

## WORKING MEMORY AND PROCESSING SPEED INDEX AS DETERMINANTS OF EXECUTIVE FUNCTIONING IN DYSCALCULICS

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### Abstract

*Dyscalculia is a type of Learning Disability also known as 'Number Blindness' or the lack of number sense. It is the conditions that hamper one's ability to acquire arithmetical skills. Mathematics is considered one of the toughest subjects since time immemorial as it requires the mastery over various components like language, space and quantity. The Dyscalculic students tend to have a deficit in various cognitive components one of them being Executive functioning, Working Memory and Processing Speed. The purpose of the present research was to assess the Executive functioning of Dyscalculics and examine the effect of Working Memory and Processing Speed Index on it. The Dyscalculic students were screened from the grade levels of VI-VIII from C.B.S.E. Boards of Agra city. A quasi-experimental research design was used with the provision of remedial intervention. The data was analysed using One-way ANOVA and t-Test. The results showed a significant effect of Working Memory and Processing Speed on Executive functioning of Dyscalculics and the remedial intervention proved beneficial for enhancing Executive functioning of Dyscalculics. Thus, the research aims to highlight that Executive functioning of Dyscalculics should be improved with the help of various remedial interventions because it is a good predictor of academic achievement and better numeracy skills.*

**Keywords:** *Dyscalculia, Executive functioning, Working memory and Processing Speed Index*

### INTRODUCTION

Learning Disabilities refers to difficulties in the sphere of learning. The term is an amalgamation of two separate terms 'learning' and 'disability'. To a layman this term may indicate some form of categorization or type of disability. But the very concept of Learning Disability comes from the need of identifying the children who had no physical or mental symptoms of the pre-conceived notions of a disability and who on the contrary seem to be like their normal peer group. This concept came into forefront due to the rigorous efforts of Kirk (1963) who explored this concept in reference to the neurobiological dimensions and demarcated it from the general notion of handicap.

Dyscalculia is one such Learning Disability also known as 'Number Blindness' (Butterworth, 2003) or the lack of number sense. It is the condition that hamper one's ability to acquire arithmetical skills. Mathematics is considered one of the toughest subjects since time immemorial as it requires the mastery over various components like language, space and quantity. Dyscalculia came into forefront by

the efforts of Kosci (1974) who studied it under the neuro-biological orientation. It's hard to define Dyscalculia in its broadest sense due to the complexity of numerical processing. The Department for Education and Skills, USA (DfES, 2001) considers Dyscalculia as a condition which affects the arithmetic skills and the individual may have a difficulty in

(a) understanding simple number facts, (b) low grasping ability, and (c) difficulty in learning number facts and procedures, and even if they are able to do the above it may be solely mechanically. Further, the Diagnostic and Statistical Manual of Mental Disorders (DSM-V, 2013) refers Dyscalculia as 'Mathematics Disorder' and identifies them as individuals who have problem in (a) remembering number facts, (b) slow arithmetic calculation, (c) inaccurate mathematical reasoning and (d) avoidance of activities dealing with mathematics. It is for this reason that students with Dyscalculia usually rely on 'immature methods' of counting on fingers, using tally, etc. which are not suitable to one's mental and chronological age (Butterworth, 1999). Dyscalculics, then further there is problem in developmental delay in counting, addition and subtraction (Geary et al., 2000). A longitudinal study by Ostad (1997,1999) suggests these

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delay exist in fifth class for addition and seventh class for subtraction. The recent researches also report a deficit in various cognitive components of Working Memory (McClellan & Hitch, 1999), Executive Dysfunction (McClellan & Hitch, 1999; Passolunghi & Siegel, 2004). Thus, Dyscalculics face significant problems when it comes to numero-spatial or verbal abilities.

### Emergence of the Problem

“Children’s underachievement in mathematics is a consistent and significant problem” (Dowker, 2009). “These problems endure into adulthood, and it is estimated that a fifth of adults have numeracy skills below the basic level needed for everyday situations” (William et al., 2003). “Mathematics ability is crucial for success and poor mathematics skills have a bigger impact on life chances than poor literacy” (Parsons & Byrnes, 2005).

“Many factors contribute to differences in mathematics achievement, including attitudes, motivation, language ability and IQ, in addition to social, and educational factors. It is clear that domain-specific numerical skills and knowledge are important for success with mathematics” (Gilmore et al., 2010), but other cognitive factors also play an important role. “In particular, the domain-general skill of holding and manipulating information in mind (working memory) has been found to be critical” (Raghubar, 2010). “Inhibition, the ability to suppress distracting information and unwanted responses, and shifting, the ability to flexibly switch attention between different tasks, have also been implicated in mathematics achievement” (Bull & Scerif, 2001). These processes fall under the umbrella of Executive function (EF); skills required to monitor and control thought and action. Thus, these process have a significant connect with Mathematics.

But the situation takes a grim route when it comes to students who have yet another

genetic learning disability to follow in Mathematics, i.e., Dyscalculia. Dyscalculia is a specific learning disability which affects 6 percent of the population. Dyscalculics are not unintelligent but struggle to learn mathematics and mathematics related learning concepts (such as quantity, place value, and time), difficulty memorizing math facts, difficulty organizing numbers, and understanding how problems are organized on the page but still have a normal or above normal IQ.

### Objectives of the Study

The following objectives are laid down in this study

1. To examine the Executive Functioning of Dyscalculics.
2. To examine the effect of Working Memory on Executive Functioning of Dyscalculics.
3. To find out the effect of Processing Speed Index on Executive Functioning of
4. To provide Remedial intervention for improving Working Memory and Processing Speed Index of Dyscalculics.

### Hypotheses of the Study

In the context of the above-mentioned objectives the following null hypothesis are formulated:

- H<sub>01</sub>: There will be no effect of Working Memory on Executive Functioning of Dyscalculics.
- H<sub>02</sub>: There will be no effect of Processing Speed Index on the Executive Functioning of Dyscalculics.
- H<sub>03</sub>: There will be no effect of Remedial intervention for improving the Working Memory and Processing Speed Index of Dyscalculics.

## METHOD USED IN THE PRESENT STUDY

The researcher used 'Quasi-experimental Method' in the study

## SELECTION OF THE SAMPLE

The sample of 40 Dyscalculic students studying in school affiliated to CBSE board were selected from classes 6-8. The Radhaballab public school was selected for that present study. Dyscalculic Identification Scale was administered on the students from class VI-VIII standards. After evaluation the researcher has diagnosed about forty students with Dyscalculia.

## TOOLS OF THE STUDY

The present research makes use of the following tools in the study:

1. Dyscalculic Identification Scale by Vashistha & Gupta (2014).
2. Self-constructed tools of Executive functioning, Working Memory and Processing Speed Index.

## FINDINGS OF THE STUDY

### To examine the Executive Functioning of Dyscalculics

The self-constructed tool of Executive functioning was administered on the identified sample of Dyscalculics before dividing them in the controlled and experimental groups. The tool consists of seven dimensions of Executive functioning namely: Concept Formation (an inductive teaching strategy that helps form a clear understanding of a concept through studying a set of examples), Verbal fluency (The ability to form and express words compatible with required for optimal communication and deduction), Organization (recognizing the right pattern and sequencing the information in the right order), Visuo-spatial processing ( a human computational capacity that provides the ability to solve spatial problems), Planning( the process of thinking and organizing the activities),

Inhibition (cancelling out the undesired stimuli from the environment) and Cognitive flexibility ( the mental ability to switch between thinking between concepts and think about multiple concepts).

### To examine the effect of Working Memory on Executive Functioning of Dyscalculics

Findings that were reported in regard to the effect of the one Predictive variable on the Criterion variable of the study, where Predictive variable being Working Memory and the Criterion variable being the Executive functioning. This effect was analyzed with the help of one way ANOVA in the SPSS version 20. The findings are as follows:

**Table 1.1:** F-table exhibiting the effect of Working Memory on Executive functioning of Dyscalculics

| SN | Values         | Sum of Square | df | Mean Square | F     | p-value |
|----|----------------|---------------|----|-------------|-------|---------|
| 1  | Between Groups | 163.413       | 9  | 18.157      | 7.713 | .130    |
| 2  | Within Groups  | 317.962       | 30 | 10.599      |       |         |
| 3  | Total          | 481.375       | 39 |             |       |         |

The  $F(163.4, 317.9)$  with significance value since the p-value was less than the 0.01 level of significance the null hypothesis was rejected. Indicating a significant effect of Working Memory on Executive functioning of the Dyscalculics. Various other researches have also shown a significant effect of Working Memory on Executive functioning in reference to the Mathematical ability (Bull & Scherif, 2012) and Miyake, et al. (2001) suggested a latent relation between the above two Predictive and Criterion variables.

### The effect of Processing Speed Index on Executive functioning on Dyscalculics

To study the effect of Processing Speed index on Executive functioning on Dyscalculics the approved statistics used was One Way ANOVA with the help of SPSS.

**Table 1.2 :** F-table exhibiting the effect of Working Memory on Executive functioning of Dyscalculics

| SN | Values         | Sum of Squares | df | Mean Squares | F     | p-value |
|----|----------------|----------------|----|--------------|-------|---------|
| 1  | Between Groups | 153.413        | 9  | 18.157       | 8.713 | .130    |
| 2  | Within Groups  | 324.962        | 30 | 10.599       |       |         |
| 3  | Total          | 481.375        | 39 |              |       |         |

Then it was found that the F-value is 8.7 with significance value since the p-value was less than the 0.01 level of significance hence, the null hypothesis was rejected. Indicating a significant effect of Processing Speed Index on Executive functioning of the Dyscalculics. The studies in coincidence with the above findings was proved by a longitudinal study done on 6-85 year olds by Cepeda, Blackwell & Munakata (2013).

**The effect of Remedial intervention on Working Memory and Executive functioning on Executive functioning of Dyscalculics.**

For the purpose of providing the remedial intervention a fourteen session instruction set was administered on the Experimental group of 20 Dyscalculics of Classes 6-8 (C.B.S.E. Board). But before administering the remediation the Experimental and Control groups were equated by comparing their sample means with the help of Students' t- Test. The results indicated an Experimental mean of 18.05 whereas, Control mean of 17.2 and the S.D. values of both the Experimental and Control group was 2.68 and 2.41 respectively. Thus, indicating a very marginal difference. The Student t-Test value came to be 0.71 which was insignificant at the p-value of 0.484. Hence showing that there was no difference between the Experimental and Control groups in reference to their Executive functioning scores.

**Table 1.3:** Paired t-values for Pre- and Post-test Scores of the Experimental group

Now the remedial intervention is provided to the Experimental group consisting of 20 Dyscalculic children on the grounds of

| Variable           | Paired Differences |                |                 |   | t       | df   | P-value* |       |
|--------------------|--------------------|----------------|-----------------|---|---------|------|----------|-------|
|                    | Mean               | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference |         |      |          |       |
|                    |                    |                |                 | Lower                                     |         |      |          | Upper |
| EF Pre & Post-test | 3.35000            | 1.49649        | 2.649           | .33462                                    | -4.0503 | 10.0 | 19       | .000  |

\*significant at 0.05 level of significance

Working Memory and Processing Speed remediation. The Executive functioning tool when applied to the Experimental group is later reassessed after the sessions of remediation. The scores are assessed with the help of Paired t- Test using SPSS version 20. The results indicated a t- value of 10.01 with a p-value of 0.00 which was highly significant on the 0.05 level of significance.

**Significance of the Study**

Today we live in a world of challenges which can be converted into the desired opportunities if one has the right skill to do so. These challenges become all the more challenging for students with learning disabilities. The world runs around the number game. Good numeracy skills are important for being a successful member of the society. Bad numeracy skills are a handicap than poor literacy skills when it comes to getting a job, maintain a job and being promoted within employment. Keeping this in view a learning disorder related to Mathematics makes the situation all the more gross. Thus, students with Dyscalculia when enter this demanding world are somewhat slow paced when compared to their peers. They face problems in day to daysimple calculations and skills required to take decisions. Hence in the long run they fall victim to anxiety, low self-esteem and depression.

Executive functions play a vital role and have a significant relation with the numerical ability. The students with dyscalculia are said to have

problems the managing the various cognitive processes. They lack behind their peers because low working memory and processing speed index. Both working memory and processing speed are interrelated with executive functions. Hence, if these students are helped regarding the enhancement of these major components it will lead to the efficient execution and management of these cognitive processes. It is the cognitive abilities that keep the Dyscalculics from true progress.

Hence, it becomes all the more important to deal with their day to day inefficiency at various tasks not just numerical tasks in general. It's important to identify their prevalence rate of the Dyscalculic students at the Elementary level and then to assess the Executive functioning. Then its important to examine the effect both Working Memory and Processing Speed Index have on Executive functioning of the Dyscalculics. The major task at hand is to provide a remedial intervention for bringing about an improvement in Working Memory and Processing Speed Index of these mathematics learning disables.

As Dyscalculia is a genetic disorder and cannot be cured one cannot wait for the conditions to worsen. But an immediate need arises to intervene from the very beginning. Its crucial that the parents, teachers and policy-makers help these students to be successful to make appropriate decisions.

Therefore this endeavor of the researcher to assess the effect of Working memory and Processing speed index of students with Dyscalculia and to improve the them to bring about a constructive difference in the Executive functioning of the Dyscalculics. Which in turn can help the policy makers and curriculum constructors better understand the Dyscalculics and include the components which enhance their Executive functioning in the very curricula. Thus its greatest benefit making life happy and a bit easy in the long run for the already strenuous life that these students lead in the world.

## REFERENCES

- Butterworth, B. (2003). *Dyscalculia Screener*. London: Nelson Publishing Company Ltd
- Butterworth, B. (2005). Developmental Dyscalculia. In J.I.D. Campbell (Ed.), *Handbook of Mathematical Cognition* (pp. 455-468). New York: Psychology Press.
- Cepeda, J. N., Blackwell, A. K., & Munakata, Y. (2013). Speed isn't everything: Complex processing speed measures mask individual differences and developmental changes in executive control. *Developmental Science*, 16(2), 269-286. doi:10.1111/desc.1204
- Chan, C. K. R., Shum, D., Touplopoulou, T., & Chen, Y. E. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of Clinical Neuropsychology*, 23, 201-216. doi:10.1016/j.acn.2007.08.010
- Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology*, 19(3), 273-293.
- Dowker, A. (2009). Use of derived fact strategies by children with mathematical difficulties. *Cognitive Development*, 24(4), 401-410.
- Geary, C. D., Hamson, C. O., & Hoard, M. K. (2000). Numerical and arithmetical cognition: a longitudinal study of process and concept deficits in children with learning disability. *Journal of Experimental Child Psychology*, 77, 236-263.
- Geary, C. D., Bailey, D. H., Littlefield, A., wood, P., Hoard, M. K., & nugent, L. (2009). First-grade predictors of mathematical learning disability: A latent class trajectory analysis. *Cognitive Development*, 24(4), 411-429.
- Gilmore, C. K., McCarthy, S. E., & Spelke, E. S. (2010). Non-symbolic arithmetic abilities and

mathematics achievement in the first year of formal schooling. *Cognition*, 115(3), 394-406.

Kosc, L. (1974). Developmental dyscalculia. *Journal of Learning Disabilities*, 7, 159-162.

McLean, J. F., & Hitch, G. J. (1999). Working memory impairments in children with specific arithmetic learning difficulties. *Journal of experimental child psychology*, 74(3), 240-260.

Miyake, A., Friedman, N. P., Rettinger, D. A., Shah, P., & Hegarty, M. (2001). How are visuospatial working memory, executive functioning, and spatial abilities related? A latent variable analysis. *Journal of experimental psychology: General*, 130(4), 621.

Ostad, S. A. (1999). Developmental progression of subtraction strategies: A comparison of mathematically normal and mathematically disabled children. *European Journal of Special Needs Education*, 14(1), 21-36.

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and individual differences*, 20(2), 110-122.

Williams, J. (2003). The Skills for Life survey: A national needs and impact survey of literacy,

numeracy and ICT skills (No. 490). The Stationery Office.

Ramma, S., & Gowramma, I. P. (2002). A systematic procedure for identifying and classifying children with dyscalculia among primary school children in India. *Dyslexia*, 8, 67-85.

Shalev, R. (2004). Developmental dyscalculia: Review. *Journal of Child neurology*, 19(10), 765-771.

Titz, C., & Karbach, J. (2014). Working memory and executive functions: Effects of training on academic achievement. *Psychological Research*, 78(6), 852-868.

Vaughn, S., & Fuchs, S. L. (2003). Redefining learning disabilities as inadequate response to instruction: The promise and potential problems. *Learning Disabilities Research and Practise*, 18(3), 137-146

Zimmermann, U. (2008). Working memory and processing speed as correlates of math skills in adult with learning disabilities (3317770). Retrieved from <http://search.proquest.com/docview/304835>

