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Predicting Working Memory (Visual-Spatial) Based on Selective Attention and Phonological Awareness in 8-12 Year Old Male Students with Dyslexia in 5th Discrete of Tehran, Iran

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Original Article

Abstract

Introduction: Working memory (WM) is a limited-capacity processing resource, which includes storing information when processing information. However, children with dyslexia have difficulty remembering this limited amount. Therefore, the purpose of this study is to predict WM based on selective attention and phonological awareness of elementary school children with dyslexia.

Materials and Methods: This study was a correlational study in which the samples consisted of 203 male students aged 8-12 years studying at schools in the fifth district of Tehran Metropolitan, Iran, who were selected using multi-stage random sampling method. Dyslexia checklist, Andre Rey's Spatial Visual Memory Test, Stroop test, and Phonological Awareness Survey were applied to collect information. In addition to descriptive statistical methods, simultaneous multiple regression analysis method was used.

Results: The results showed that 36.5% of the variance of WM in the selective attention test can be explained, with the highest mean related to the cognitive control level. Moreover, 35.5% of the variance of visual WM can be explained in the phonological awareness test, with the highest average associated with the final phoneme removal.

Conclusion: Selective attention and phonological awareness seem to play a significant role in predicting visual-spatial WM in boys with dyslexia.

Key words: Working memory (visual-spatial); Selective attention; Phonological awareness; Dyslexia

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Introduction

Specific learning disorder (SLD) is a neurodevelopmental disorder with a biological origin and is based on cognitive disorders. Behavioral symptoms of this disorder begin in childhood (1). In most cases, the onset of learning disabilities is identified between pre-primary and second grade (2). The onset of learning disabilities before the first grade often indicates a developmental delay in language, a delay in learning new concepts at home, or a delay in performance compared to peers, and starting early in school is more often characterized by low grades and poor learning. Learning disabilities often improve with treatment, but in difficult cases, they continue less severely into adulthood (3).

One type of SLD is dyslexia with an incidence of between 5 and 10% in the population and 66% of this population are children with dyslexia. Research has shown that children with special learning disabilities have extensive problems with working memory (WM). Impaired WM can be one of the causes of poor reading and writing skills. WM is a limited-capacity processing resource that stores and processes information, but children with dyslexia also have difficulty memorizing the same limited amount of the WM capacity. These children experience WM deficits and are weaker in performing WM tasks (3,4). In general, WM is the basis of thinking and learning, allowing the organism to expand representations of a given stimulus for a short time after the stimulus has been presented and then use that stored representation (5). This model is responsible for short-term storage of visual and spatial

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information such as objects and places (6).

One of the factors explaining the underlying mechanism of WM is selective attention, which indicates the ability to regulate thoughts, emotions, and responses, especially in situations of conflict and interference (7). Individuals with high WM capacity have more selective attention than those with lower WM capacity. This is especially important in the context of the entry of irrelevant information and leads to the successful performance of the individual in reasoning situations (8).

Phonological awareness includes knowing the structure of the words spoken regardless of their semantic and syntactic role; So that the child knows that the words are made up of smaller parts such as syllables or phonemes. This awareness includes three levels of awareness of syllables, intra-syllable structures, and phoneme (9). Reading has two main elements of decoding and comprehension (10). Decoding is the mechanical aspect of converting printed letters into spoken language or spoken equivalents (11). It seems that reading skills and phonology awareness are interrelated and are influenced by each other, and children cannot cope with some tasks that measure phonology awareness before learning reading (12). Inability to read has very serious consequences on educational achievement, employment, and success in life (13), level of anxiety (14,15), level of educational motivation, self-esteem and well-being, being bullied by classmates, being neglected by the teacher (most likely), continuous failure and the resulting despair, and feelings of shame and humiliation (16). Over time, these feelings deepen, so that older children feel angry or depressed and show low self-esteem (14,15).

Therefore, WM can have a negative impact on several aspects of the life of children with dyslexia and lead to psychological, educational, and occupational problems in the future. The aim of this study was to predict (visual-spatial) WM based on selective attention and phonological awareness in male children with dyslexia aged 8 to 12 years.

Materials and Methods

The statistical population of the study included all male elementary school students in District 5 of Tehran, Iran in the academic year 2019-2019. The sample size was estimated as 203 people based on Cochran method in quantitative studies. In order to select the desired sample from among the students of schools in District 5 of Tehran, a multi-stage cluster random method was applied; First, three schools were randomly selected from all boys' schools in District 5, and in the next step, about 70 subjects were randomly selected from each school. The study inclusion criteria were age between 8 and 12 years, no medication, no seizures, no head trauma, and six months from the onset of the disorder. Presence of attention deficit hyperactivity disorder (ADHD), mental retardation, late learning, autism, existence of any kind of problem including neurological diseases, or neural lesions and presence of vision and hearing problems were also considered as the exclusion criteria.

The tools used to collect the data are detailed below.

Diagnostic reading test: In order to evaluate reading disorder, a reading diagnostic test was used. This test was introduced by Sima-Shirazi T, Nili-Pour. This test was performed on 605 first grade male and female students who were randomly selected from different parts of Tehran. In addition to determining the percentages, means, and standard deviation (SD) of reading accuracy and speed, Pearson and Mann-Whitney correlation coefficient were also used. The validity of the test was confirmed through equivalence forms (90%) and its validity through content validity. A high correlation coefficient of reading accuracy between its two texts (0.87) and a very high correlation coefficient of reading speed were obtained in these two texts (0.94). This test, which has a supplementary section consisting of subtests of spelling, phoneme-character correspondence, reading irregular words, reading non-words, and reading handwriting, can be used in the diagnosis of dyslexia and reading-related injuries. In the implementation method, after diagnostic evaluation and review of the child's history, the three texts were scored in terms of speed, accuracy, and comprehension using the answer booklet. Percentage of error (substitution, refusal, deletion, incorrect pronunciation, etc.) and percentage of correct answers were recorded and based on the table, a raw score was obtained (18).

Rey Complex Figure Test (RCFT) (Visual-Spatial WM): This test was used to determine the visual-spatial WM. This test was invented in 1942 to measure the type of the perceptual activity of visual-spatial WM of patients referred to psychology and psychiatric clinics. The test is performed twice after selecting each card. In the first time, a card (A) or (B) is placed in the appropriate direction in front of the subject and he/she is asked to draw a similar one on a blank white paper. In the second time, while the card has been taken away from the subject and three minutes have passed, he/she is asked to draw the previously observed image carefully by heart. The validity of this test is 77% in the copy stage and 51% in the recall stage and its validity is 62.4%, with the retest validity as 62% (19).

Phonological awareness test: In order to determine the level of phonological awareness, the phonological awareness test was employed. This test was introduced in 2017 by Jalalian Chaleshtory and Zarifian. In this test, the items were selected based on the position in the words, the syllable structure type, the placement of the phoneme within the consonant cluster, the phonological class, and the imagery. In this test, the desired image is presented to the child and named by the examiner. The child is then asked to rename the image and then delete the phoneme the examiner presents to him/her, and then say the remaining phoneme chain. Correct and incorrect answers are given a score of 1 and 0, respectively. The content validity index for each of the initial, middle, and final phoneme removal subtests were 0.89, 0.86, and 0.93, respectively, and the Cronbach's alpha coefficient for each of these subtests was obtained as respectively 0.92, 0.89, and 0.78. In addition, the Pearson correlation coefficient of test-retest comparison for the initial, middle, and final phoneme removal subtest was calculated to be 0.98, 0.94, and 0.91, respectively (20).

Stroop test: To determine the level of selective attention, the Stroop Color and Word Test (SCWT) was used. This test was first designed in 1953 by Ridley Stroop to measure selective attention and cognitive flexibility. The test consists of two stages. The first stage is to name the color and the subject is asked to specify the color of the desired shape in a color set (specify the color of the circle that is displayed alternately in four colors red, blue, yellow, and green on the monitor screen). The purpose of this step is only to practice and recognize the colors and the location of the keys on the keyboard and has no effect on the final result. The main Stroop test is performed in the second step. At this stage, 48 congruent color words and 48 incongruent color words with red, blue, yellow, and green colors are displayed to the subject. Congruent words are words that have the same color as the meaning of the word; For example, the word blue, which is indicated by blue. Incongruent words are those whose color is different from its meaning; For example, the word green, which is indicated by red, blue, or yellow.

In total, 96 congruent and incongruent color words are displayed randomly and sequentially. The subject is supposed to determine only the apparent color of the words, regardless of their meaning. The time each stimulus is presented on the screen is 2 seconds and the interval between the presentation of the two stimuli is 800 thousandths of a second. Researchers believe that the color-word task (the second stage of the experiment) measures mental flexibility, interference, and response inhibition. The response inhibition score and the degree of interference are obtained by subtracting the score of the correct incongruent number from the score of the correct congruent number. Ghadiri et al. reported the retest reliability of all three attempts of this test as 0.60, 0.83, and 0.97, respectively (21).

First, descriptive data of the study variables were presented and then the obtained data were analyzed in line with the study hypotheses and using statistical models. The criterion variable included visual-spatial WM and the predictor variable included selective attention and phonological awareness. The Kolmogorov-Smirnov (KS) test was used to evaluate the normality of data distribution. Descriptive statistics included mean and standard deviation (SD) and inferential statistics tests included multiple regression analysis with simultaneous method, which was analyzed in SPSS software (version 20, IBM Corporation, Armonk, NY, USA).

Results

The characteristics of the study samples in terms of visual-spatial WM level, selective attention, and phonological awareness are presented in table 1.

Table 1. Mean score of subjects in the components of visual-spatial working memory (WM), selective attention, and phonological awareness

Variable	Statistical indicators	Mean ± SD	Skewness	Kurtosis
Visual-spatial WM				
	Copy	15.30 ±6.14	-0.48	-0.19
	Reproducibility	34.38 ±5.70	-0.50	-0.16
Selective attention				
	Cognitive processing speed	3.01 ±1.99	0.31	-0.40
	Attention capacity	7.94 ±5.59	0.24	-1.37
Phonological awareness				
	Cognitive control level	19.25 ±4.90	0.01	-1.63
	Homogeneity recognition	17.88 ±2.74	-0.04	-1.63
	Rhyme recognition	10.84 ±3.22	0.24	-1.37
	Phonological composition	11.68 ±3.22	0.10	-1.67
	Phonological segmentation	29.10 ±4.55	0.98	-0.07
	Final phoneme recognition	42.94 ±82.40	0.33	-0.95
	Middle phoneme deletion	22.97 ±3.10	0.47	-0.16
	Initial phoneme deletion	12.81 ±13.90	0.43	-0.19
	Syllable recognition	21.33 ±4.25	0.15	-1.59

SD: Standard deviation; WM: Working memory

Table 2. Summary of regression model, analysis of variance (ANOVA), and statistical characteristics of visual-spatial working memory (WM) regression given selective attention

Variable	Model index	Sum of squares	Mean squares	F statistic	P	Correlation coefficient	Coefficient of determination
Selective attention	Regression	14240.67	2373.44	18.86	≤ 0.001	0.60	0.36
	Residue	24783.44	1250.80				
	Total	39023.68					

The results of table 1 suggested that given the skewness and kurtosis, the data follows a normal distribution. To examine the univariate normality, a general criterion recommends that if the skewness and kurtosis are not in the range of 3 to -3, the data will not have a normal distribution (Kuliken). Accordingly, the skewness and kurtosis index of any of the indicators was not outside the range of 3 to -3. Therefore, they can be considered normal or close to normal.

Based on the information presented in table 2, the multiple correlation coefficient between the study variables was R = 0.604 and R_2 = 0.365. In other words, 36.5% of the variance of WM could be explained based on the linear combination of the variables of cognitive processing speed, attention capacity, and level of cognitive control in the Stroop test. In this model, the analysis of variance (ANOVA) test, considering the values of F = 18.886 and P = 0.001, confirmed the efficiency of the model used in predicting the dependent variable and there was a significant relationship between the linear combination of the predictor variables entered in the model with visual-spatial WM.

In table 3, based on the values of β (standard regression coefficients), the rate of change in the criterion variable (visual-spatial WM) per unit of change in the predictor variable (selective attention and phonological awareness) is presented for each of the variables.

The tolerance coefficient values are in the range of 0 to 1 (22) and here, for cognitive processing speed, attention capacity, and cognitive control level 72, 63, and 70, respectively. Considering the values of t and its significance levels, it can be concluded that cognitive processing speed, attention capacity, and cognitive control level had a significant contribution in predicting visual-spatial WM.

Based on the data presented in table 4, the multiple correlation coefficient between the studied variables was R = 0.596 and R_2 = 0.355. In other words, 35.5% of the variance of visual-spatial WM could be explained based on the linear combination of variables of syllable recognition, homogeneity recognition, rhyme recognition, phonological composition, recognition of words with initial phoneme, recognition of words with final phoneme, phonological segmentation, naming and deleting the final phoneme, deleting the middle phoneme, and deleting the initial phoneme. In this model, the ANOVA test, considering the values of F = 21.820 and P = 0.001, confirmed the efficiency of the model used in predicting the dependent variable and it can be claimed that a significant relationship was observed between the linear combination of predictor variables entered in the model with visual-spatial WM.

In table 5, based on the β values, standard regression coefficients, the rate of change in the criterion variable (spatial visual WM) per unit change in the predictor variable for each of the variables is presented. Given the t values and its significance levels, it can be concluded that the components of syllable recognition, homogeneity recognition, rhyme recognition, phonological composition, recognition of words with initial phoneme, recognition of words with final phoneme, phonological segmentation, naming and deleting the final phoneme, deleting the middle phoneme, and deleting the initial phoneme predict the visual-spatial memory. Accordingly, it can be declared that standard regression coefficients have a significant contribution in predicting visual-spatial WM.

Discussion

The aim of this study was to predict (visual-spatial) WM based on selective attention and phonological awareness in male students with dyslexia aged 8 to 12 years.

Table 3. Regression of visual-spatial working memory (WM) based on selective attention variables

	B (non-standard coefficients)	B (standard coefficients) beta	T statistic	P	Tolerance coefficient	VIF
Y-Intercept	193.08		13.94	≤ 0.001		
Cognitive processing speed	1.03	0.44	4.60	≤ 0.001	0.72	1.37
Attention capacity	0.44	0.22	2.18	0.020	0.63	1.57
Cognitive control level	0.56	0.12	1.31	0.050	0.70	1.42

VIF: Variance inflation factor

Table 4. Summary of regression model, analysis of variance (ANOVA), and statistical characteristics of visual-spatial working memory (WM) regression due to phonological awareness

Variable	Model index	Sum of squares	Degree of freedom	Mean squares	F statistic	P	R	R^2
Phonological awareness	Regression	13863.32	5	2772.66	21.82	0.010	0.59	0.35
	Residue	25160.36	198	127.07				
	Total	39023.86	203					

The results showed that 35.5% of the variance of visual-spatial WM can be explained based on linear composition in syllable recognition, homogeneity recognition, rhyme recognition, phonological composition, recognition of words with initial phoneme, recognition of words with final phoneme, phoneme segmentation, naming and deletion of final phoneme, deletion of middle phoneme, and deletion of initial phoneme.

Learners' attention to the subject of the lesson is one of the main factors in teaching and learning (22). Bandura emphasizes that the initial stage of any learning begins with attention, and if attention is not sufficient, the individual's learning is impaired (23).

Attention is one of the most important high level functions of the mind and alone is one of the main aspects of cognitive structure that also plays an important role in the structure of intelligence, memory, and perception (14). Deficiencies in attention retention take away the opportunity to process, store, and retrieve information (24). Based on the results of the present study, the WM variance of 36.5% could be explained based on the linear combination of variables cognitive processing speed, attention capacity, and cognitive control level in the selective attention test, which was consistent with the results of previous studies (11,25). Phonological awareness had a prediction with reading skills in children and the task of removing phonemes also had the greatest impact on children (26).

The findings of the present study suggested that the variance of visual-spatial WM based on linear composition in syllable recognition, homogeneity recognition, phonological composition, recognition of words with initial phoneme, recognition of words with final phoneme, phonological segmentation, naming and deleting final phoneme, middle phoneme deletion, and deletion of the initial phoneme could be explained by 35.5%.

Limitations

Children with dyslexia have deficiencies in the visual and auditory memory sequences [such as Marad instead of Madar (mother) in Persian] and auditory memory (word Malal instead of Maral) that were not examined in the present study. Additionally, the effect of some factors of general intelligence and socio-economic status of the family on the study results was not controlled; While given the existing research, these factors, as confounding factors, can affect the WM (visual-spatial), selective attention, and phonological awareness of the child (8). Among the limitations of the present study was its limitation to the student population and samples of 8 to 12 years old, which can affect the generalizability of the findings.

Recommendations

In future studies, it is suggested that auditory memory and the visual-auditory memory sequence be examined, and that future researchers examine other components of executive functions, including planning, organization, and time sensitivity, and control the effect of these confounding variables.

Table 5. Regression of visual-spatial working memory (WM) based on components of phonological awareness

	B (non-standard coefficients)	B (standard coefficients) beta	T statistic	P	Tolerance coefficient	VIF
Y-Intercept	92.98		10.71	≤ 0.001		
Phoneme recognition	1.03	0.31	2.68	0.090	0.47	2.09
Homogeneity recognition	0.78	0.15	1.29	0.190	0.46	2.13
Rhyme recognition	-1.19	-0.27	-3.29	0.020	0.91	1.09
Phoneme composition	-0.12	-0.30	-0.33	0.400	0.84	1.18
Recognition of words with initial phoneme	0.45	0.15	1.13	0.190	0.38	2.60
Recognition of words with final phoneme	2.50	0.36	2.39	0.090	0.29	3.40
Phoneme segmentation	-0.93	-0.37	-3.32	0.010	0.52	1.92
Naming and deletion of final phoneme	-0.49	-0.17	-1.37	0.170	0.42	2.37
Naming and deletion of middle phoneme	0.49	0.25	1.39	0.080	0.47	2.14
Naming and deletion of initial phoneme	-0.12	-0.05	-0.43	0.340	0.82	1.12

VIF: Variance inflation factor

The officials and those involved in education and health system, with long-term planning, should try to identify students with learning disabilities and provide appropriate programs to strengthen and improve children's performance in the field of memory (visual-spatial), attention, and phonological awareness at the school level.

Conclusion

The results of the present study are consistent with the findings of previous studies in Iran in the selective attention subscale (10) and other countries in the selective attention and cognitive awareness subscales (11,25,27-29).

The findings of the present study were not consistent with the results of some previous studies that examined the role of phonological awareness in the treatment of dyslexia in primary school students (30). These studies concluded that phonological awareness education is not necessary as part of the treatment of children with dyslexia and phonological awareness deficits, but a visual reading technique after the initial reading stage can compensate for the phonological awareness deficits in these children (30). This inequality can be explained by geographical location or intelligence, which can affect the results. Phonological representation in people with dyslexia is said to be healthy and flawless, but access to it is impaired. Some studies have reported that based on neurological evidence, phonological representation takes place in people with dyslexia similar to normal individuals (28), but is less available in higher-level phonological processes (31).

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Authors' Contribution

Marjan Sadat Momeni: study design and ideation, providing study equipment and samples, data collection, analysis and interpretation of results, manuscript preparation, specialized evaluation of manuscript in terms of scientific concepts, approval of the final manuscript to send to the journal office, responsibility for maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Majid Zargham-Hajebi: attracting financial resources for the study, study support, executive, and scientific services, specialized statistical services, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to send to the journal office, responsibility for maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Nader Monirpoor: study support, executive, and scientific services, providing study equipment and samples, specialized statistics services, manuscript preparation, specialized evaluation of manuscripts in terms of scientific concepts, approval of the final manuscript to send to the journal office, responsibility for maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments.

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Conflict of Interest

The authors do not have a conflict of interest. Dr. Majid Hajebi was an Assistant Professor in the Department of Psychology, Qom Branch, Islamic Azad University and the dissertation supervisor, and Dr. Nader Monirpour was an Assistant Professor, Department of Psychology, Qom Branch, Islamic Azad University and the dissertation consultant. Marjan Sadat Momeni has been a PhD student at the Qom Branch, Islamic Azad University since 2016.

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