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To Link this Article: http://dx.doi.org/10.6007/IJARPED/v9-i3/8257 DOI:10.6007/IJARPED/v9-i3/8257

Received: 15 October 2020, Revised: 19 November 2020, Accepted: 30 November 2020

Published Online: 13 December 2020

In-Text Citation: (May & Ahmad, 2020)
To Cite this Article: May, Y. S., & Ahmad, N. A. (2020). A View on Theories and Models in the Study of Dyscalculia. International Journal of Academic Research in Business and Social Sciences, 9(3), 128–137.

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Vol. 9(3) 2020, Pg. 128 - 137
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A View on Theories and Models in the Study of Dyscalculia

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Abstract
Dyscalculia is a learning disability in Mathematics. The prevalence rate of dyscalculia is between four to six percent among the population. Dyscalculia affects the academic achievement, social relationship, and even lifestyle of an individual. The purpose of this paper is to discuss two theories and two models of dyscalculia, namely Cognitive Development Theory, Theory of Minimal Cognitive Architecture, Triple-Code Model, and Model of Number Processing System. Piaget’s Cognitive Development Theory explains that every pupil has their own individual differences in cognitive development. Four stages of cognitive development are sensorimotor, preoperational, concrete operational, and formal operations. Anderson’s Theory of Minimal Cognitive Architecture demonstrates the ways of knowledge transmitting into brain. Pupils with learning disabilities such as dyscalculia are said to be mismatched with their chronological age. Dehaene’s Triple-Code Model predicts different pathways for learning in dyscalculia. Three main codes in this model are analogue magnitude representation, visual Arabic number form, and auditory verbal word frame. Six aspects in Model of Number Processing System are arithmetic facts, calculation procedures, Arabic numbers comprehension, verbal numbers comprehension, Arabic numbers production, and verbal numbers production. Overall, these theories and models are particular and suitable to be used to support the study in dyscalculia. Based on the theoretical framework, the learning process of dyscalculic pupils can be identified. The implication of this paper is they can be used to design a model or module for dyscalculia and to develop the instruments suitable for dyscalculic pupils.

Keywords: Dyscalculia, Cognitive Development Theory, Theory of Minimal Cognitive Architecture, Triple-Code Model, Model of Number Processing System.

Introduction
The clear practical and theoretical frameworks are necessary for teachers dealing with special educational needs (Ahmad, 2018). The theoretical framework is a structure that can hold or support a theory of a study. It introduces and describes the theory that explains why the research problem under study exists. In this paper, a theoretical framework regarding the problem of
dyscalculia will be discussed. Two theories and two models will be used to explain about the problems among the dyscalculic pupils.

**Dyscalculia**

There are many terms related to dyscalculia, such as developmental dyscalculia, math disability, mathematical disability, mathematical learning disability, math difficulties, disorder in mathematics, numeracy deficit, math anxiety, and so on. Table 1 shows the different terms related to dyscalculia. Nonetheless, math anxiety is interrelated with dyscalculia but it is not the same with dyscalculia. In another word, the pupils with math anxiety will have dyscalculia, but not all the dyscalculic pupils will have math anxiety.

**Table 1. Different Terms Related to Dyscalculia**

| Terms                        | Sources                                                                 |
|------------------------------|-------------------------------------------------------------------------|
| Developmental Dyscalculia    | Anobile, Castaldi, Turi, Tinelli, & Burr (2016)                         |
|                              | Attout & Majerus (2015)                                                 |
|                              | Attout, Salmon, & Majerus (2015)                                        |
|                              | Bugden & Ansari (2016)                                                  |
|                              | McCaskey, von Aster, Tuura & Kucian (2017)                              |
|                              | Rosenberg-Lee, Ashkenazi, Chen, Young, Geary, & Menon (2015)            |
|                              | Sousa, Dias, & Cadime (2016)                                            |
| Math Disability              | Bashir Abu-Hamour (2018)                                                |
| Mathematical Disability      | Radhika & Kiran (2017)                                                 |
| Mathematical Learning        | Kroesbergen & van Dijk (2015)                                          |
| Disability                   | Lewis & Fisher (2016)                                                  |
|                              | Schwartz, Epinat-duclos, Leone, Poisson, & Prado (2018)                |
| Math Difficulties            | Bashir Abu-Hamour & Hanan Al-hmouz (2016)                              |
|                              | Karakonstantaki, Simos, Michalis, & Micheloyannis (2017)               |
|                              | Monei & Pedro (2017)                                                   |
| Disorder in Mathematics      | Zygouris, Stamoulis, & Vavougios (2017)                                |
| Numeracy Deficit             | Ribeiro, Tonoli, Pancini, & Antunes (2017)                             |
| Math Anxiety                 | Kucian, McCaskey, Tuura, & von Aster (2018)                             |
|                              | Mammarella, Caviola, & Borella (2017)                                  |
|                              | Rubinston (2015)                                                       |

In this study, the researchers will consistent with the usage of the term dyscalculia. Often, these pupils who always failed in their Mathematics subject were identified as stupid or lazy as they cannot perform as the typical pupils in the same age and class (Yoong & Ahmad, 2019). The teachers should assist them in order to ensure that they are not left behind in class (Hasan & Ahmad, 2018).

**Cognitive Development Theory**

From the Piagetian perspective, cognitive growth involves changes in the actual systems of thought. Piaget has attempted to represent those systems in terms of mathematical logic and set
Piaget’s work on children’s quantitative development has provided Mathematics educators with crucial insights into how children learn mathematical concepts and ideas (Ojose, 2008). Understanding cognitive development can help educators to work with children to support them in learning optimally (Newcombe, 2013). Poor academic achievement during the early school years is highly associated with cognitive ability of the pupils (Nordin, Ahmad, Nayan, Yahya, Abdullah, Rahman, et al., 2012). Figure 1 shows four developmental stages according to Piaget’s Cognitive Development Theory.

Theory of Minimal Cognitive Architecture

Figure 2 shows the theory of minimal cognitive architecture underlying intelligence and development. This theory states that there are two routes to knowledge. The first route is thinking. It is equivalent to gaining knowledge through thought. As such, the speed of the basic processing generates $g$ and increasing speed increases intelligence. A novel hypothesis of this theory is that speed of processing does not change with development. This means that
developmental change and individual differences are necessarily two independent dimensions of $g$. That speed of processing is unchanging with development also brings with it an explanation for the relative stability of IQ differences across years of considerable change in functioning intelligence or mental age. It is the second route to knowledge acquisition the theory claims is subject to major developmental changes (Anderson, 2017).

![Figure 2. Theory of Minimal Cognitive Architecture underlying Intelligence and Development (Anderson, 1992).](image)

The theory of the minimal cognitive architecture argues not only that processing speed underlies differences in IQ but that processing speed is unchanging through development. Slow processing speed will be a pervasive feature of the cognitive processes of people with intellectual disabilities. Some aspects of development in people with intellectual disabilities should follow a biological and possibly experiential programme that is no different to development in intellectually normal children. In short, certain features of developmental change should be on a similar trajectory to that of average IQ children and consequently best correlated with chronological age (Anderson, 2001).

As a summary, Anderson’s theory of minimal cognitive architecture explains about the ways of knowledge transmitting into brain. Children with learning disabilities such as dyscalculic pupils have lower cognitive load capability and lower processing speed if compared with their peers in the same age. Hence, the cognitive development of these pupils are said to be mismatched with their chronological age.
**Triple-Code Model**

Triple-code model can be viewed as an attempt to reconcile Campbell and Clark’s multiple-codes hypothesis with a rigorous information-processing model. It is based on two premises; (1) numbers may be presented mentally in three different codes; (2) each numerical procedure is tied to a specific input and output code (Dehaene, 1992). Figure 3 shows triple-code model for numerical cognition.

![Triple-Code Model for Numerical Cognition](image)

**Figure 3. The Triple-Code Model for Numerical Cognition** (von Aster, 2000).

Within the triple-code model, abilities such as approximation and number comparison are attributed to the analogue module whereas abilities such as counting, the use of counting procedures in addition and subtraction, and arithmetical fact retrieval are attributed to the verbal module. Multi-digit operations and parity judgments rely on the third module, the [visual Arabic number form] in which numbers are represented by their Arabic code. These three modules constitute a system for number processing and calculation in which the modules are autonomous, interconnected, and activated according to the particular needs of a given task (von Aster, 2000).
In summary, triple-code model is a model to predict different pathways of learning for dyscalculia. Three main codes in this framework are analogue magnitude representation, visual Arabic number form, and auditory verbal word frame. Each of the codes in this model is intercorrelated. Hence, teachers should understand and consider these aspects when designing teaching and learning activities for dyscalculic pupils.

**Model of Number Processing System**

Model of number processing system provides a principled basis for interpreting number processing deficits and that interpretation of the deficits requires the distinctions we have drawn between production and comprehension mechanisms, Arabic, and verbal number processing mechanisms, and lexical and syntactic processing mechanisms. This model implicated in the use of numbers draws a basic distinction between the number-processing system and the calculation system. The number processing system comprises the mechanisms for comprehending and producing numbers, whereas the calculation system consists of the facts and procedures required specifically for carrying out calculations (McCloskey, Caramazza, & Basili, 1985).

In a nutshell, dyscalculic pupils show a difference between their mental age and chronological age due to their lacking in the six aspects as illustrated in Model of Number Processing System by McCloskey, Caramazza, and Basili (1985). Thus, teachers need to understand about the abstract internal representation of the children so that proper intervention or diagnosis which is suitable with their developmental ability can be provideds.

**Conclusion**

Education for pupils with learning disabilities should be given priority. Teachers should be able to implement the education policy in a flexible way (Yahya, Ahmad, & Yoong, 2019). If these pupils are not being detected, they will continue to be left out or labelled (Yoong & Ahmad, 2020). Dyscalculia is also known as number dyslexia. Often, they are being labelled as lazy, not intelligent, or incompetent. These negative perceptions affect their psychology. Subsequently,
they may start to believe that they will never acquire the numeracy skills as good as their peers or friends. As this happen day by day, they may even develop a deliberate avoidance of numbers. Dyscalculia is nearly as common as dyslexia, yet these pupils often left unidentified and undiagnosed even after finishing their school years. Even more, there is also a possibility for misjudging the dyscalculic pupils. As a result, this may lead to the inefficient and improper diagnosis given to them.

In this paper, the researchers had discussed about two theories and two models relevant to the study of dyscalculia, namely Piaget’s Cognitive Development Theory, Anderson’s Theory of Minimal Cognitive Architecture, Dehaene’s Triple-Code Model, and Model of Number Processing System by McCloskey, Caramazza, and Basili. On the whole, this paper has suggested a theoretical framework in the field of dyscalculia. Since the researches of dyscalculia is yet to be developed, so the future researchers are suggested to design and develop models, modules, or instruments for the dyscalculic pupils in order to enhance and improve their Mathematics learning.

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References
Ahmad, N. A. (2018). Inclusive education: better and for the best. *International Journal of Academic Research in Progressive Education and Development, 7*(3), 557-568.

Anderson, M. (1992). *Intelligence and development: a cognitive theory*. Oxford: Blackwell.

Anderson, M. (2001). Annotation: conceptions of intelligence. *Journal of Child Psychology and Psychiatry, 42*(3), 287-298.

Anderson, M. (2017). Binet’s error: developmental change and individual differences in intelligence are related to different mechanisms. *Journal of Intelligence, 5*(24), 1-16.

Anobile, G., Castaldi, E., Turi, M., Tinelli, F., & Burr, D.C. (2016). Numerosity but not texture-density discrimination correlates with math ability in children. *Developmental Psychology, 52*(8), 1206-1216.

Attout, L., & Majerus, S. (2015). Working memory deficits in developmental dyscalculia: the importance of serial order. *Child Neuropsychology, 21*(4), 432-450.

Attout, L., Salmon, E., & Majerus, S. (2015). Working memory for serial order is dysfunctional in adults with a history of developmental dyscalculia: evidence from behavioural and neuroimaging data. *Developmental Neuropsychology, 40*(4), 230-247.

Bugden, S., & Ansari, D. (2016). Probing the nature of deficits in the ‘approximate number system’ in children with persistent developmental dyscalculia. *Developmental Science, 19*(5), 817-833.

Dehaene, S. (1992). Varieties of numerical abilities. *Cognition, 44*, 1-42.

Hasan, R., & Ahmad, N. A. (2018). Conceptual framework of Scaffolding Literacy Module to help remedial students mastering reading skills. *International Journal of Academic Research in...*
Business and Social Sciences, 8(11), 1031-1038.

Karakonstantaki, E. S., Simos, P. G., Michalis, V., & Micheloyannis, S. (2017). Assessment and conceptual remediation of basic calculation skills in elementary school students. British Journal of Developmental Psychology, 36(1), 78-97.

Kroesbergen, E. H., & Van Dijk, M. (2015). Working memory and number sense as predictors of mathematical (dis-)ability. Zeitschrift fur Psychologie, 232(2), 102-109.

Kucian, K., McCaskey, U., Tuura, R. O., & Von Aster, M. (2018). Neurostructural correlate of math anxiety in the brain of children. Translational Psychiatry, 8(273), 1-11.

Lawton, J. T., Saunders, R. A., & Muhs, P. (1980). Theories of Piaget, Bruner, and Ausubel: explications and implications. The Journal of Genetic Psychology: Research and Theory on Human Development, 136(1), 121-136.

Lewis, K. E., & Fisher, M. B. (2016). Taking stock of 40 years of research on mathematical learning disability: methodological issues and future directions. National Council of Teachers of Mathematics, 47(4), 338-371.

Mammarella, I. C., Caviola, S., & Borella, E. (2017). Separating math from anxiety: the role of inhibitory mechanisms. Applied Neuropsychology Child, 7(4). 342-353.

McCaskey, U., Von Aster, M., Tuura, R. O., & Kucian, K. (2017). Adolescents with developmental dyscalculia do not have a generalized magnitude deficit — processing of discrete and continuous magnitudes. Frontiers in Human Neuroscience, 11(102), 1-19.

Monei, T., & Pedro, A. (2017). A systematic review of interventions for children presenting with dyscalculia in primary schools. Educational Psychology in Practice, 33(3), 277-293.

Newcombe, N. S. (2013). Cognitive development: changing views of cognitive change. Wiley Interdisciplinary Reviews: Cognitive Science, 4(5), 479-491.

Ojose, B. (2008). Applying Piaget’s theory of cognitive development to mathematics instruction. The Mathematics Educator, 18(1), 26-30.

Radhika, S., & Kiran, V. K. (2017). Effect of cognitive strategies in improving comprehension of students with mathematical disability. Studies on Home and Community Science, 11(1), 32-35.

Ribeiro, F. S., Tonoli, M. C., Pancini, D., & Antunes, D. S. (2017). Numeracy deficits scrutinized: evidences of primary developmental dyscalculia. Psychology & Neuroscience, 10(2), 189-200.

Rosenberg-Lee, M., Ashkenazi, S., Chen, T., Young, C. B., Geary, D. C., & Menon, V. (2015). Brain hyper-connectivity and operation-specific deficits during arithmetic problem solving in children with developmental dyscalculia. Developmental Science, 18(3), 351-372.

Rubinsten, O. (2015). Link between cognitive neuroscience and education: the case of clinical assessment of developmental dyscalculia. Frontiers in Human Neuroscience, 9(304), 1-8.

Schwartz, F., Epinat-duclos, J., Leone, J., Poisson, A., & Prado, J. (2018). Impaired neural processing of transitive relations in children with math learning difficulty. NeuroImage: Clinical, 20, 1255-1265.

Sousa, P., Dias, P. C., & Cadime, I. (2016). Predictors of primary school teachers’ knowledge about developmental dyscalculia. European Journal of Special Needs Education, 2(1), 3-10.

Von Aster, M. (2000). Developmental cognitive neuropsychology of number processing and calculation: varieties of developmental dyscalculia. European Child Adolescent Psychiatry,
Yahya, A. Y., Ahmad, N. A., & Yoong, S. M. (2019). A new dimensional in teaching non-verbal students with learning disabilities. *International Journal of Academic Research in Business and Social Sciences, 8*(12), 2099-2108.

Yoong, S. M., & Ahmad, N. A. (2019). *Development and evaluation of DoCtor WoRM’s Moduel in improving multiplication skills among year four low achievers.* Sage Submissions. Preprint.

Yoong, S. M., & Ahmad, N. A. (2020). Design and development of dyscalculia checklist instrument.

*International Journal of Academic Research in Progressive Education and Development, 9*(2), 170-178.

Zygouris, N. C., Stamoulis, G. I., & Vavougios, D. (2017). Screening for disorders of mathematics via a web application. *IEEE Global Engineering Education Conference (EDUCON)*, 502-507.