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Original Research Article

Does Phonological Awareness Influence Mathematical Word Problem Solving?

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ABSTRACT

Contemporary research in the fields of Psycholinguistics and Cognitive Linguistics is expanding and deepening our understanding of the role of phonological cognitive abilities in mathematical problem solving. Successful solving of mathematical word problems entails both reading skills and mental representation skills. Although the implications of language in learners' mathematical development have been studied extensively; only few studies have spelled out the crucial role of phonological processing abilities in mathematical performance. Building on the working memory model propounded by Baddeley and Hitch (1974), the present correlation study examines the relationship between phonological awareness and mathematical word problem solving performance in primary children. Seventh grade children (n = 40) with a mean age of 12.5 years were assessed on phoneme deletion, phoneme segmentation, phoneme blending sound categorization and mathematics word problems. Using correlation analyses, the results indicated that phonological awareness is correlated to learners' performance in mathematics word problems. Based on this finding, it is concluded that developing phonological awareness skill among learners should be given utmost importance during early years for better mathematical performance.

Keywords: *Mathematical Word Problems, Working Memory, Phonological Processing, Phonological Awareness*

INTRODUCTION

In mathematics learning and teaching, word problem solving has been gained a great deal of attention from both researchers and educational practitioners. The main objective of teaching word problems in school is to enable learners to identify and apply mathematical concepts, thereby equipping them to use mathematical knowledge inside and outside classrooms. Rasmussen and King (2000) and Timmermans et al., (2007) defined mathematical word problems as "mathematical exercises that present relevant information on a problem as text, rather than in the form of mathematical notation" (as cited in Boonen et al., 2016, p. 1). Though mathematics and language are two distinct subjects, the relation between these two have been studied extensively by many researchers (Duncan et al., 2007; Abedi & Lord, 2001; De Smedt et al., 2010). The results indicated that language abilities influence children's mathematical learning and can predict learner's math skills in the long term. Berninger (2000) categorized language into two forms: oral and literacy forms. Abilities such as phonological, grammatical, and vocabulary are included in oral language skills whereas literacy skills comprise of reading and writing skills. According to Muter et al., (2004) and Shanahan et al., (2006), oral language skills are "prerequisite of the acquisition of literacy" (as cited in Zhang et al., 2017, p. 2). Phonological processing, an oral language skill is the "conscious use of phonological information (sounds of a given language) in the speech and writing processing" (Mendes & Barrera, 2017, pp. 298 – 299). Phonological awareness a component of the broader category called phonological processing refers to "one's awareness of, and access to, the sound structure of oral language" (Wagner & Torgesen, 1987, as cited in Hecht et al., 2001, p. 196).

A longitudinal correlational study by Hecht et al. (2001) revealed a significant relation between phonological processing and mathematics computation skills. Another study by Vukovic and Lesaux (2013) has found that verbal analogies were indirectly associated to learners' mathematical knowledge through symbolic number skill. It was further reported that phonological decoding was directly correlated with arithmetic performance. These results concur with the findings of (Alloway et al., 2002; Koopen et al., 2007; Kuzmina et al., 2017; Robinson et al., 2002; Tzoneva, 2015) found that phonological awareness is significantly correlated with math fluency and skills among primary children. A similar study conducted by Jordan et al., (2010) on primary school children found that solving mathematical test items were challenging for learners with poor phonology. In the same vein, Bjork and Bowyer – Crane (2013) revealed that phonological awareness significantly predicts the learners' performance in mathematics.

Thus, it can be ascertain that word problem solving is a complex process which involves not only mental representation and text comprehension but language skills, particularly phonological awareness also have a substantial role. Several educators through their empirical findings attributed the cause of learning to "deficiency in one or more cognitive abilities, namely, phonological processing, auditory processing, long-term retrieval, attention, short-term memory, and working memory" (Masoura, 2006, as cited in Dehn, 2008, p. 95). Thus, to be mathematically proficient learners must adept in the language in which classroom instruction happens.

Taking insights from previous studies, this study aims to explore the relation between one of the aspects of phonological processing – phonological awareness and mathematics word problem solving performance. The meagerness of researches carried out in examining the relation between phonological awareness and mathematical

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word problems was one of the motivations for conducting this work.

Theoretical Framework

This study is theoretically grounded in the working memory model proposed by Baddeley and Hitch in 1974. Baddeley (1986) defined working memory as "a system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks such as comprehension, learning, and reasoning" (as cited in Dehn, 2008, p. 14). The model comprises of three subsystems: ***a phonological loop, a visuospatial sketchpad, and a central executive.***

The Phonological Loop: This subsystem is a "rehearsal circuit in working memory which holds inner speech for verbal comprehension" (Solso, 2011, p. 538). This loop is comprised of two components, a phonological input store for the temporary storage of oral information and a subvocal rehearsal mechanism where the rehearsal of this information takes place. When the input is presented in oral form, it (Hitch, 1990; Logie, 1996) "gains immediate, direct, and automatic access to the phonological loop" where the information is briefly stored in phonological form (as cited in Dehn, 2008, p. 15). The function of phonological loop is to transform the information obtained from sensory stimuli into "phonological codes (Gilliam & van Kleck, 1996) that include the acoustic, temporal, and sequential properties of the verbal stimulus" (ibid). The accurate retrieval of phonological information happens when phonological codes are equated with the existing codes (i.e., phonemes and words) present in the long-term memory.

The Visual-spatial Sketchpad: This is a short-term depository for storage, processing and manipulation of visual and spatial information. Similar to phonological loop, information or images in this loop undergo rapid decay if it is not rehearsed. Most importantly, the rate of forgetting depends on stimulus complexity and of how long it has been viewed. One of the important functions served by this working memory subsystem in reading is (Baddeley, 1986) "it visually encodes printed letters and words while maintaining a visuo-spatial frame of reference that allows the reader to backtrack and keep his or her place in the text" (as cited in Dehn, 2008, p. 19). This visual storage system is further subdivided into two storage subcomponents namely, *visual and spatial* components (Baddeley, 2006; Pickering et al., 2001; Van Der Sluis, Van Der Leji, & De Jong, 2005). A study carried out by Della Sala et al., (1999) proved that a double dissociation occurred when these components were assessed.They concluded that "there are separable visual and spatial components that make up the visuo-spatial sketchpad" (Robinson-Reigler and Robinson-Riegler, 2008, p. 153).

The Central Executive: This limited-capacity core component of working memory model, controls the two subsystems and "determines both how to expend cognitive resources and how to suppress irrelevant information that would consume those resources" (Baddeley, 1986, as cited in Smith and Kosslyn, 2008, p. 259). Above all, this central component is accountable for higher level thought processing such as reasoning, language comprehension, and conceptualization and also involved in the "activation, retrieval and manipulation of long-term memory representations" (Dehn, 2008, p. 24). This precisely shows that the effect of long-term memory on the content of working memory cannot be ignored. In order to shed light on the involvement of long-term memory, a fourth subcomponent "episodic buffer" was recently added by Baddeley (2000, 2006). In essence, the function of episodic buffer is to integrate information from working memory components and long-term memory. Bringing forth the idea of working memory, empirical research findings (Gathercole & Pickering, 2000a, 2000b) have acknowledged the role of working memory in learning, especially in acquisition of language skills and mathematics in children. In essence, mathematics word problems are an integration of several aspects of language abilities such as oral and written language.

MATERIAL AND METHOD

The main objective of this study is to explore the relationship between phonological awareness and learners' performance in mathematical word problems. This study also examined whether the performance of boys and girls differ in phonological awareness. The following research questions are framed: (1) Is there any relationships exist between phonological awareness and mathematics word problem solving performance? (2) Does gender difference exist when learners' performance in phonological awareness tasks are concerned?

Based on purposive sampling technique, 40 primary school learners from grade seven with a mean age of 12.5 years participated in this study. The two reasons underlying the sample selection are: firstly, the selected sample falls on Piaget's formal operational stage (age group 11 to 15) and secondly, the sample presumably possesses procedural and conceptual knowledge required for solving mathematical word problems. Though learners have difficulty in reading, writing and performing mathematics, no children in the sample has any kind of learning disabilities.

This study has chosen a quantitative approach and exploratory - descriptive research is the research design of the study. Three aspects of phonological analysis and one aspect of phonological synthesis are used to conceptualize the independent variable – phonological awareness. Phonological analysis aspect comprises of (Hecht et al., 2001) phoneme elision, phoneme segmentation, and sound categorization, whereas, blending phonemes into words is the phonological synthesis aspect. On the other hand, learner's performance in mathematics word problems on arithmetic and geometry are measured using Mayer's (1992) four cognitive phases: Problem Translation, Problem Integration, Solution Planning, and Solution Execution.

RESEARCH PROCEDURES:

A researcher design test was employed to assess learner's mathematical word problem solving performance. This test comprises of 20 multi step word problems from two areas of mathematics, namely, arithmetic and geometry. Sixth class CBSE mathematics curriculum is used for preparing the test items, which comprises of 10 multi step word problems each for arithmetic and geometry. Four cognitive phases advocated by Mayer (1992) are used for evaluating learner's performance in word problems. In this test, subjects are instructed to: write appropriate steps; to diagrammatically represent the information; decide appropriate computation; and execution of solution. Based on this criterion a four-point rating scale was prepared to assess the respondent's word problem solving performance and a final score was obtained for overall word problem solving performance. The value of the split-half reliability is 0 .71. The independent variable, phonological awareness is captured by administering tests on phoneme elision, phoneme segmentation, sound categorization, and phoneme blending. Each of these tests comprise of 18 items designed by the researcher. The number of correct responses is taken as the total score.

This quantitative study uses both descriptive and inferential statistics for data analysis, which has been done through SPSS version 25. As a first step, descriptive statistics such as mean and standard deviation were computed for both variables. To find out the relationship and significant difference between different measures taken, Pearson's coefficient of correlation and independent t-test were used.

RESULTS

Mean scores showed that boys displayed slightly better performance than girls in overall phonological awareness. This indicates that boys are slightly more aware than girls in focusing and manipulating individual sounds, when presented orally. Taking all the four aspects of phonological awareness, mean scores indicated that girls have slightly less ability to omit, recognize sound differences and to segment words into individual sounds as compared to boys. However, girls are better performers in phoneme blending, where the task demands the ability to combine or blend individual sounds to produce a word. Concerning the mean scores of learners' performance in word problems, it can be seen that that boys are greater performers than girls. This reveals that boys are good at problem translation, problem integration, and problem planning and problem execution and also in procedural-conceptual knowledge than girls.

Table 1: Descriptive statistics for variables

Measure	Gender	N	Min	Max	M	SD
Overall Phonological Awareness	**Boys**	20	11.500	16.500	14.825	1.244
	Girls	20	11.500	16.250	14.338	1.377
Phoneme Elision	**Boys**	20	12.000	17.000	15.700	1.689
	Girls	20	12.000	18.000	14.750	1.682
Phoneme Segmentation	**Boys**	20	10.000	16.000	13.700	2.029
	Girls	20	10.000	16.000	13.000	1.686
Phoneme Blending	**Boys**	20	13.000	18.000	15.700	1.455
	Girls	20	12.000	18.000	15.850	1.872
Sound Categorization	**Boys**	20	11.000	17.000	14.250	1.682
	Girls	20	9.000	17.000	13.750	2.221
Mathematics word problem solving performance	**Boys**	20	168.000	283.000	234.200	34.910
	Girls	20	92.000	270.000	209.500	50.094

Results from the following table 2 reveal a significant moderate positive correlation between learners' performance in phonological awareness tasks and mathematical word problems (r = .446, p < .01). Thus, null hypothesis has been rejected.

Table 2: **Correlation between overall phonological awareness and Mathematics Word Problem Solving Performance**

Correlations			
		Phonological Awareness	**Mathematical Word Problem Solving Performance**
Phonological Awareness	**Pearson Correlation**	1	.446**
	Sig. (2-tailed)		.004
	N	40	40

***< 0.01 level*

It can be observed from the following table 3, that there exists moderate significant positive correlations between phoneme elision, phoneme blending, sound categorization and mathematical word problem solving performance (r = .408, p < .01, r = .408, p < .01 and r = .394, p < .05). Thus, rejecting the null hypotheses. However, insignificant but positive correlation is reported between phoneme segmentation and word problem solving performance (r = .107, p > .01, .05). Thus, failed to reject null hypothesis.

The following table 4 results shows that the *p* – value is .247, which is greater than the chosen level of significance α = .05. This indicates that the mean scores between the two groups is not significant; hence, accepting the null hypothesis. It can be concluded that significant difference in the mean scores of boys (M = 14.825, SD = 1.244) and girls (M = 14.338, SD = 1.377) does not prevail in phonological awareness tasks. This suggests that gender is not an influencing factor in learners' performance in phonological awareness tasks.

DISCUSSION

The current study explored the correlation between phonological awareness and mathematics word problem solving performance. Consistent with the prediction, it was found that significant moderate positive relation exist between phonological awareness and mathematical word problem solving performance. This concords with previous studies, which reported correlation between phonological processing abilities and mathematic skills, which includes, computation skills, math fluency, and arithmetic word problems (Hecht et al., 2000; Vukovic and Lesaux, 2013; Tzoneva, 2015; Kuzmina et al., 2019). This reveals that the present sample possess the ability to recognize individual letters corresponding to its sound, which further assists the child to use the speech sounds in processing written language. To put it in another way, as the learners' performance in phonological awareness tasks increases, their performance in word problems also increases correspondingly.

Table 3: Relation between four aspects of phonological awareness and Mathematics Word Problem Solving Performance

Correlations						
		Phoneme Elision	**Phoneme Segmentation**	**Phoneme Blending**	**Sound Categorization**	**Mathematical word problem solving performance**
Phoneme Elision	**Pearson Correlation**	1	.409**	.367*	.294	.408**
	Sig. 2-tailed		.009	.020	.065	.009
	N	40	40	40	40	40
Phoneme Segmentation	**Pearson Correlation**	.409**	1	.307	.411**	.107
	Sig. 2-tailed	.009		.054	.008	.513
	N	40	40	40	40	40
Phoneme Blending	**Pearson Correlation**	.367*	.307	1	.450**	.408**
	Sig. 2-tailed	.020	.054		.004	.009
	N	40	40	40	40	40
Sound Categorization	**Pearson Correlation**	.294	.411**	.450**	1	.394*
	Sig. 2-tailed	.065	.008	.004		.012
	N	40	40	40	40	40
Mathematical word problem solving performance	**Pearson Correlation**	.408**	.107	.408**	.394*	1
	Sig. 2-tailed	.009	.513	.009	.012	
	N	40	40	40	40	40

As a broader category of phonological processing, phonological awareness "encompasses phonological working memory skills and lexical retrieval" (Elhassan et al., 2017, p. 1). It was discussed by (Hecht et al., 2000), that phonological awareness tasks and math computation skills substantially require working memory resources (p. 197). One model that can be used to "capture proficiency in working memory as it applies to word problem solving is "Baddeley's multicomponent model" (Swanson, 2004). It was evidenced from past studies that phonological awareness was associated with word reading efficiency (Knoop - van Campen et al., 2018), which further assists learners to read and comprehend word problems effectively. Thus, it can be argued that working memory components have a substantial role in recognizing and manipulating sound structures of words and also in mathematical word problem solving performance. Most importantly, the phonological awareness tasks demands simultaneous processing and storage of information, this also validates the involvement of working memory. Since, phonological awareness necessitates the "conscious manipulation of the phonological components of speech, it is considered as an explicit process" (Cockcroft and Alloway, 2012, p.13). In contrast, implicit processing of phonemes happens in the verbal components of the working memory in particular, as they "involve unconscious speech codes" (Gombert, 1992).

From the perspective of working memory model, verbal information is maintained in phonological loop with the help of two parts of this component, namely phonological store and an articulatory rehearsal system. In order to perform the phonological awareness tasks children must (Bradley & Bryant, 1985; McBride- Chang, Wagner, & Chang, 1997; Perfetti et al., 1987; Torgesen et al., 1990) "encode and maintain accurate representations of the phonemes in words in phonological memory" (as cited in Hecht et al., 2001, p. 196). For example, performing a phoneme blending task demands the child to produce words, where the learner has to first encode and store the individual sounds in the articulatory loop. In other words, efficient differentiation and blending of each of the individual sounds require accurate encoding of phonemes. Thus, it is the phonological short-term memory (phonological store) part of phonological loop stores verbal information temporarily; and the articulatory part rescues the decline of verbal information by mental repetition or subvocal rehearsal. This conveys the critical role played by phonological working memory in oral language comprehension. Thus, "identification, manipulation and segmentation of minimum units of speech" or "phonological awareness" is essential for reading, occurs in the phonological loop.

In this study word problems were given in written form, thus how phonological awareness aids learners word problem solving performance is questionable. In this context, the involvement of the second component of working memory, visualspatial sketchpad cannot be negated, though the learner has efficient phonemic fluency. Thus, not only phonological loop but the visual cache and the inner scribe parts of the visualspatial sketchpad are also involved in word problems. It was delineated by Baddeley (1986) that while reading, this component of working memory "visually encodes printed letters and words while maintaining a visuospatial frame of reference that allows the reader to backtrack and keep his or her place in the text" (as cited in Dehn, 2008, p. 19). It was pointed out by Kemps (1999) that though visualspatial sketchpad can function independently, the two stores of each of the two components of working memory are dependent on each other. However, the acquiescence of phonological information into visualspatial component happens through (Richardson, 1996a) "the deliberate process of recoding visuospatial information into verbal information, which occurs when the individual verbalizes the names of the objects and locations to be remembered" (as cited in Dehn, 2008, p. 21). Despite the efficiency of two components of working memory in information transformation, visual-to-verbal recoding does not happen among children until age 10. This is due to the limited capacity of the working memory to process and transform visual to verbal information.

As the age progresses, the capacity of working memory increases among typically developed children, hence they rely more on visual-to-verbal recoding. It can be argued that children having difficulty in speech-sound or oral language production and visual imagery may have impairments in phonological working memory and visualspatial sketchpad, respectively. However, the potential role of the domain-general core component of working memory, the central executive in storing, processing, managing and controlling the two domain-specific components and in long-term retrieval cannot be ignored. To sum up, the working memory model has an appreciable role in enhancing phonological awareness skills, which subsequently reflect on learners' word problem solving performance.

CONCLUSION

It is needful to affirm that the generalizability of the results to the broader population is limited by the small sample size of this study. Further, the findings are limited by evaluating only one of the aspects of phonological processing. Nevertheless, it provides necessary quantitative evidence to ascertain that impairment in the functioning of working memory resources affects phonological processing abilities, which further impose difficulty in word problem solving. Despite the fact that mathematical thinking is independent of language, children often needs language support when subjected to word problems, which demands reading and text comprehension. In conclusion, the current findings follow the general idea of association between phonological awareness and math skills. Thus, paramount importance to enhance phonological awareness skills among learners is to be provisioned at an early age. This can be done by applying appropriate phonemic awareness strategies, which includes training on precursor skills such as blending, segmenting, rhyming, visual cues and the like.

REFERENCES

Abedi, J., & Lord, C. (2001). The language factor in mathematics tests. *Applied Measurement in Education*, *14,* 219–234. Available at: https://doi.org/10.1207/S15324818AME1403_2

Adams, T. L. (2003). Reading mathematics: More than words can say. *The Reading Teacher, 56* (8), 786 – 795.

Adams, T. L., & Lowery, R. M. (2007). An anlaysis children's strategies for reading mathematics. *Reading & Writing Quarterly, 23,* 161 – 177. Available at: https://doi.org/10.1080/10573560601158479.

Alloway, T. P., Gathercole, S. E., Adams, A., Willis, C., Eaglen, R., & Lamont, E. (2005). Working memory and phonological awareness as predictors of progress towards early learning goals at school entry. *British Journal of Developmental Psychology, 23* (3), 417-426. doi:10.1348/026151005X26804

Baddeley, A. (1986). Working memory. New York, NY, US: Clarendon Press/Oxford University Press.

Baddeley, A. D. (2006). Working memory: An overview. In S.J. Pickering (Ed.), *Working memory and education* (pp. 1-31). Burlington, Ma: academic Press

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G.H. Bower (Ed.), *Recent advances in learning and motivation* (pp. 47–89). New York: Academic Press.

Berninger, V.W. (2000). Development of language by hand and its connections with language by ear, mouth, and eye. *Topics in Language Disorders*, *20*, 65–84. Available at: https://doi.org/10.1097/00011363-200020040-00007

Bjork, I. M., & Bowyer-Crane, C. (2013). Cognitive skills used to solve mathematical word problems and numerical operations: A study of 6- to 7-year-old children. *European Journal of Psychology of Education, 28* (4), 1345 - 1360. doi: 10.1007/s 10212-012-0169-7

Boonen, A. J. H., Koning, B., Jolles, J., & Schoot, M. (2016). Word Problem Solving in Contemporary Math Education: A Plea for Reading Comprehension Skills Training. *Frontiers in Psychology, 7,* 1-10. doi: 10.3389/fpsyg.2016.00191.

Bradley, L., & Bryant, P. (1985). *Rhyme & reason in reading & spelling*. Ann Arbor, MI: Univ. of Michigan Press.

Cockcroft, K., & Alloway, T. P. (2012). Phonological awareness and working memory: Comparisons between South African and British children. *Southern African Linguistics and Applied Language Studies, 30* (1), 13 – 24. doi: 10.2989/16073614.2012.693706.

Dehn, M. J. (2008).*Working Memory and Academic Learning: Assessment and Intervention.* Hobiken, New Jersey: John Wiley & Sons, Inc. Retrieved from www. ugcascru.org

Della Sala, S., Gray, C., Baddeley, A., Allamano, N., & Wilson, L. (1999). Pattern span: A tool for unwelding visuo-spatial memory. *Neuropsychologia, 37,* 1189-1199.

De Smedt, B.,Taylor, J., Archibald, L., & Ansari, D. (2010). How is phonological processing related to individual differences in children's arithmetic skills? *Developmental Science*, *13,* 508–520. https://doi.org/10.1111/j.1467-7687.2009.00897.

Duncan, G. J., Dowsett, C. J, Claessens, A., Magnuson, K., Huston, A. C., & Klebanov, P. et al. (2007). School readiness and later achievement. *Developmental Psychology*, *43*. Avaliable at: https://doi.org/10.1037/0012- 1649.43.6.1428

Elhassan, Z., Crewther, S. G., & Bavin, E. L. (2017). The contribution of phonological awareness to reading fluency and its individual sub-skills in readers aged 9- t0 -12 years. *Frontiers in Psychology, 8,* 1-11. doi: 10.3389/fpsyg.2017.00533.

Ellis, N. (1990). Reading, phonological skills and short-term memory: Interactive tributaries of development. *Journal of Research in Reading, 13* (2), 107-122. doi: 10.1111/j.1467-9817.1990.tb00328.x

Gathercole, S. E., & Pickering, S. J. (2000a). Assessemnt of working memory in six- and –seven year –old children. *Journal of Educational Psychology, 92* (2), 377-390.

Gathercole, S. E., & Pickering, S. J. (2000b). Working memory deficits in children with low achievement in the national curriculum at 7 years of age. *The British Journal of Educational Psychology, 70* (2), 177-194.

Gilliam, R. B., & vanKleck, A. (1996). Phonological awareness training and short-term working memory: Clinical implications. *Topics in language disorders*, *17*, 72-81. doi:10.1097/00011363-199611000-00008

Gombert, J. E. (1992). *Metalinguistic development*. London: Harvester-Wheatsheaf.

Hall, K. (2015). The effects of blending and segmenting decoding strategies on reading (Master Theses, Cardinal Stritch University). https://digitalcommons.stritch.edu/etd/216

Hecht, S. A., Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2001). The relations between phonological processing abilities and emerging individual differences in mathematical computation skills: A longitudinal study from second to fifth grades. *Journal of Experimental Child Psychology*, *79*, 192–227. Available at: https://doi. org/10.1006/jecp.2000.2586.

Jordan, J. -A., Wylie, J., & Mulhern, G. (2010). Phonological awareness and mathematical difficulty: A longitudinal perspective. *British Journal of Developmental Psychology, 28*, 89-107.
doi: 10.1348/026151010X485197.

Kemps, E. (1999).Effects of complexity on visuo-spatial working memory. *European Journal of Cognitive Psychology, 11*, 335-356.

Knoop van- Campen, C. A. N., Segers, E., &Verhoeve, L. (2018). How phonological awareness mediates the relation between working memory and word reading efficiency in children with dyslexia. *Dyslexia, 24* (5), 1 -14.
doi: 10.1002/dys.1583.

Koedel, C., & Tyhurst, E. (2012). Math skills and labor-market outcomes: Evidence from a resume-based field experiment. *Economics of Education Review, 31,* 131–140.

Koponen, T., Aro, T., Räsänen, P., & Ahonen, T. (2007). Language-based retrieval difficulties in arithmetic: A single case intervention study comparing two children with SLI. *Educational and Child Psychology, 24*(2), 98-107.

Kuzmina, Y., Ivanova, A., &Kaiky, D. (2019). The effect of phonological processing on mathematics performance in elementary school varies for boys and girls: Fixed-effects longitudinal analysis. *British Education Research journal, 45* (3), 640-660. Available at: https://doi.org/10.1002/berj.3518

Masoura, E. V. (2006). Establishing the link between working memory function and learning disabilities. *Learning disabilitiesds: A contemporary Journal, 4,* 29-41.

Mayer, R. E. (1992). *Thinking, problem solving, cognition*. WH Freeman/Times Books/Henry Holt & Co.

McBride-Chang, C., Wagner, R. K., & Chang, L. (1997).Growth modeling of phonological awareness. *Journal of Educational Psychology*, *89***,** 621–630.

Mendes, G. G., & Barrera, S. (2017). Phonological Processing and Reading and Writing Skills in Literacy. *Paidéia, 27*(68), 298-305. doi: 10.1590/1982-43272768201707.

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: Evidence from a longitudinal study. *Developmental Psychology*. *40*, 665–681. Available at: https://doi.org/10.1037/0012-1649.40.5.665.

Perfetti, C. A., Beck, I., Bell, L., & Hughes, C. (1987). Phonemic knowledge and learning to read are reciprocal: A longitudinal study of first grade children. *Merrill-Palmer Quarterly*, *33***,** 283–319.

Pickering, S. J., Gathercole, S. E., Hall, M., & Loyd, S. A. (2001). Development of memory for pattern and path: Further evidence for the fractionation of visuo-spatial memory. *Quarterly Journal of Experimental Psychology, 54*A, 397-420.

Rasmussen, C. L., & King, K. D. (2000). Locating starting points in differential equations: a realistic mathematics education approach. *International Journal of Mathematical Education in Science and Technology, 31* (2), 161-72.

Richardson, J. T. E. (1996a). Evolving concepts of working memory. In J. T. E. Richardson, R.W. Engle, L. Hasher, R. H. Logie, E. R. Stoltzfus, & R. T. Zacks (Eds.), *Working memory and human cognition* (pp. 120 – 154). New York: Oxford University Press.

Robinson-Riegler, G., & Robinson-Riegler, B. (2008).*Cognitive Psychology* (2nded). New Delhi, India: Dorling Kindersley

Robinson, C. S., Menchetti, B. M., &Torgesen, J. K. (2002). Toward a two-factor theory of one type of mathematics disabilities.*Learning Disabilities Research & Practice, 17* (2). doi:10.1111/1540-5826.00035

Schleppegrell, M. J. (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading & Writing Quarterly, 23,* 139 – 159. Available at:
https://dx.doi.org/10.1080/10573560601158461

Shanahan, T., MacArthur, C. A., Graham, S., & Fitzgerald, J. (2006). Relations among oral language, reading, and writing development.In *Handbook of writing research* (pp. 171 – 183). New York: Springer

Smith, E. E., & Kosslyn, S. M. (2008). *Cognitive Psychology:Mind and Brain*. New Delhi, India: Prentice-Hall of India

Solso, R. L. (2011). *Cognitive Psychology* (6th ed.). New Delhi, India: Dorling Kindersley

Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not a risk for serious math difficulties.*Journal of Educational Psychology, 96*, 471- 491. Available at:
http://dx.doi.org/10. 1037/0022-0663.96.3.471.

Szucs, D., Devine, A., Soltesz, F., Nobes, A., & Gabriel, F. (2014). Cognitive components of a mathematical processing network in 9-year-old children. *Developmental Science, 17* (4), 506-524. Available at:
https://doi.org/10.1111/desc.12144

Timmermans, R. E., Van Lieshout, E. D. C. M., &Verhoeven, L. (2007). Gender related effects of contemporary math instruction for low performers on problem-solving behavior. *Learning and Instruction, 17* (1), 42–54. doi: 10.1016/j.learninstruc.2006.11.005.

Torgesen, J. K., Wagner, R. K., Simmons, K., & Laughon, P. (1990). Identifying phonological coding problems in disabled readers: Naming, counting, or span measures. *Learning Disability, Quarterly*, *13***,** 236–243.

Tzoneva, I. (2015). *The Relations between Working Memory and Mathematics Achievement of Children in the Primary Grades.*(Doctoral dissertation, Simon Fraser University). Available at: https://pdfs.semanticscholar.org

Van Der Sluis, S., Van Der Leji, a., & De Jong, P. F. (2005). Working memory in Dutch children with reading-and arithmetic-related LD. *Journal of Leraning Disabilities, 38,* 207-221.

Vukovic, R. K., &Lesaux, N. K. (2013). The relationship between linguistic skills and arithmetic knowledge. *Learning and Individual Differences, 23,* 87 – 91. doi:10.1016/j.lindif.2012.10.007

Wagner, R. K., &Torgesen, J. K. (1987). The nature of phonological awareness and its causal role in the acquisition of reading skills.*Psychology Bulletin, 101,*192-212.

Zhang, J., Fan, X., Chenug, S. K., Meng, Y., Cai, Z., & Hu, B. Y. (2017). The role of early language abilities on math skills among Chinese children. *Plos One*, *12* (7), 1- 14.
https://doi.org/10.1371/journal.pone.0181074