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A PRELIMINARY STUDY FOR DYSCALCULIA IN SABAH, MALAYSIA.

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ABSTRACT: In Malaysia, it is reported that the number of registered students with learning disabilities increased from 7,919 in year 2000 to 20,814 in year 2006 (Teoh & Lim, 2007). It is estimated that the prevalence of Dyscalculia in the general population is 5-8% (Adler, 2008). This research intends to develop an instrument for measuring dyscalculia and identify the prevalence of Dyscalculia among primary school students in Sabah, Malaysia. The Dyscalculia instrument developed in this study is a computer-based assessment for children that aims to identify the characteristics of Dyscalculia by measuring response accuracy and response time to test items. The purpose of this paper is to report the results of a preliminary study for Dyscalculia which involved 91 students in three primary schools in Sabah, Malaysia. The results show that 5.5% of the primary school students in Sabah suffer from Dyscalculia.

Key words: Prevalence, Dyscalculia.

INTRODUCTION

In England, 'Dyscalculia' has been defined as 'the condition that affects the ability to acquire mathematical skills. Dyscalculia is a term most commonly used for those having disability in learning mathematics. Dyscalculia means severe or complete inability to count (Hallahan *et al.*, 2005). According to Newman (1998), Dyscalculia means "specific learning disability in mathematics". People with Dyscalculia generally have normal intellectual ability but having troubles in certain thought processes in particular cognitive process (Adler, 2008).

The research of Adler (2008) had supported the long-term study of Shalev and Von Aster (2008) which indicated that many children with Dyscalculia outgrow their diagnosis after a few years. If a child is getting the right treatment and support, the possibility for the development of mathematical ability will increase. There are still some difficulties remain in a milder form such as the problem of recalling numerical facts. It is common that students will continue to have such difficulties in a milder form throughout their lives. The ability to concentrate might be improved greatly and this will help in the understanding of mathematical concepts and symbols.

This study involves the identification of pupils who suffer from Dyscalculia. The instruments used in this study was developed based on the theory of making sense of mathematic as proposed by Chin and Tall (2012) and the concept of numerosity as suggested by Butterworth (2002). Additionally the work by several researchers such as Geary (2006), Murphy (2006), Gersten *et al.* (2008), and Shalev and Von Aster (2007) also contributed to the development of this instrument. Prevalence of Dyscalculia among primary school students in Sabah is obtained by analyzing the data obtained through this instrument.

METHODS and PROCEDURES

This study focuses on 7-9 year old children who experience difficulties in learning mathematics. The main objective of this project is to design and develop a Malaysian Dyscalculia instrument that can be used to screen and measure the extent of Dyscalculia among primary school students. The identification of learning disabled students involves screening and diagnosis. Screening is used to examine large groups of children to identify those performing above or below the norm. Diagnosis is used to investigate selected children to determine the precise nature of their difficulties (Mohd Sharani Ahmad, 2004).There are three main constructs in this

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framework which involves seven tests namely simple reaction time, short term memory, number sense, matching items, dot enumeration, number comparison and arithmetic (see Table 1). In order to ensure that the instrument is fit to be used and measures what it is suppose to measure, the reliability and the validity of the instrument are seriously taken into account (Creswell, 2005). Reliability of the research instrument is based on its consistency to measure what is being measured. While, validity plays a role of judgement of how well an instrument measures what it purports to measure in a particular context (Cohen & Swedlik, 2005). Table 1 below shows the constructs for Malaysian Dyscalculia instrument developed by the researchers and Table 2 shows the results of analysis of reliability based on Cronbach's index of internal consistency and item fit based on the in-fit square values.

Table 1: Constructs for Malaysian Dyscalculia Instrument

No.	Construct	Description of items	Capacity/Test	Researchers
1	Simple Reaction Time	10 items for left, 10 items for right.	Response Time	Butterworth (2003), Murphy (2006)
2	Short Term Memory	10 items	Short term memory	Gersten et. al (2008)
3	Numerosity			
	(a) Number Sense	10 items	Sense of Numerosity	Buterworth (1999), Geary (2006), Gersten et. al (2008), Shalev & Von Aster (2007)
	(b) Matching Items	10 items	Numerosity as a property of sets	Butterworth (2002), Geary (2006)
	(c) Dot Enumeration	10 items	Enumeration (counting)	Butterworth (2002)
	(d) Number Comparison	10 items	Sense of ordered numerosities	Butterworth (2002)
4	Arithmetic Test	10 items	Arithmetic	Butterworth (2003), Geary (2006)

Table 2: Reliability and Items fit for Malaysian Dyscalculia Instrument

No.	Construct	Cronbach Alpha, α	No of Fit Items
1	Simple Reaction Time	0.800	19/20
2	Short Term Memory	0.720	10/10
3	Matching Item	0.827	10/10
4	Number Sense	0.769	10/10
5	Dot Enumeration	0.845	10/10
6	Numerical Stroop	0.872	10/10
7	Arithmetic Test	0.768	9/10
OVERALL (SCREENER)		0.896	79/80

1. ***Simple Reaction Time*** is a test to measure the psychomotor response time. Recorded response time is taken into account in order to identify the actual cognitive processing time (Butterworth, 2003). Figure 1 shows the chronology of the items in simple reaction time. This process will be repeated for ten times for left and right hands respectively. The response times on the following six tests are adjusted to take this measure into account.

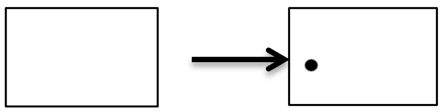

Figure 1: Simple Reaction Time

2. In general, students with learning disabilities have a very limited working memory (Gersten *et al.*, 2008). Siegal and Ryan (1989) found that children with Dyscalculia did less well than control on a working memory task involving counting and remembering digits. Working memory is **Short Term Memory** (Baddeley, 2002)

and the concept of working memory evolved from earlier concepts of **Short Term Memory** (Lervag & Hulme, 2013). Pupils are asked to make a short memory on the picture (see Figure 2) and have to give an answer whether the number of black dots that appear on the left or right of the screen is more.

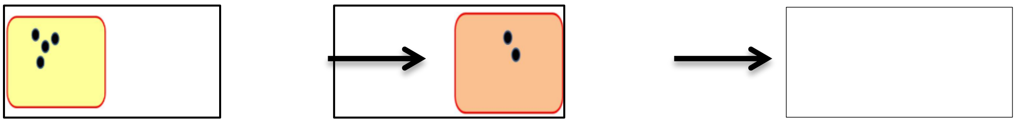

Figure 2: Short Term Memory

3. The idea of numerosity (Butterworth, 1999) involves familiar consequences such as two sets of things might have the same numerosity as the other, or a larger or smaller numerosity. This innate ability is called **Number Sense** (Butterworth, 2002). Figure 3 shows a sample item of number sense which is used to evaluate whether a pupil possesses the concept of quantity and the scientists called this concept as numerosity (Santos-Sousa, 2007). Pupils must provide their answers by identifying which diagram has more black dots.

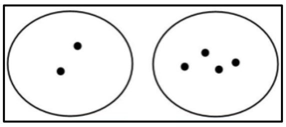

Figure 3: Number Sense

4. Butterworth (2002) proposes that two sets have the same numerosity if and only if the members of each set can be put in a form of one-to-one correspondence with none left over. This involves the principle of matching every item of one set to the items of other set. Hence, the researchers have included **Matching Items** (see Figure 4) in order to test whether a student understands the one-to-one correspondence principle.

Figure 4: Matching Items

5. **Dot Enumeration** is a test (see Figure 5) that requires better skills in counting numerals and using symbols (Butterworth, 2002). Learning the basic counting sequence, "one, two, three and four ..." is not difficult and almost all the children including Dyscalculic students can learn this (Geary 2006). However, it is not only about the sequence but also involved the ability to assign to each counted object and represents the quantity of items in the counted set.

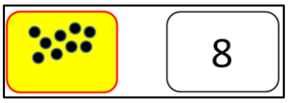

Figure 5: Dot Enumeration

6. According to Geary (2006), Dyscalculia students usually do not know basic number names such as "7" = "Seven". They have difficulty in discriminating large numbers and small numbers. This difficulty can be identified by using items which are about number comparison such as "Which is bigger, 6 or 8?". Hence, the **Number Comparison** (see Figure 6) construct is crucial to test the brain area which is specialised for quantity comprehension. According to Butterworth (2002), this is also known as the sense of ordered numerosities.

Figure 6: Number Comparison

7. Many children with Dyscalculia have difficulty in remembering basic arithmetic facts. They have great difficulties in memorising simple addition, subtraction and multiplication facts. The **Arithmetic** test (see Figure

7) is a test which consists of addition and subtraction of two numbers and the children need to choose whether each of the given mathematical statements is true or false.

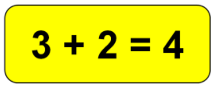

Figure 7: Arithmetic Test

Classification of Dyscalculia

The model for Dyscalculia Classification (see Figure 8) employed in this research was developed by our research team based on the model of numerical cognition (Von Aster & Shalev, 2007), concept of Numerosity (Butterworth, 1995 & 2002) and the Theory of Cognitive Development in Mathematical Thinking (Tall, 1995 & 2007).

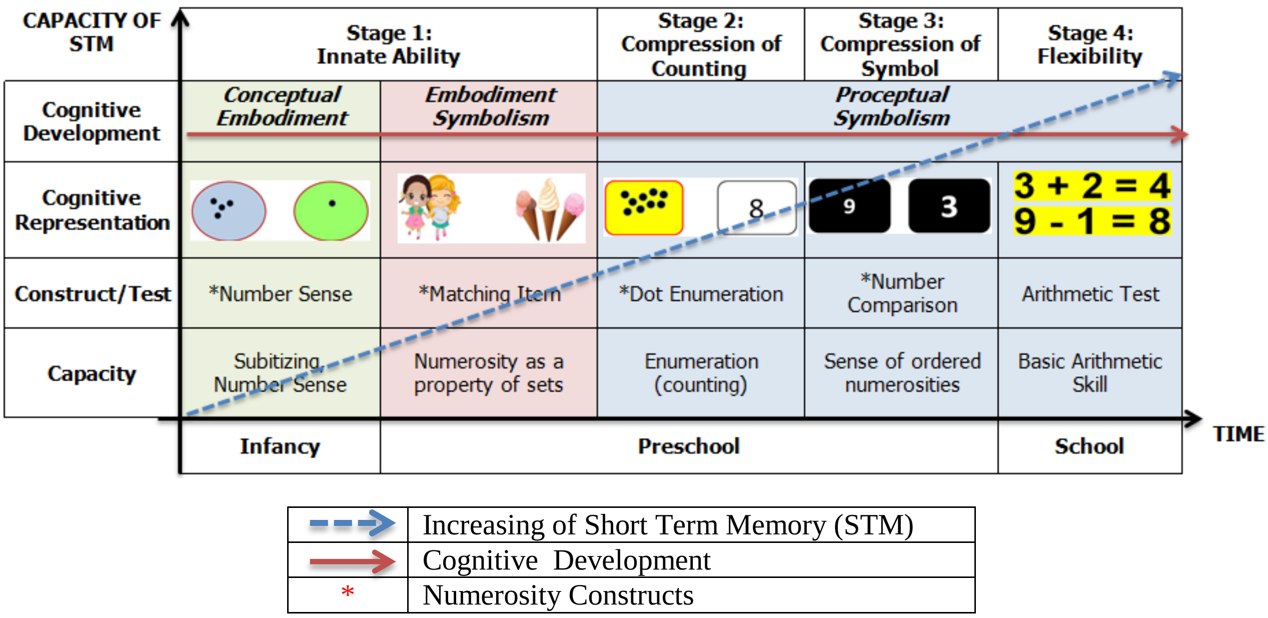

Figure 8: The Model of Dyscalculia Classification

According to this model, a normal pupil (6 and above) should have the ability to perform appropriately from stage 1 to 4 and this involves the ability to compress knowledge into thinkable concepts (Tall, 2006). Based on Feikes and Schwingendorf (2008), complex mathematical thinking will occur if a person is able to compress previous ideas into a compact and precise mathematical object.

In Stage 1, Butterworth's (2003) research outcomes had showed that the infants noticed the constancy of objects and detected differences in their numerical quantities. An infant seems to be able to discriminate visual arrays on the basis of numerosity even in the first week of life. Tall (2008) proposed the notion of 'set befores' to denote a mental structure that all humans born with which may take a little time to mature as our brains make connections in early life. *Recognition* of similarities and differences, *repetition* of complex actions that becomes automatic and the use of *language* to name, describe and refine meanings are the three abilities (set befores) that form the foundation for the development of mathematical thinking. In other words, these innate abilities help pupils to perform appropriately at this stage. A deficit in these abilities could contribute to Dyscalculia.

Stage 2 and stage 3 have been instrumental to get strong evidence for Dyscalculia (Butterworth, 2003). The ability to compress knowledge into a useable form will give an edge to master the tasks in these stages. In Stage 2, the ability to compress the actions of counting into a number will enable a pupil to answer the items of Dot Enumeration construct correctly. Meanwhile in stage 3, a pupil should be able to compare the numbers displayed on a screen without performing the counting actions because he/she had already compressed the counting actions into a number in stage 2.

In Stage 4, a pupil will achieve the flexibility to see mathematics symbol as process and concept. Tall (2004) used the notion of '*procept*' to indicate this flexibility. It is an idea generated by looking at a symbol such as 3+2 both as a process (of addition) and a concept (of sum). It was extended by Gray and Tall (2001) to include different symbols and different processes that give rise to the same mental object in the mind of a particular individual. Thus 3+2, 4+1, 5, 7-2 can all represent the same *procept*, involved in composing and decomposing arithmetic processes that give 5. The task in this stage involves two basic operations (addition and subtraction) of arithmetic as a test of basic arithmetic skill. A deficit of this task could not contribute to Dyscalculia. We can only claim a pupil who is either good in arithmetic or poor in arithmetic based on the results of this task.

Generally, if a pupil can perform appropriately in these four stages, he/she is unlikely to have dyscalculia. Meanwhile, it is possible that the pupil will guess because of an inability to answer the question, but other causes cannot be excluded. To identify such cases, further analysis of data is required for identifying pupils who were guessing the answers to most of the questions in the test.

Table 3: Summary of Dyscalculia Classification

No.	Type	Classification
1	Poor in 4 Numerosity constructs	Evidence of Dyscalculia
2	Poor in Number Sense OR/AND Matching Item Poor in ANY 3 Numerosity constructs	High Risk of Dyscalculia
3	Poor in ANY 2 Numerosity constructs	Moderate Risk of Dyscalculia
4	Poor in ANY 1 Numerosity construct	Low Risk of Dyscalculia
5	Poor in Arithmetic	Poor Arithmetic without dyscalculia
	Normal	Normal Performance
6	Guessing	Guessing

The description of Dyscalculia Classification below is based on Table 3.

***Type 1*: Poor in 4 Numerosity constructs**

The pupil has low performance in all the four capacity tests of numerosity constructs. This pattern of results is evidence of Dyscalculia.

***Type 2*: Poor in Number Sense OR/AND Poor in Matching Item OR Poor in ANY 3 Numerosity constructs**

***Sub-type 2.1*: Poor in Number Sense OR/AND Matching Item**

The pupil has low performance in the Number Sense or/and Matching Item constructs. This pattern of results suggests that the pupil has high risk to have Dyscalculia.

***Sub-type 2.2*: Poor in ANY 3 Numerosity Construts**

The pupil has low performance in three out of the four numerosity constructs. This pattern of results suggests that the pupil has high risk to have Dyscalculia.

***Type 3*: Poor in ANY 2 Numerosity constructs**

The pupil has low performance in two out of the four numerosity constructs. This pattern of results suggests that the pupil has moderate risk to have Dyscalculia.

***Type 4*: Poor in ANY 1 Numerosity construct**

The pupil has low performance in the one of the four numerosity constructs. This pattern of results suggests that the pupil has low risk to have Dyscalculia.

***Type 5*: Normal Performance in Numerosity Constructs**

***Sub-type 5.1*: Poor in Arithmetic**

The pupil performs appropriately in all the numerosity constructs but poor in Arithmetics Test. This pattern of results suggests that the pupil is not failing in arithmetic because of Dyscalculia.

***Sub-type 5.2*: Normal**
The pupil performs appropriately in all the numerosity constructs and Arithmetics Test therefore he/she is unlikely to have Dyscalculia.

Type 6: Guessing
The pupil appears to have been guessing the answers on some or all of the tests. It is not possible to give a diagnosis since there may be various reasons for this behavior, including not trying. It is possible that he/she is Dyscalculic and cannot answer any of the questions satisfactorily.

It is suggested that the test should be repeated on another occasion. If he/she still guesses rather than tries to answer the questions, then he should be provisionally classified as Dyscalculic until further investigation can be carried out.

RESULTS

The preliminary study involved a sample of 91 primary school students aged between 7-9 years old who were selected randomly from three different schools in the state of Sabah, Malaysia. Each student took 10-12 minutes for the screening process. Table 4 shows the result of the preliminary study.

Table 4: Analysis of Preliminary Study

No.	Result/Category	Total	Prevalence (%)
1	Evidence of Dyscalculia	5	5.5
2	High Risk to have Dyscalculia	23	25.3
3	Moderate Risk to have Dyscalculia	1	1.1
4	Low Risk to have Dyscalculia	9	9.9
5	Poor Arithmetic without dyscalculia	9	9.9
6	Normal Performance	44	48.3
	Total	91	100

In this study, 5 out of 91 students were under the category of ”Evidence of Dyscalculia” and this is equivalent to a prevalence of 5.5%. Generally, if a pupil can perform appropriately, he/she is unlikely to have Dyscalculia. Meanwhile, a pupil who is incapable of answering a particular question can simply select a random answer and still have chance of receiving score for it. In order to identify such cases, a further analysis of the data is required for identifying pupils who were guessing the answers for most of the items in the test. The result of this study had supported the research of Butterworth *et al.* (2011) which stated that the development Dyscalculia is a mathematics disorder with an estimated prevalence of about 5-7%.

Geary (2004) found that between 5% and 8% of children in school have some forms of disabilities in mathematics. As we can see in Table 5, these figures were confirmed by a number of researchers in different countries. The research study performed by Voutsina and Ismail (2007) in South England showed that the prevalence of Dyscalculia was 5%. Based on Fuchs (2006), the prevalence of Dyscalculia ranges from 4-7%. Meanwhile Belgium researchers found that the prevalence of Dyscalculia ranges from 3-8% (Desoete *et al.*, 2004). Flanagan & Alfonso (2011) conducted a survey of recent work of authors and found that the prevalence was 7%. Reigosa-Crespo *et al.* (2011) discovered that the basic numerical deficits had affected 4.54% of school-age population.

Shalev and Von Aster (2008) reported the prevalence rate of Dyscalculia as 6% and they claimed that the estimation of prevalence was only depends on the accuracy of the diagnosis which could be based on a valid instruments test and representing the whole population. Although there were differences in the use of criteria and test instruments in different research studies however the prevalence rate obtained was around 6% thus this estimate is reliable.

Table 5: Prevalence Rate of Dyscalculia by Several Researchers

Author	Prevalence	Methodology	Location
Voutsina. C. & Qaimah Ismail. (2007)	5 %	Dyscalculia Screener (Butterworth, 2003)	South England
Geary D. C. (2004)	5 – 8%	survey of recent work of authors	Columbia
Desoete, A., Roeyers, H. & De Clercq, A. (2004).	3 – 8%	TEDI-MATH a Belgian dyscalculia battery	Belgium
Teresa Guillemot	3 – 6%	survey of recent work of authors	Sweden
Butterworth et.al (2011)	5 – 7%	Dyscalculia Screener (Butterworth, 2003)	UK
Fuchs, L. S. (2006)	4 – 7%	intervention approach: conceptual instruction and drill and practice	United State
Reigosa-Crespo et. al (2011)	4.54%	Dyscalculia Screener (Butterworth, 2003)	Havana, Cuba.
Shalev, R. S., & von Aster, M. G. (2008)	6%	survey of recent work of authors	few different countries
Flanagan & Alfonso (2011)	7%	survey of recent work of authors	-

CONCLUSION

The prevalence of learning disabilities among school children varies from country to country. This is largely dependent on the definition used to classify learning disabled children in each country. This involved about 5.5% of the students in school (aged 6 to 17) for special education due to learning disabilities (Teoh, Cheong & Woo, 2007). In a study conducted by Komoula *et al.* (2004) which involved 240 Greek students aged between of 7 - 11 years old from rural and urban areas, they had found that the prevalence of developmental Dyscalculia among rural students was higher than in urban schools. Therefore, specific learning disability might be more common among rural students.

In 1991, the National Statistical Office of Thailand reported a prevalence rate of 1.9% for visual impairment, 5.4% for speech impairment, 13.2% for hearing impairment and 10% for intellectual disability. In 2002, the Malaysia Department of Special Education reported 14,535 children with learning disabilities in 700 schools across the country. These statistics included children who had learning disabilities, hearing impairment and visually impaired in special schools or integrated schools (Teoh, Cheong & Woo, 2008). Although the prevalence of mathematics disability is high, the research in this domain is limited (Desoete, Roeyers & De Clercq, 2004). Nowadays, more studies on this issue have evolved (Butterworth, Varma & Laurillard, 2011).

Recently, more attention is focused on students who demonstrated challenges in learning mathematics skills and concepts taught in schools at all levels. Starting as early as pre-school, parents, educators, and researchers are aware that some students seem easily to be confused with the simple mathematical learning skills. For example, some young children have difficulties in learning numbers, recognizing, and counting items in a group. Some of these children continue to show these mathematical learning difficulties as they attend the mathematics lessons. All these difficulties might be related to Dyscalculia therefore by realizing that 5% to 8% of school-age children are identified as having a mathematics disability (Braynt, 2005), we will be in a better position in helping the children to cope with this learning disability.

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