering from Dyscalculia.

INTRODUCTION

Educators have achieved a consensus about the crucial part that mathematics plays in survival and success in everyday life (Ramaa & Gowramma, 2002). Solving everyday problems require analysis, reason, logic and mathematical conceptualisation. The term Dyscalculia comes from two words. A Greek root 'dys' used to refer to difficulty and a Latin word 'calculia,' which is drawn from the word calculus (Gillum,2012). Basically, it is a small pebble or stone that can be used in carrying out calculations. Dyscalculia refers to any difficulty experienced with numbers and often results from an acquired difficulty in cases of brain injury or through a developmental cognitive condition. An assertion made by Kucian and Von Aster (2015) in their study shows the importance of numerical skills in everyday life and that any chance for the development of impairment in number calculations and processing may have profound negative impacts on an individual's self-esteem, professional careers and Schooling.

The modern-day society is filled with manifestations of numbers and digits everywhere. Be it on the stores, street signs or billboards; numbers are everywhere. That aside, in a school setting, mathematics remains a core and mandatory subject that all students have to learn. Therefore, when a child fails to understand mathematical concepts and skills, he or she can easily be left behind in a technology-intensive and information science world that exists today, which highly relies on mathematical concepts to get through daily living. There has been a growing number of researches being focused on basic numerical abilities, for example, counting and arithmetic (Landerl, Bevan & Butterworth, 2004). It has been noted that in a paediatric population that about 10% of all the children do face and continue to face difficulties when it comes to learning basic mathematical skills. Out of the 10%, only 3-7% have satisfied the diagnostic criteria of a mathematics-based disorder, which in this case is also known as the Dyscalculia (Sigmundsson, Anholt, & Talcott, 2010). Dyscalculia's significance remains greatly underappreciated. Both the individual and society get to suffer the burden of having a poor mathematical ability. A study done in England on a large cohort of study participants shows a great correlation between a poor mathematical ability to greater economic and psychosocial risks. That is, about 70-90% of the individuals affected by the disorder showed a trend of dropping out of school by the age of 16. By the time, they were getting to 30 years of age only a handful are employed under full-time conditions. It can also be noted according to Parsons & Bynner (2010), that for such individuals, the likelihood of developing depression from remaining unemployed was recorded as being twice as high compared to individuals with no dyscalculia. The costs of Dyscalculia are very high with Great Britain posting estimates of about £2.4 billion yearly (Gross et al., 2009).

In Malaysia, the concept of Dyscalculia remains in an infancy stage. According to Fu's (2002) survey in Sabah, about 57.5% of the participants attested to not knowing having knowledge pf Dyscalculia. Additionally. About three quarters of the respondents mentioned not getting prior exposure to this topic during their training in teachers' colleges. Another 78.8% said that the issue of Dyscalculia was rarely if ever mentioned and discussed during their continuous professional development courses. Additionally, it can be noted that the Malaysian Ministry of social welfare misdiagnosed and treated Dyscalculia with interventions made for Dyslexia. Such a scenario would have resulted in the implementation of inaccurate intervention as both conditions do not face similar learning issues. The aim of this paper is to give an overview of Dyscalculia using an interdisciplinary approach (e.g. Psychology, Neuropsychology and Education) and to discuss the research gap regarding Dyscalculia in the Malaysian context.

1. Definition of Dyscalculia

Dyscalculia can be termed as a Specific Learning Disability, a term with a number of variations such as learning difference, a learning disorder, learning difficulty or learning disability. Other terms cannot be included as they are often inconsistently or poorly defined. The existing differences between the terminologies in this area of study impose key challenges to readers looking to study it. According to the World Health Organization (WHO), Dyscalculia can be defined as a specific disorder that encompasses deprived mathematical skills in an individual. The Diagnostic and Statistical Manual (DSM-IV), on the other hand, defines Dyscalculia as a mathematics disorder. The UK department for education and skills remains solely fixated on the use of the term "dyscalculia."

A study done by Dowker (2005) denotes while that current research on Dyscalculia terms it as a mathematical difficulty, referring to it as an arithmetic difficulty would be more appropriate. The field of mathematics is divided into various branches whereby arithmetic falls as a branch and a relatively unimportant one. The resulting proliferation of names caused by such situations creates ground for more confusion. It can also be noted that using various exclusions, tests and criteria make the investigation and comparison of Dyscalculia more complicated.

Most of the researches conducted in Malaysia Defined Dyscalculia as the inability to comprehend the concept of numbers and to acquire arithmetic skills (Miyundy et al., 2019; Mazeyanti et al., 2018; Sarpudin & Zambri, 2014; Patwary, Omar, & Tahir, 2020). (Wei et al., 2019) defined Dyscalculia as the arithmetic difficulties, computing capacity significantly lower than its intelligence, age and education level. However, even in the light of the confusion arising from the wording used, all the definitions have a common denominator; they talk about a severe disability that impedes the ability of an individual to comprehend arithmetic despite having general intelligence level.

2. Characteristics of Dyscalculia

Difficulties in mathematics in children can be caused by a myriad of factors, with Dyscalculia being one of them. Therefore, identifying the main reason for the mathematical difficulty is necessary. Even with a consensus lacking in the definition of Dyscalculia, researchers have come to a common agreement regarding its characteristics. The characteristics can be found in the Learning Support Services Booklet titled "what is Dyscalculia?" They include:

- A deficiency in the primary aspect of number sense that is manifested by being unable to see things without counting (subitise), specifically in scenarios involving smaller quantities.
- A poor number sense, which is related to number operations, number relations and whole numbers. Key examples would include an inability to tell which number is large out of two, experiencing difficulties in reliably counting numbers backwards and the inability to gauge and tell if a numerical answer is somewhat reasonable befitting the context.
- Using fingers as a "counting on" strategies rather than relying on efficient calculation methods and confusing mathematical signs such as the addition and multiplication signs. They also exhibit inefficiencies exhibited in money management.
- Problems with discerning the various time aspects. Such can be manifested in scenarios such as the inability to effectively manage time in day-to-day life and the inability to tell time from an analogue watch.
- Issues related to memory. For example, an individual experiencing short-term and long-term memory weakness, directional and sequencing confusion in a way that one cannot tell between east and west, left and right, and difficulty in learning the mathematical tables.

When providing an insight into the best alternative strategies for dealing with dyscalculics, there is a need to consider various time aspects. That is, more time should be allowed for them to process calculations. Additionally, as noted by Butterworth (2003), such individuals will, therefore, need to be allowed more time when undertaking their examinations. This is because such individuals portray a poor sense of organisation and elapsed time. Dyscalculics should, therefore, be furnished with digital clocks as they experience key challenges dealing with analogue ones (Williams, 2013).

3. Dyscalculia Hypothesis

In an attempt to differentiate Dyscalculia with other mathematical difficulties and provide an explanation of provided characteristics, scientists rely on the main three paradigms.

The first paradigm argues out a neuropsychologist's view, who view Dyscalculia as a neurological disorder (Butterworth & Laurillard, 2010). This concept is also known as the 'core deficit hypothesis.' This concept relies on neuroimaging to predict the association between the IPS and numeric concepts such as numerosity, magnitude and quantity. The concept is further classified as a processing number magnitude deficit (Landerl k, Bevan A, Butterworth, 2004; Alom, Patwary, & Khan, 2019). The second paradigm refers to Dyscalculia as a deficit in an individual's working memory and is also referred to as the "General Domain Hypothesis." According to proponents of this paradigm, Dyscalculia can be divided further into subtypes that result from the existing cognitive processes. The subtypes include deficits in visuospatial processing, long-term memory that facilitates the storage and retrieval of mathematical facts and formulas, and verbal WM, which allows for the acquisition of math procedures (Geary, 2004). According to Gifford (2006), The third paradigm believes in the notion that there is nothing like Dyscalculia and that the resulting behavioural characteristics are caused by certain experiential and emotional causes. It is important to note that the first paradigm is the most used and relied on by Malaysian researchers of Dyscalculia in generating comprehension regarding the behavioural characteristics of Dyscalculia.

4. Causes of Dyscalculia

Computation is very complex and demands the interaction of numerous brain functions. Children with a computational disorder show significantly reduced activity in the brain regions that belong to the neural network of quantity and number processing during the processing of simple computational tasks (Ashkenazi, Rosenberg-Lee, Tenison & Menon, 2012; Kucian et al., 2006). This is probably the result of a genetic deficiency of congenital core competencies, which leads to certain cognitive functions not developing according to developmental tasks (Butterworth, 2005; von Aster et al., 2007). For example, the connection between an Arabic numeral ("8") and the corresponding set is usually activated automatically, which is not the case for a person with Dyscalculia (Rubinsten & Henik, 2006). Numbers to them are like words without meaning. Other basic mathematical skills are also impaired in the case of computational error (Gaupp et al., 2004; Landerl et al., 2004; von Aster et al., 2005). These include the rapid (at a glance) counting of small quantities, the comparison of quantities (more/less) and numbers (larger/ smaller), the naming and writing down of numbers, as well as the development of a mental line of numbers. Deficits in general cognitive functions such as memory, processing speed, and visual-spatial functions, were also reported (Landerl & Kaufmann, 2008). Family and twin studies indicate that Dyscalculia could be genetic (Alarcon, DeFries, Gillis Light & Pennington, 1997; Docherty et al., 2010; Petrill et al., 2012; Shalev et al., 2001; Islam & Patwary, 2013).

Studies on neurophysiological correlate using MRI, fMRI, and ERPs were able to identify brain regions that correlate with different computational processes (Vogel & Ansari, 2012). The activation of the intraparietal Sulcus (IPS) of both hemispheres was found, for example, depending on the ability to detect numerical distances between numbers. The linguistic processing of numbers in computational operations, on the other hand, is associated with activation in the left gyrus angularis. Studies with children with Dyscalculia confirmed the importance of IPS for estimating and comparing amounts. Kucian et al. (2006) found lower activation in children with Dyscalculia is a numerical estimation task (EG 4 + 3= 9 or 6). Further studies confirm the connection between lower IPS activation and basic numerical abilities (Kaufmann, Vogel et al., 2009; Price, Holloway, Räsänen, Vesterinen & Ansari, 2007). Other basic mathematical skills are also impaired in the case of computational error which includes the rapid (at a glance) counting of small quantities, the comparison of quantities (more/less) and numbers (larger/ smaller), the naming and writing down of numbers, as well as the development of a mental line of numbers. Deficits in general cognitive functions such as memory, processing speed, and visual-spatial Functions, were also reported (Gaupp et al., 2004; Landerl et al., 2004; von Aster et al., 2005). Studies with children with Dyscalculia confirmed the importance of IPS for estimating and comparing numbers. Kucian et al. (2006) found lower activation in children with Dyscalculia for a numerical estimation task (e.g. 4 + 3 = 9 or 6). Further studies confirm the connection between lower IPS activation and basic numerical abilities (Kaufmann, Vogel et al., 2009; Price, Holloway, Räsänen, Vesterinen & Ansari, 2007).

5. Dyscalculia Identification Methodology

There are two key methods that one can use in conjunction with the stated paradigms to identify Dyscalculia. These include qualitative or quantitative methods. Qualitative methods are provided for under WHO, UK learning support services, DfES and the DSM-IV. The qualitative methods used, on the other hand, can rely on one of the three categories of the model. These include the discrepancy model, severity model and the "resistance to treatment" model. According to the discrepancy model, there exists a significant inconsistency in a child's performance in arithmetic compared to the overall performance/ achievements. The severity model relies upon cut off points such as percentiles to determine the condition's level of severity.

Lastly, the "resistance to treatment" is employed in scenarios where a child remains unresponsive to any implemented interventions and chooses to continue using immature arithmetic strategies rather than efficient ones. For example, the child might decide to go back to finger counting as they experience difficulties in remembering number bonds (Shalev & von Aster, 2008). However, there is no explicit explanation of the followed method for Dyscalculia identification mentioned by Malaysian Dyscalculia researchers.

6. Dyscalculia Prevalence

Dyscalculia's level of prevalence remains largely unknown. A study done by Butterworth (2002) shows that the total number of dyscalculia diagnosis remained at 5-6%, while Geary (2004) places the number at a contradictory 8%.

With the study's statistics being drawn for children, the prevalence of Dyscalculia might be high as the whole chunk of adult learners are yet to be diagnosed or assessed. As people become more aware of Dyscalculia, the number of diagnoses is expected to increase. When it comes to data regarding the prevalence of the condition, there exists a wide range of data that highlights it and will mainly depend on the criteria utilised in the cutoffs and identification for determination. From the available research, it can be noted that data on prevalence shows a variation of about 3-7% (Kauffman et al., 2012). When the same prevalence is compared in terms of gender, the results obtained have heavily relied on the criteria chosen for the identification and the accruing differences between the genders that might have been omitted under the relative discrepancy criteria and thresholds that are crucial in the definition of Dyscalculia (Soares et al., 2018). Interestingly, there lacks comprehensive research evidence that details the prevalence of Dyscalculia in the whole of Malaysia. According to Wong et al., (2014) pilot study conducted among 91 primary school pupils show that a total of 5.5% of school-going kids have exhibited Dyscalculia. Another study conducted by Miundy et al., (2019) in Selangor among 50 students of primary schools using Virtual Reality based system show Dyscalculia prevalence rate of 4%. Keong's (2016) study further the research by showing that 4.38% of girls and 3.47% of boys in any settings are likely to suffer from Dyscalculia in Malaysia. Even with those studies being focused on an isolated case, they are helpful in revealing that some Malaysian children in school settings indeed exhibit Dyscalculia

7. Comorbidity of Dyscalculia

Dyscalculia and Dyslexia are two disorders that have considerable overlaps. For example, a number of studies have shown that Dyscalculia will occur more often in children compared to word blindness dyslexia. However, there is much that remains unknown about Dyscalculia regarding treatment, causes or prevalence (Diwan, 2008). Studies have noted that both disorders might occur at the same time affecting about 20-60% of all students (Hannell, 2005). Concerning the review of studies on the relationship between Dyscalculia and Dyslexia, a study conducted by (Orly & Avishai, 2006) has revealed that dyscalculics have difficulty in automatically associating numerals with magnitudes but no problem in associating letters with phonemes, whereas dyslexics show the opposite pattern. Another study conducted on naming speed in Dyslexia and Dyscalculia, found that the cognitive bases of Dyslexia and Dyscalculia are independent of each other (Willburger et al., 2008).

In Malaysia, it has been claimed by Rani et al., (2014) that Dyslexic students in Malaysia are suffering from Mathematics because of their difficulties in reading and writing. Other than that, cognitive deficits also affect their learning ability as well as their common characteristics like thinking style, visual difficulties, and memory deficits (Rani, Rohizan, Rahman; 2014).

8. Diagnosis of Dyscalculia

Screening for Dyscalculia can be done in a number of ways. The available screeners for Dyscalculia were developed in regard to the researchers' discipline. For example, one key example of such a screener is one developed by Butterworth (2003). This is the most common commercial screener used across the UK and is Also known as the Dyscalculia screener. This screener is based on the notion that Dyscalculia is caused by a numerosity deficit. The screener relies on computer technology and takes about 20 minutes to finish the whole screening process. By using an item-timed calculation, this screener makes it easy for one to identify the finger counters from fluent counters. Butterworth's screener comprises of 4 main tests which include:

- An arithmetic achievement test (multiplication and addition). This test helps the administer of the text distinguish children using strategies to record number facts or those who can do so without the intervention of any strategies.

- The numerical stroop or number comparison. This helps point out dyscalculic children as they often experience difficulty when making a comparison between the magnitude of various numbers.
- The dot enumeration test which acts as a measure of a child's ability to subsidise. A difficulty to subsidise is a key characteristic of Dyscalculia.
- The simple reaction time test: This test is crucial in giving an accurate estimate of the time taken by a child to give a response. Slow response time can signal a dyscalculic

Another screening method is the Von Ater & Dellatolas's (2006) ZAREKI-R screener which is comprised of 12 major subsets. These include Number comparisons, word problems, cognitive quantity assessment. Perceptive quantity assessment, number comparison, repeating numbers forwards and backwards, arranging numbers on a number line, reading numbers, mental arithmetic, writing numbers, counting backwards orally and counting.

The next screening method is the Number Sense Screener (NSS), a quantitative screener developed by Jordan (2012), a psychologist in an attempt to help with the identification of Dyscalculia. The basis of this screener is the notion that Dyscalculia results from the lack of a number sense. The NSS test by Jordan help identify a child's aspect of number sense. Jordan's screener involves the use of tests such as number combinations, story problems, nonverbal calculation, number comparison, number recognition and counting tests.

Another key screener is the Number Sets Test, which was developed by cognitive developmental psychologist Geary et al. (2012). The main aim of this test is to carry out an assessment of the accuracy and speed that a child uses in identifying and processing any process that encompasses Arabic objects and numerals sets. At the moment, Malaysia lacks a standardised instrument that can be used in the diagnosis of Dyscalculia. However, there have been a number of efforts towards the development of such an instrument made by Wong's et al., (2014) who named it as "Malaysian Dyscalculia instrument Plus" (MDI+). This screener is built on a computer system that measures four variables including Arithmetic, Numerosity, short term memory and simple reaction time. This screener is founded on Butterworth and Geary dyscalculia screeners and comprises of three tests. They include Arithmetic Test, Numerosity, short term memory and simple reaction time.

9. Dyscalculia Remedial Measures

After carrying out an assessment, it is imperative that remediation follows immediately. This is because an accurate assessment of a child will determine the form of remediation to be used. Mathematics is an easy subject to teach (Emerson & Babtie, 2010). It involves an analysis of the topic to be taught and identifying a child's firm ground. After this, one can proceed forward from there. Even with mathematics being a very easy subject to teach, the main difficulty comes in carrying out an assessment of children with any learning disability. However, it should be noted that any remediation process should be preceded by a careful assessment. In the previous years, teachers have relied on a multi-sensory instruction paired with the use of games in an attempt to help children learn and assimilate more. This is especially done in children experiencing mathematics anxiety. The use of games when learning math act as a guide, which takes away the feeling of learning mathematics and giving the child ample time to experience wins. Wins in children experiencing learning difficulties help increase a child's self-efficacy through positive verbal feedback and experiences. The games used can be categorised into two: Real games or math computer exercises or games with each having its own set of advantages and disadvantages. The advantage of using real games such as dominoes allow social interaction, which induces multi-sensory experience. When playing dominoes, children can decide on which level to play with the basic level helping them match canonical patterns—for example, matching the word 'five' to five dots. Maths computer games, on the other hand, can be very motivating to a child provided that the set level does not prove to be too easy or too hard, enabling him or her focus on a specific skill. However, in most cases, computer games tend to be too hard or present difficulties in dyscalculic children. Additionally, there only exists a few computer games whose focus ins mainly on extending comprehension of a topic rather than looking to perfect a skill (Williams,2013).

This puts Malaysian children at a disadvantage as the required resources and interventions for dealing with Dyscalculia are limited. (Arffin et al.,2017) experimented the effectiveness of mobile app named "Calculic Kids" on Dyscalculia children and found a positive result. Yet the problem with the experiment was that the participants were collected from Persatuan Dyslexia Malaysia and no Dyscalculia screening was conducted to confirm if they fit into the category of Dyscalculia.(Fiqa,2018) proposed a mobile app design model for the intervention of dyscalculia children name 'Calculic Model' based on practitioner's interviews for in order to support learning for Dyscalculia children. Yet no empirical data is available to measure its efficiency for Malaysian Dyscalculia Children. Kaur et al., (2018) proposed "i-Matematik " conceptual model based on a cognitive and conceptual theory which has been implemented in web-based courseware. However, both models are yet to be tested in real-life Dyscalculia scenario in Malaysia. Moreover, studies detailing interviews done on Malaysian teachers record 80% of complaints regarding the frequent lack of technical support and the lack of availability of ICT based resources for children.

Additionally, the teachers stated being overworked and disorganised as the tasks and materials given to them keep varying. In regard to the emergence and utilisation of web-based education such as Graphogame Math, Number Race, Dots2Track, Dots2Digit games have been experimented on Dyscalculia Children and achieved significant improvement of mathematical skills improvement among Dysalculia Children. However, data drawn from the teachers' interviews show a contradictory argument with about 60% of all teachers stating that there exist certain barriers when using technological based learning approaches such as weak internet and access to web services and the internet and the constant breakdowns of these systems (Keong et al.,2016).

Early detection methods will also come a long way on helping the fight against Dyscalculia. For example, Mazeyanti et al. record success when using the CheckDysc mobile game in identifying children with Dyscalculia. The parents and teachers of such students, mainly those in pre-school, might be unaware that the student is Dyscalculic. However, the use of mobile game apps such as CheckDysc has managed to provide an early detection system that can alert both parents and teachers, which will be prompted to institute the best remedial measures.

For example, the study done in Sabah, Malaysia reported that by using a computer-based Dyscalculia screener, they were able to discover that about 5.5% of all students were suffering from Dyscalculia. The screener would examine the student's response time and accuracy to test items. From the success recorded in this study, it would be helpful if such measures are implemented across all primary schools across Malaysia. This will ensure that such students are identified and corrective remedies and measures instituted at an early stage. With a number of research showing the existence of a significant percentage of Dyscalculic students in any primary school setting, it should not be ignored.

Teachers and care providers should be trained to adopt a more lenient approach that is supportive and understanding of Dyscalculic students rather than terming them as lazy or stupid. A number of studies have suggested the training of teachers to integrate pictorial presentations and concrete materials in teaching abstract concepts such as number lines and place values. The teaching method should then gradually shit to abstract representations. However, one of the key challenges faced in Malaysia today is the lack of proper Dyscalculia knowledge and sensitisation. Teachers and educators have to have knowledge of Dyscalculia to help with identifying the affected students and working towards developing a teaching technique that will suit the Dyscalculic students. Previous studies have shown that only a fraction of the teachers believe they can identify the signs of Dyscalculia while the majority remain unaware of what it is. Additionally, others have denoted that teachers who have knowledge of this condition remain insecure while dealing with it due to limited information. The government should work to ensure that teachers encounter Dyscalculia during training. This will help increase the level of awareness among teachers and educators about Dyscalculia.

Augmented Reality remains an untapped potential as remediation of Dyscalculia. The use of AR technology helps enhance the visual perception of learners with Dyscalculia, thereby enriching the real world. The use of AR on Dyscalculia learners have the potential of improving their creativity, accessibility, smooth integration with others and boosted attention and motivation. Research has shown that AR provides immense benefits at a relatively low cost, making it an ideal remediation technique for Malaysian schools. Augmented Reality enhances both the teaching process and the learning process. Students get access to an increased level of elaboration from AR since it aids the integration of integration through a sensory elaboration using tactile, proprioceptive, verbal and visual-spatial memory. AR increases the number of memory channels, which can be used to allow full encoding of the content, allowing for long-term retention.

10. Conclusion

Dyscalculia is a condition that remains unknown even though it has placed negative implications for children, youth and the society at large. In Malaysia, studies have shown that the prevalence of Dyscalculia stands at 5% -8% of all primary school children. However, in the midst of all this, research on intervention measures and research evidence remain very scarce, placing a great impediment in helping Dyscalculia learners. There is much that has to be done to ensure that Dyscalculia is managed—for example, investing in special educators, training educators and teachers and the use of technology. All these methods have been researched and posted immense benefits. While Dyscalculia remains an untreatable condition, such interventions paired with proper care allow Dyscalculia learners to adjust to the usual Reality.

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