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Mathematics Performance of the Primary School Students: Attention and Shifting

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Abstract

The purpose of this study was to understand the relationship between executive functions and mathematical abilities to determine the contribution of these functions to math performance. In this study, 30 students were selected from among 4th graders of elementary school, in two groups with low achievement in mathematics (poor) and high achievement in mathematics (strong), such that their IQ and reading ability were as close as possible. These groups were measured and compared in terms of attention by means of continuous performance test and shifting by means of Wisconsin Card Sorting Test. The ANOVA and t-test showed that the low-achieving group stood significantly lower than the high-achieving group in shifting, which mirrors the effect of this function in math performance of the students. However, there was no significant difference between the two groups in terms of attention.

Keywords: executive function, attention, shifting, math performance

1. Introduction

Mathematics is a branch of human knowledge which has received a lot of attention in recent years. Power has been currently gained on the basis of technology, which heavily rests on mathematics. Problems in learning mathematics appear at a very early stage in children, but mostly in elementary school, and then continue up to high school (Gersten, Jordan, & Flojo, 2005). Math disability has been addressed by many researchers from various aspects. Many have attributed math disability to information processing inefficiency, yet others have attempted to draw a dividing line between such educational progress problems and cognition (Geary, Brown, & Samaranayake, 1991). Moreover, Corno & Mandinach (1983) have reported cognitive involvement as an effective cognitive factor in educational progress. Low cognitive involvement is defined with surface processing strategies (such as mental reviewing) and high cognitive involvement with deep processing strategies (such as organizing). Accordingly, some researchers have studied the influence of effective factors on educational performance and have shown that educational performance is influenced by executive functions (Best, Miller, & Naglieri, 2011).

Roberts & Pennington (1996) have regarded executive functions as a set of related functions with independent abilities including programming, preservation, impulse control, working memory, and attention control, whose components such as complex information processing, organization ability, and inclination towards the goal should be studied. This study is an attempt to determine the proportion of executive functions in math performance. Attention is the first executive functions, which is the focus of this study. Seidman (2006) considers attention as a complex mental operation which involves focusing on or engaging in a goal, holding or tolerating something or being vigilant for a long time, encoding the properties of a stimulus, and shifting focus. Determining the components of attention is problematic in many ways. Firstly attention is usually measured with regard to some form of activity, which makes it difficult to be measured. In addition, various parts of the brain affect attention processing (Mirsky, 1996). Nonetheless, theories take the following as the components of attention: impulse regulation, selective attention, sustained attention, attention span, divided attention, inhabitation, and behavior control (Seidman, 2006; Valera & Seidman, 2006; Barkley, 1997).

Presto, Heaton, McCann, Watson, & Selke (2009) found that lack of attention control can justify a considerable portion of the problems in all walks of education; therefore, attention control strategies are good predictors of performance in educational tests. Bull & Scerif (2001) maintain that children's ability in attention.executive functions in pre-school period can predict their ability in reading comprehension and math in the coming years. It has also been shown that executive function disorder can persist even in older ages causing problem in carrying out schools tasks or daily life activities; therefore, timely diagnosis and intervention is imperative (Valera & Seidman, 2006; McCloskey, Perkins, & Van Divner, 2008). On the other hand, Lan et al. (2011) studied Chinese and American children and reported that attention control equally predicts all aspects of achievement, yet it is the strongest predictor of reading comprehension performance in students.

The second executive function discussed in this paper is shifting, which is free shifting from one state or activity or part of a problem into another (Jivia, 2001, cited in Cox, 2004). Disability in carrying out this function leads to stability of the initial state. It is assumed that shifting ability is involved in math performance by alternate support of calculation strategies (such as addition, subtraction, and multiplication) or math sub-solutions in multi-level problems; children with math disabilities have shown weaker shifting abilities particularly in terms of measurements which arise from complex shifting tasks (Bull, Johnston, & Roy, 1999; Mclean, & Hitch, 1999). In another study, Bull & Scerif (2001) studied a group of children by math tests and showed that math ability significantly correlates with performance in inhabitation, shifting, and working memory, yet it does not have a significant relationship with reading comprehension and IQ. However, the study conducted by Bull, Johnston, & Roy (1999) in order to measure the central executive functions by Wisconsin test revealed that the low-achievement group was significantly different in math performance from the control group in terms of the number of preservation and non-preservation errors even when IQ and reading comprehension were controlled. The results of the partial correlation indicated that there is a negative correlation between retrieving math realities and error preservation in Wisconsin test.

In their study of 9-12-year old children, Van der Sluis, de Joung, & Van der Leij (2007) reported that shifting is concerned with nonverbal reasoning and reading comprehension, and contrary to aforesaid study they found no correlation between shifting and math. They maintained that the relationship reported between shifting and math in the previous studies might have arisen from non-executive needs such as reading speed as a non-executive factor, which accounts for a large variance in cognitive abilities. Given the contradictory findings, further research is required which accounts for effective factors on math performance. In this study, we controlled non-executive variables of IQ and reading comprehension. Although there might be other non-executive variables influencing our study, we attempted to minimize the effect by random selection of the sample. The present study has selected two groups of high-achieving and low-achieving students in mathematics. Having controlled intelligence and reading comprehension, the study tried to find out what role working memory and inhabitation serve in math performance of the students so that priorities for better correction of students could be proposed.

2. Method

2.1 Participants

Thirty children aged 10 in grade 4 (Mean=10.33, SD=2.85) were recruited from elementary schools located in different suburbs in the city of Yazd (sixteenth largest city in Iran; population: 1.07 million). This study is a casual-comparative one. It aims at determining math performance of students (dependent variable) based on executive functions (independent variable). The study is designed in such a way which could be categorized as a causal-comparative one: among the three necessary conditions for a causal relationship, there are two statistical relationship conditions (comparison groups) and competing hypotheses (variable control) can be removed. However, the causal relationship cannot be studied here since random assignment of students to the groups was not possible as low-achievement in math could not be manipulated. The study underwent the following steps: Based on the literature, the characteristics of low-achieving students were determined, which included executive functions and non-executive functions. The teachers were asked to present a list of low-achieving and high-achieving students in their math classes (25 participants). The students were given a math test to ensure they belonged to the lower or proper group. Both low-achieving group (step 2) and high-achieving group (step 3) were asked to take an intelligence and a reading comprehension test. This was carried out in order to have homogeneous groups in terms of non-executive functions so the executive functions could be meticulously studied. The participants not achieving within the proper limit of intelligence and reading comprehension variables were excluded from the groups. The participants included in the study were asked to take executive functions tests, which were administered in a number of sessions. Overall, those achieving below 85 in the intelligence test and whose age did not match their grade were excluded from the study. Thus, the IQ score required was between the standard of 85-115. The participants were finally divided into “high-achieving” and “low-achieving” groups as follows: (1) The high-achieving group composed of 15 participants with an IQ score of above 110 and an average reading comprehension ability (30-70%).(2) The low-achieving group composed of 15 participants with an IQ score of below 90 and an average reading comprehension ability (30-70%).

2.2 Procedure

The tests were performed in 50 days in a quiet school room. Each test was administered to each individual participant. Each session lasted almost 1 hour, including the break time. The following tests were administered: Math Test; Wechsler Intelligence Scale for Children including verbal and picture completion subtests; and reading words, non-words, and chains of words. Executive functions tests were performed in the final sessions. To avoid the interference of the sequence of the tests, the order of the tests was changed for each participant.

3. Measures

3.1 Iran Key-Math Test

The Key-math test was developed by Connolly in 1988. It is extensively used to identify students with math disabilities (Connolly, 1988). The content areas of the test include Basic Concepts, Operations, and Applications. In addition to the difficulty of the test, correlation of each item with the whole test, and correlation of each item with the subtest, the content, discriminant, predictive, and concurrent validities were obtained. The validity of the test has been reported in Cronbach's alpha in 5 grades between 0.80 and 0.84. The raw score of the whole test (sum of all the subtests) is converted to a standard average score of 100 and standard deviation of 15. The standard scores are presented based on age (the average performance at a particular age) or class (class or classes across the country or province whose raw scores have been used to standardize the score). Age was used in this study.

3.2 Reading Comprehension

Karami Nouri, and Moradi’s reading comprehension test (2008), which is developed for measuring reading comprehension ability of male and female normal elementary school students, was used for the purpose of the study. The score of each subtest is obtained by the number of correct answers. The subtests include reading words, non-words, and chains of words. It is important to rely on a reliable element so that the test measures not only the child’s reading level but also his.her progress. The simplest and most comprehensive of these reading tests is word list. In addition to Persian students, the score of this test is normalized for bilingual students in cities of Tabriz and Sanandaj, Iran. The overall Cronbach's alpha for the whole test is 0.82 (Karami Nouri, & Moradi, 2005).

3.3 Wechsler Intelligence Scale for Children

This test was developed by Wechsler in 1949 and was revised in 1974 and after it was normalized was called Wechsler Intelligence Scale for Children (wisc-r). Shahim (1995) has normalized the test in Iran. The test-retest reliability of the test is reported to be 0.44-0.94. The present research used a binary form and picture completion since they can be used to measure verbal and non-verbal skills. Moreover, they are more useful than other binary forms which highly correlate with IQ (such as words or cubes). With a reliability of 0.87these tests have priority over other binary forms (for they use parallel forms).

3.4 Continuous Performance Test

This test is used to measure attention and was developed by McCorth for measuring the precision and speed of performance (McCorth & Taylor, 1963, cited in Epstein et al., 2003). The test is used to assess the errors in selective attention and impulse and requires sustained attention during the test and inhabitation of impulsive answers. Researchers believe that responding to a stimulus other than that the one in focus (commission error) shows impulsivity, and ignoring the main stimulus (omission error) shows lack of attention. This study used the paper and pencil format of the continuous performance test. The test-retest of the test is reported to be 0.80 for the correct answers and 0.58 for the omission error by Aminzadeh (2009).

3.5 Wisconsin Card Sorting Test

This test was first used by Grant & Berg (1948) to measure abstract reasoning, concept formation, and response strategies to changing. The test was used in the present study to measure shifting. Researchers hold that this test is the best predictor among the various strategies for shifting ability (Miyake et al., 2000). The number of correct items and error preservation were measured by this test in our study. Aminzadeh’s study (2009) showed the test-retest reliability of the test to be 0.51 for the correct items and 0.72 for the error preservation.

3.6 Data Analysis

Statistical analyses were carried out using SPSS v21 (IBM Corp, 2012). One sample t-test was used for only the weaker group and ANOVA was used for comparing the groups. Covariance was used to statistically control intelligence and reading comprehension.

4. Result

It should be noted that continuous performance test was used to measure attention. This test was administered to two groups of male and female low-achieving and high-achieving students in the 4th grade of elementary school. The results for the two groups were compared in Table 1 based on three score in the continuous performance test: attention, omission error, and commission error.

Table 1. Mean and standard deviation based on the group and gender

Group	Gender	Attention		Omission error		N
		M	SD	M	SD	
Strong	Male	13.39	39.14	50.2	69.1	8
	Female	14.49	44.11	57.1	15.2	7
Weak	Male	92.38	74.7	57.3	26.3	7
	Female	40. 05	38.11	38.4	42.3	8
Overall	Male	73.38	37.11	00.3	51.2	15
	Female	44. 53	86.11	07.3	15.3	15

Table 2. Summary of statistics and univariate analysis for homogeneous groups of variables

Items	Weak group =15n		Strong group =15n			One sample t-test		
	SD	Mean	SD	Mean		F	P	η
Working memory	66.1	93.7	28.1	73.12	Uncontrolled	73.0	001.0	20.78
					Controlled	59.0	001.0	29.35
Facilitation score	83.1	33.2	34.1	33.1	Uncontrolled	09.0	10.0	89.2
					Controlled	04.0	29.0	12.1
Interference score	10.13	00.33	10.9	13.27	Uncontrolled	06.0	16.0	02.2
					Controlled	07.0	18.0	88.1
Number of correct answers- Continuous Performance	57.9	47.39	65.13	80.43	Uncontrolled	03.0	32.0	01.1
					Controlled	00.0	98.0	00.0
Remove error	25.3	00.4	90.1	07.2	Uncontrolled	12.0	06.0	94.3
					Controlled	11.0	09.0	96.2

4.1 Attention

Given the results of Table 2, One-way analysis of variance (ANOVA) was used to study the difference between the two groups in terms of attention so that the results could be compared with those of the covariance analysis. The results of the Levene test showed that the variances were homogeneous (p=0.12, $F_{(1,28)}$= 2.57). The ANOVA test showed that when the poor and strong groups were compared without controlling attention, there was no significant difference between the strong (m=43.80) and poor (M=39.47) groups (p=0.32, $F_{(1,28)}$=1.01). Analysis of covariance was carried out while controlling IQ and the one-way analysis of variance for the continuous performance test showed that when IQ is taken as the control variable, there is no significant difference between the two groups (p=0.78, $F_{(1,27)}$=0.08); when reading comprehension was also controlled (words, non-words, and chains of words), there was no significant relationship between the two groups (p=0.98, $F_{(1,24)}$=0.00).

When the groups were compared for omission error, the ANOVA showed that there was no significant difference between the strong (M=2.07) and weak (M=4.00) groups in (p=0.06, $F_{(1,28)}$=3.94). When IQ was regarded as the control variable, there was still no difference between the groups (p=0.22, $F_{(1,27)}$=1.59(; when reading comprehension was also controlled (words, non-words, and chains of words), there was no significant relationship between the two groups regarding the mean of omission error (p=0.09, $F_{(1,24)}$=2.96). The strong group did not receive any scores for the error commission as they committed no errors; therefore, the t-test was just carried out for the weak group (table 2).

Table 3. Mean and mean of standard error of error commission for the weak group

Group	*N*	*M*	*SD*	*Mean of standard error*
weak commission error	15	13.0	52.0	13.0

Table 4. T-test results

Variable	*T*	*df*	*Sig*	*Mean difference*	*Confidence level of 95%*	
					upper	lower
commission error	1.00	14	33.0	13.0	0.42	-0.15

As presented in Table 3&4, with 14 degrees of freedom, the value of t is 1 and its significance is 0.33, which is larger than 0.05. Thus, it is concluded that there is no significant difference between the strong and poor groups in terms of error commission in the continuous performance test and both groups performed equally well. Moreover, the mean error score for the weak group (M=0.13) was compared to the strong group, which committed no error; the results show that there was no significant difference between the groups.

4.2 Shifting

Wisconsin card sorting test was used in this study to measure shifting. The child must sort cards of similar color, shape, and number. When 10 cards are correctly sorted, a deck is formed, and the test continues until 6 decks are formed. Inability in changing the criterion for sorting the cards after the criterion is changed reflects "preservation". These errors and the number of the decks are then used to score the participant. In this study, the test was administered to high-achieving and low-achieving students in math, which included male and female 4th graders in elementary school. The students in the strong group equally performed 6 decks with no error preservation in the Wisconsin test. Therefore, descriptive information was provided for this group and the t-test was carried out for the weak group (table 5).

Table 5. Mean and standard error for shifting in the weak group

Measures	*M*	*SD*	*N*	*Mean of standard error*
Deck	00.5	93.0	15	24.0
Preservation	07.8	93.7	15	05.2

Table 6. T-test results

Variable	*T*	*Df*	*Sig*	*Mean difference*	*Confidence level of 95%*	
					upper	lower
Number of decks	-4.18	14	0.00	-1.00	-0.49	-1.51
Preservation	3.94	14	0.00	0.78	12.46	3.67

As presented in Table 6, with 14 degrees of freedom, the obtained value of the t for docks is -4.18 with a significance of 0.00, which is smaller than 0.05. Hence, it can be concluded that there is a significant relationship between strong and poor groups regarding the number correct decks in the Wisconsin test, with the strong group performing better. Furthermore, with 14 degrees of freedom, the obtained value of the t for preservation is 3.49 with a significance of 0.00, which is smaller than 0.05. Therefore, it can be concluded that there is a significant difference between the groups regarding error preservation in the Wisconsin test, with the strong group exhibiting a better performance and making fewer error. The mean of error preservation for the weak group (M=8.07) was compared to that of the strong group (M=0.00), which showed a significant difference between the two groups, with the strong group significantly making fewer mistakes and showing a better performance.

5. Discussion

As a communication system, knowledge of math helps people to gain a precise understanding of information, patterns, and reasoning. Rapid scientific developments and their impact on various aspects of human life have made it crucial to be familiar with the basics of mathematics even for the simplest of jobs. Problems in learning math begin in early childhood for some children, but usually appear in school and find their way to high school (Gersten, Jordan, & Flojo, 2005). The notable influences of math in educational progress on the one hand and educational underachievement in this area on the other have urged the educational psychology researchers to undergo pathology of the problem. One element discussed in the literature is deficiency in executive functions

(Geary, 1993). Executive functions are a set of cognitive and metacognitive abilities required by children for school learning (McCloskey, Perkins, & Van Divner, 2008) and carrying out daily activities and school assignments (Zelazo et al., 2003).

The results of this study show that compered to high-achieving students, students who have poor performance in math demonstrated no significant difference in attention as measured by the continuous performance test. This finding does not confirm other studies carried out on attention (e.g., McCloskey, Perkins, & Van Divner, 2008; Bull & Scerif, 2001; Presto, Heaton, McCann, Watson, & Selke, 2009; Valera & Seidman, 2006; Seidman, 2006), which have shown that a major part of the problems in all educational areas including math can be predicted by attention, and accordingly attention is a good predictor for math performance.

Yet other researches such as Lan et al. (2011) did not find a significant relationship between attention and math. Similarly, Monuteaux et al. (2005) grouped students in mathematically normal and mathematically disable groups and showed that there is no significant relationship between math disability and attention deficit.

The findings of this study show the type of grouping the participants as well as controlling IQ and reading comprehension can affect the formation of the relationship between attention and math performance. Moreover, in studying attention, lack of significance in performance of the groups can result from the "overall" math test score—which shows the overall ability of the individual in math—and not from a particular study which measures an ability in a specific area. That is so because children with disabilities in math have good performance in some aspects of math and bad performance in others. Additionally, math tests are multi-faceted and when the overall score is generalized to all the abilities, some of the abilities are over- or under-represented. Finally, it should be noted that not reaching a significant difference between the two groups does not imply that attention is not required to solve math problems. This function cannot be totally ignored.

The results of this study showed that the math performances of the weak and strong groups were significantly different in terms of shifting in Wisconsin test. Thus, shifting can be a good predictor of math progress. These findings are in line with Mclean & Hitch (1999) and Bull, Johnston, & Roy (1999). Bull, Johnston, & Roy (1999) found a significant relationship between math performance and shifting before and after controlling IQ and reading comprehension.

But Bull & Scerif (2001) reached different findings with a different grouping of the participants. They showed that before controlling IQ and reading comprehension, there was a significant relationship between math disability and shifting; however, controlling these variables removed the significant difference. Hence, it could be said that when the grouping entails people with a wide range of abilities, the same instrument used for measuring executive functions and the same control methods can lead to different results.

The adverse and considerable effect of math problems in understanding and interpreting the complex aspects of the modern society is obvious. Prevalence of disability in math makes it crucial to diagnose and resolve the problem in early childhood. According to findings of the present study, executive functions must be taken into account in any rehabilitation method which is adopted, and each individual be offered a particular correction plan with respect to his. her psychological background.

Parents and teachers can provide facilities for student to learn math. Besides, they should keep in mind that learning math does not come only through extensive practice and assignments; they should account for the individual differences—in our case executive functions—and other effective factors and according apply proper methods with respect to the conditions of each individual student. On the other hand, teachers should assist each student in learning more effectively at the time of teaching by drawing the student's attention, speaking calmly and clearly, breaking complex instructions into small ones, and devoting sufficient time for response to each section of the learning. Therefore, given the effects exerted by shifting in improving students' math performance, it could be concluded that this function, as the fundamental skills in learning math, can be regarded as a proper approach to correcting problems in math performance.

The participants of this study involved 4th graders in elementary school. It seems that comparing strong and poor groups in math performance from different ages can provide good information for resolving the problems in learning math. Therefore, it is recommended that future studies also account for other age groups. One limitation of the study was that the students' problems in math could have arisen from other psycho-neurological aspects or other elements of executive functions such as spatial-visual organization and auditory time organization, which are suggested to be taken into account in future studies.

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