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**Original Research Paper**

# Working Memory Predicts Reading Skills of Children at Risk of Dyslexia

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## ABSTRACT

Working memory enables storage of information in our mind for brief periods and makes it available for current thinking and activities. Many studies have documented the role of working memory in academic achievements. The study examines the relationship between working memory and reading skills among children at risk of dyslexia. It also attempts to see if working memory can significantly predict these reading skills. The study comprises 40 children at risk of dyslexia selected through purposive sampling method. Various standardized tools were used to assess working memory and reading skills of the participants. The data were quantitatively analyzed using correlation and regression analysis methods. The findings of the study show that there is statistically significant relationship between working memory and reading skills among children at risk of dyslexia and working memory can predict reading skills such as reading rate, accuracy and fluency. However no significant relationship was found between working memory and comprehension. It confirms various theories that emphasize on the role working memory in reading. Thus it can be inferred that training targeting working memory may improve reading skills.

***Keywords:*** *Children At Risk Of Dyslexia, Working Memory, Reading Rate, Accuracy, Fluency, Comprehension*

**D**evelopmental dyslexia is one of the common learning disabilities. The characteristic feature of dyslexia is reading disability in spite of adequate intellectual abilities, proper schooling and conducive socio-cultural environment (Zhu, Wang, & Wu, 2012). American Psychiatric Association (2013) defines dyslexia as "a form of specific learning disorder characterized by difficulties with reading words, accurate reading, word recognition, decoding, spelling, fluency, and poor reading comprehension that is substantially below what would be expected of person's age, cognitive and education level". According to Fletcher, Lyon, Fuchs, & Barnes (2007), 6-7% of school age population has symptoms of dyslexia. In India the incidence rate of dyslexia has been reported to be between 2% and 18% (Ramaa & Gowramma, 2000).

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Working memory is a system that enables temporary holding and manipulation of information during the performance of various cognitive tasks like comprehension, learning and reasoning (Baddeley, 1986). It is required for simultaneous storage, processing and retrieval of information. Numerous studies have examined the relation between reading skills and working memory and identified components of working memory, such as phonological loops, visuospatial sketchpads, and central executive functioning which may be impaired in persons with dyslexia (Cohen-Mimran & Sapir, 2007; Wang, et al., 2010). Many studies have linked working memory capacity with reading ability (De Jong, 1998; Gathercole, Brown, & Pickering, 2003; Alloway, Gathercole, Kirkwood, & Elliott, 2009). Significant impairment in task involving working memory has been demonstrated in children with dyslexia (Hellen & Asbjornsen, 2004; Palmer, 2000).

Also supporting the notion are several studies on Dyslexic children showing poor working memory skills (Jeffries & Everatt, 2004; Reiter, Tucha, & Lange, 2004). Deficit in working memory skills is considered as one of the underlying causes of failure to acquire accurate and fluent reading (Baddeley, 1986; Cohen-Mimran & Sapir 2007).

***Objectives***

1. To study the relationship between working memory and reading skills of children at risk of dyslexia
2. To study if working memory predicts reading skills of children at risk of dyslexia

***Hypothesis***

1. There will be a significant relationship between working memory and reading skills among children at risk of dyslexia
2. Working memory will significantly predict reading skills among children at risk of dyslexia

## METHODOLOGY

***Sample***

The present study was conducted on third to fifth grade children from two English medium schools. The study comprised 40 children from medium socio-economic background and at risk of dyslexia (Boys=26, Girls=14, $M_{age}$=9 years 5 months, age range: 7 years 6 months-11 years) identified using Dyslexia Junior test India Edition. The intellectual abilities of the participants range from average to above average.

***Instruments***

Three measures were used in this study,

1. ***The Raven's Coloured Progressive Matrices, (RCPM)***: It is a nonverbal test developed by Raven in 1984. It is used to assess cognitive processes, nonverbal and abstract reasoning of 5 to 11 years old children. The test is divided into 3 parts: Set A, Set B and Set Ab consisting of 12 items each. All 36 problems are given in the form of incomplete

matrices. The test can be given either as an individual test or as a group test. The test retest reliability coefficient of RCPM is 0.80.

2. ***Dyslexia Screening Test- Junior India Edition (DST-J India$^{Edition}$)****:* It was developed by Fawcett & Nicolson in 2012. It is used to assess risk of reading failure so that children at risk of reading disability can be identified and extra support can be given. The scores obtained from DST-J can't be used for diagnosis but for screening purpose only. It gives a complete profile 'at a glance' indicating relative strengths and weaknesses of the child. It is applicable for children of 6 years and 6 month to 11 years and 5 month. It can be administered in 30 minutes. It consists of following 12 subtests all having good to excellent reliability. The test retest reliability was assessed by administering the test on separate occasions about a week apart on the groups of children aged from 6 years 5 months to 12 years. Test retest reliability is excellent for one minute reading (.994), spelling (.983), nonsense passage reading (.969) and one minute writing (.906). It is good to very good for rapid naming (.852), Phonemic segmentation (.883), Backward digit span (.823) and Verbal Fluency (.806) and satisfactory for bead threading (.762), Postural Stability (.724) and semantic fluency (.777). One minute reading (.981) and vocabulary (.846).
3. ***Gray Oral Reading Test 4 (GORT-4):*** It was developed by Wiederholt & Bryant in 2001. It is used to assess reading rate, reading accuracy, fluency and comprehension of children of age group 6 years to 18 years and 11 months. It is a parallel forms test (Form A and Form B), each consisting of 14 different stories, followed by five multiple comprehension questions after each story. It can be administer in 15-45 minutes depending upon the student's reading ability. The test retest reliability for rate is .95, for accuracy is 0.92, for fluency is 0.93 and for comprehension is 0.86. The normative data were keyed to the 2000 census data of U.S. population.
4. ***Wechsler Intelligence Scale for children-Fourth UK Edition (WSIC-IV).*** Digit Span Backward test From WISC-IV. It was developed by Wechsler in 2003. It is designed to measure verbal working memory. It involves transformation of information, mental manipulations and visuospatial imaging. In digit span backward the participant repeats numbers in the reverse order of that presented aloud by the examiner. Reliability: the internal consistency reliability was 0.80, test retest 0.67. The WISC-IV normative information is based on 2200 children of the U.S. population in age ranging from 6:0 to 16:11.

***Procedure***

The present study was conducted in two English medium schools. On the basis of suggestion by class teacher children with reading difficulties, including those who have problems in reading, spelling and writing were selected from IIIrd to Vth standard. None of them had received any form of remedial measures for their reading difficulties. With consent of parent/guardian and school authorities, assessment was done and the students were administered DST-J India$^{Edition}$ and also their IQ's were measured. Students with average to above average IQ's and at risk quotient of 0.6- 0.8 were identified as mild risk of dyslexia, 0.9-.11 as moderate risk, and 1.2 and above were identified as being at severe risk of

dyslexia. The final sample in the present study included 40 children at risk of dyslexia. Measures of reading skill were taken by using following assessment tools: RCPM, DST-J India[Edition], GORT-4, WISC IV. Pearson product moment correlation and linear regression analysis were used for statistical analysis.

## RESULTS

***Table 1. Representing distribution of participants***

| At Risk Quotient | Frequencies | Percentage (%) |
|---|---|---|
| Mild Risk | 2 | 5 |
| Moderate Risk | 13 | 32.5 |
| Severe Risk | 25 | 62.5 |

As shown in Table 1, 62.5% of the participants have severe risk, followed by 32.5% with moderate risk and 5% with mild risk of developing dyslexia. It suggests that all participants have difficulties in various domain of DST-J.

***Table 2. Relationship between Working Memory and Reading Skills***

| Dimensions | Working Memory (r) | p (one tailed) | M | SD |
|---|---|---|---|---|
| Rate | .39** | .006 | 7.57 | 5.78 |
| Accuracy | .49*** | .001 | 4.57 | 3.75 |
| Fluency | .45** | .002 | 12.15 | 9.18 |
| Comprehension | .12 | .238 | 2.7 | 2.08 |
| M | 6.25 | | | |
| SD | 1.89 | | | |

*Note. *p<.05, **p<.01, ***p<.001.* Means and standard deviations of working memory are presented in last two rows. Means and standard deviations of reading skills are presented in the last two columns.

The results of Pearson product moment correlation show that there are significant positive relationships between working memory and reading rate, accuracy and fluency, p<.05, but no relationship was seen with comprehension and spelling at p>.05. Thus the overall findings indicate a low to moderate positive correlation between working memory and some reading skills.

***Table 3. Linear Regression Analysis Between Working Memory and Reading Skills***

| Predictor(s) | Criterion Variables | Model Summary | | Coefficient Model | |
|---|---|---|---|---|---|
| | | $\Delta R^2$ | F | B | T |
| Working Memory | Reading Rate | .13 | 6.88* | .39 | 2.62* |
| Working Memory | Accuracy | .22 | 11.97*** | .49 | 3.46*** |
| Working Memory | Fluency | .18 | 9.46** | .45 | 3.08** |
| Working Memory | Comprehension | .01 | .52 | .12 | .48 |

*Note. *p<.05, **p<.01, ***p<.001*

The findings of linear regression analysis show that working memory explains a significant amount of variance in reading rate, accuracy, and fluency p<.05. Working memory explains

13% of variance in reading rate and also significantly predicts values of reading rate, $p<.05$. Working memory explains 22% of variance in accuracy and significantly predicts values of accuracy, $p<.001$. Working memory also explains 18% of variance in fluency and significantly predicts values of fluency, $p<.01$. However, working memory neither explains a significant amount of variance in comprehension nor predicts value of comprehension, $p>.05$, of children at risk of dyslexia. Thus, it can be inferred that working memory serves a predictor of various reading skills among children at risk of dyslexia.

## DISCUSSION

Working memory enables us to maintain active recollection of things at hand during a cognitive task (Baddeley & Hitch, 1976). The role of working memory in reading has been well documented in literature. The present study focuses on the possible role and predictive value of working memory on certain reading skills in children at risk of dyslexia.

The results of the present study show a positive correlation between working memory and reading rate, accuracy and fluency skills among children at risk of dyslexia, thus proving the first hypothesis. Many previous studies support our findings. Relations between working memory and academic skills have been well documented (Carretti, Borella, Cornoldi, & De Beni, 2009; Swanson, 1993, 1994). Chung et.al, (2011) reported significant association of word reading with verbal working memory. Luo (2013) suggested that working memory enhancement might contribute to reading effectiveness and focused reading. Blankenship, O'Neill, Ross, Bell 2015; Ellis, 1996 have also suggested a positive correlation between working memory and reading fluency. Deficit in working memory skills is considered as one of the underlying causes of failure to acquire accurate and fluent reading (Baddeley, 1986; Cohen-Mimran & Sapir 2007). The present study shows that working memory significantly explains variance in reading rate, accuracy and fluency and it is found to be a significant predictor for reading rate, accuracy and fluency among children at risk of dyslexia. These findings are supported by previous researches. For instance, Swanson and Jerman (2007) postulated that deficits in working memory are significant predictors of reading disabilities. Working memory is significant predictor of oral reading fluency (Jacobson, 2011). The findings of present study do support the possibility of a causal and direct role of working memory in academic achievement. According to Holmes (2012) working memory is required for any complex and demanding activity including reading. The process of reading sentences requires holding pieces of information for a temporary period in the mind and thus working memory is required for reading. Baddeley (2003) suggests that working memory contributes to reading by helping in conceptualization of words and maintaining them for comprehension. According to the visual attention span hypothesis (Ans, Carbonnel, & Valdois, 1998; Valdois et al., 2004), two successive reading procedures exist: In the global procedure, words are processed as a whole. Only if a word is not identified through the global procedure, the analytic procedure is activated and the word is read through serial activation of smaller orthographic units, such as syllables, letter clusters or letters, for which phonological outputs are successively generated and maintained in short-term memory. A defect in working memory would thus affect reading skills.

However working memory neither had statistically significant relationship with comprehension nor it is a predictor of comprehension. In contrary to present finding previous studies reported positive association between working memory and reading comprehension (Cain Oakhill & Bryant, 2004; Blankenship, O'Neill, Ross & Bell 2015). This disparity could be due to the focus on a single cognitive skill i.e. working memory rather than a holistic cognitive approach in the study since other cognitive skills also affect reading. The same has been commented on before by Daneman & Hannon (2001); Nevo & Breznitz (2010). Reading requires many mechanisms (Paivio, 1990). Thus, there is a need to involve multiple cognitive processes for a comprehensive study.

The present study confirms central role of working memory in reading. It advocates the notion that deficits in working memory hamper reading ability and thus, working memory plays a vital role in academic achievements of children at risk of dyslexia. It raises the possibility that interventions intended at improving working memory skill may consequently improve the quality of reading of children at risk of dyslexia. Several limitations of the present study include small sample size, limited cognitive and reading skill parameters studied. The results of the present study may not be generalized to children belonging to low or high socioeconomic status and also it could not address all the reading skills associated with dyslexia. Further studies are needed to observe the role of other cognitive skills in reading and possible remedial role of cognitive training in dyslexia.

## CONCLUSION

On the basis of the findings of our study, it can be concluded that working memory has a significant relationship and can predict various reading skills including reading rate, accuracy and fluency, in children at risk of dyslexia. This has significant implications as proper cognitive training involving working memory can help in treatment of children with dyslexia. Further studies are needed to identify the possible correlation between other cognitive skills and reading abilities. This would enable us find a multi pronged and holistic approach in treating reading problems.

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