

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 Disability	Kroesbergen & van Dijk (2015) 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) Rubinsten (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 theory (Lawton, Saunders, & Muhs, 1980). 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 helps 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.

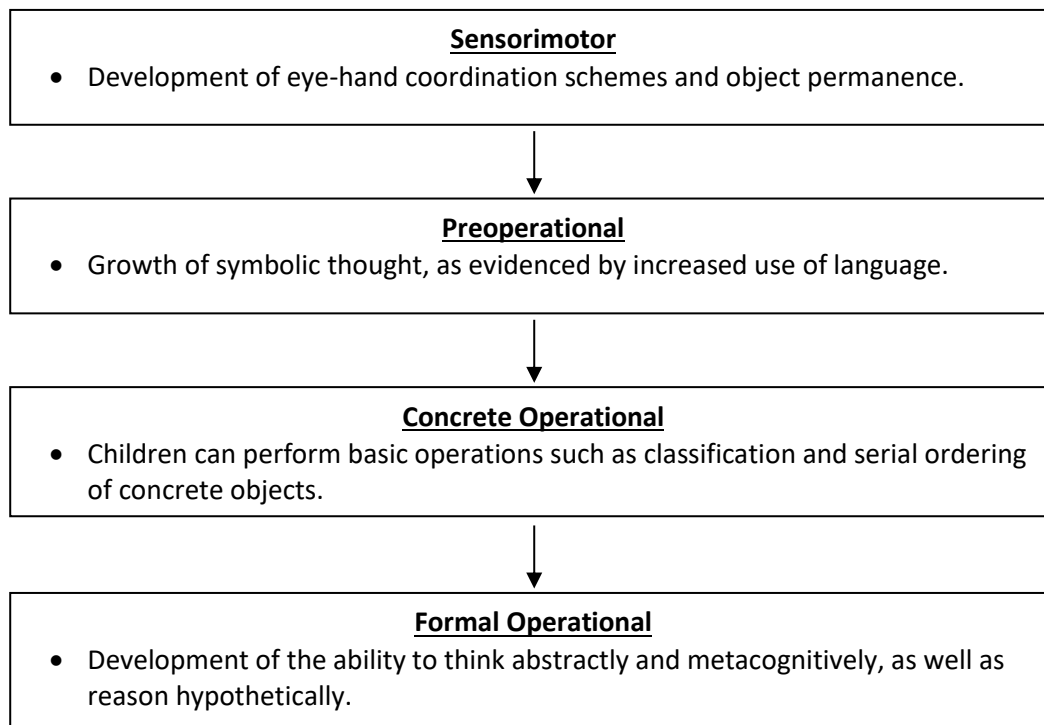


Figure 1. Four Developmental Stages according to Piaget's Cognitive Development Theory (Ojose, 2008).

In short, Piaget's Cognitive Development Theory proposed that there are four stages of cognitive development stages, namely; (1) sensorimotor; (2) preoperational; (3) concrete operational; and (4) formal operations. Every pupil has their own individual differences in cognitive development. Some categories of pupils such as pupils with learning disabilities may undergo slower pace in the development of cognitive. Hence, teachers should be able to know in which stages are their pupils belong to, and able to design teaching and task suitable to their level.

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).

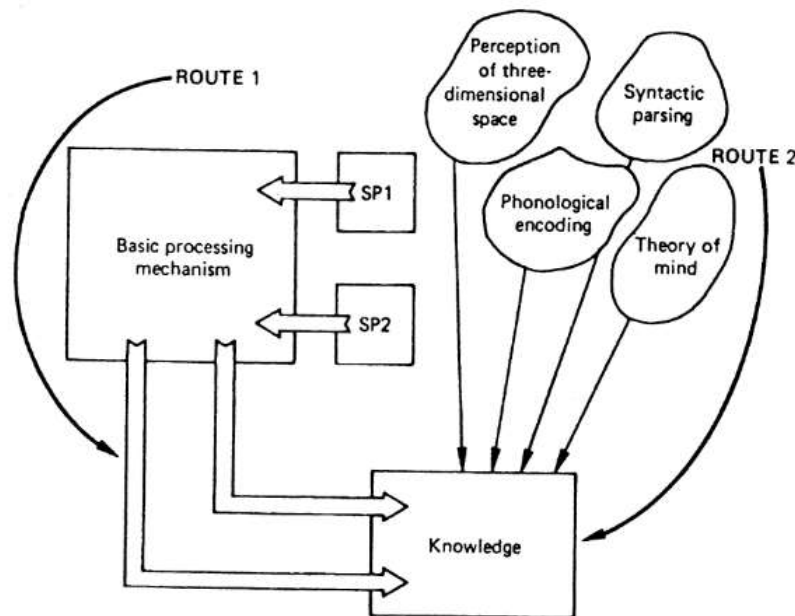


Figure 2. Theory of Minimal Cognitive Architecture underlying Intelligence and Development (Anderson, 1992).

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.

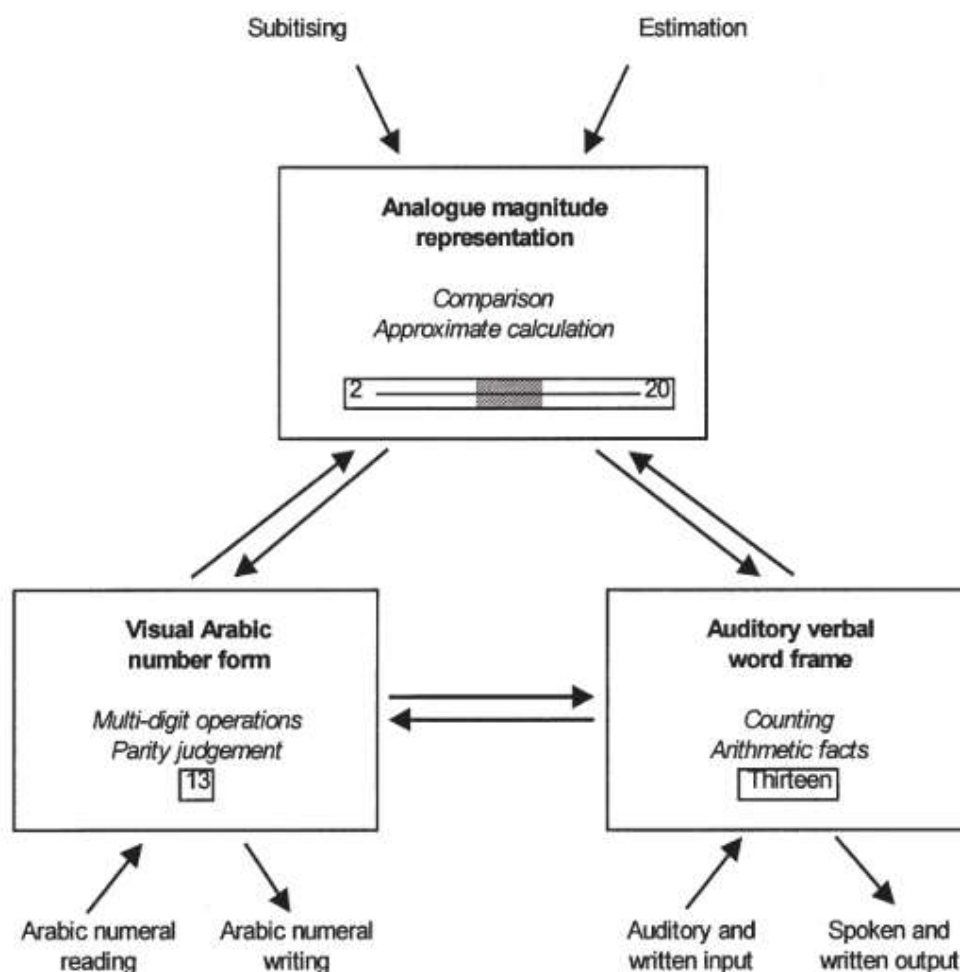


Figure 3. The Triple-Code Model for Numerical Cognition (von Aster, 2000).

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 inter-correlated. 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).

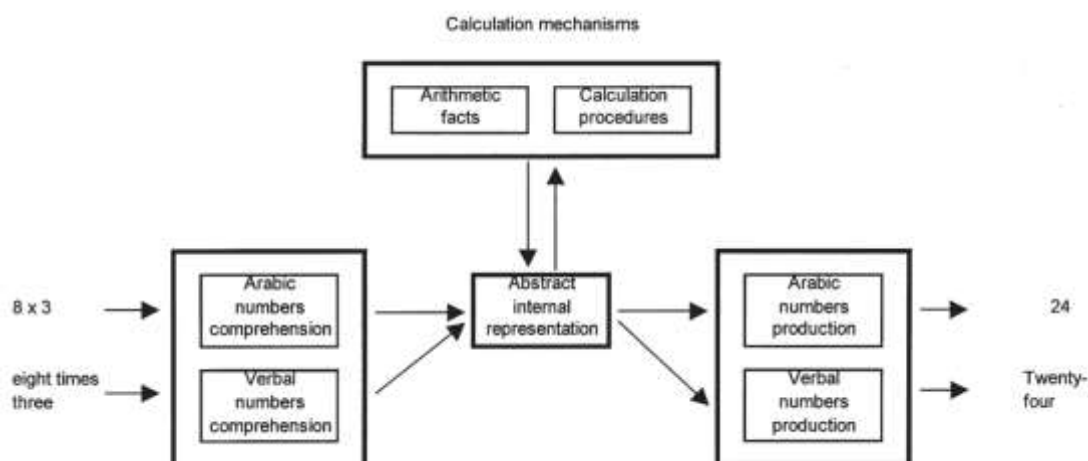


Figure 4. Model of Number Processing System (von Aster, 2000).

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 provided.

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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