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The Effectiveness of Cognitive Rehabilitation Using the I-Math Educational Program on Executive Functions and Math Performance of First-Grade Children with Math Anxiety

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ABSTRACT

Objective: This study aimed to determine the effectiveness of cognitive rehabilitation with I-Math program on executive functions and math performance of first grade children with math anxiety. The focus was on assessing mathematical progress and anxiety reduction.

Methods: The research employed a quasi- experimental design with pre-test and post-test control group. The research population included all first-grade students in Yazd in 2024. The sample comprised 30 first grade students with math anxiety in Yazd, selected through convenience sampling and randomly assigned to experimental and control groups. The experimental group participated in sixteen 60-minute sessions of cognitive rehabilitation with I-Math program. Date were collected using The Behavior Rating Inventory of Executive Function (BRIEF) and Mathematical anxiety test and analyzed using MANCOVA with SPSS 22.

Results: The results indicated significant improvements in the experimental group's executive functions, particularly in working memory, planning and attention compared to those of the control group. Additionally, cognitive rehabilitation with I-Math program can decrease the anxiety in first grade students with math anxiety.

Conclusion: It can be concluded that cognitive rehabilitation with I-Math program proves to be an effective tool for enhancing math performance in first grade students through improvement in their executive functions.

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Introduction

Education in most countries is divided into various academic levels. Many psychologists believe that the first grade of elementary school is one of the most important and foundational stages in which students are introduced to a range of subjects, with mathematics being one of the most crucial. Math skills are regarded as essential tools and a vital component for effective functioning in daily life (Brankaer et al., 2017). These skills are fundamental for analyzing and interpreting information, as well as for making both basic and complex decisions. Progress in mathematics depends on abilities in specific and general areas, such as executive functioning and visuospatial skills (Kahl et al., 2021). It is crucial to monitor children's math performance in both elementary school and preschool levels. Identifying math difficulties at a young age allows for timely interventions to support children more effectively. A study found that mathematical progress and performance can be predicted by a child's cognitive functioning and visuospatial skills. Executive functions were linearly and variably related to mathematical performance with age, and they showed a stronger, curvilinear relationship with the spatial abilities of adolescents (Kahl et al., 2022).

Although many theories have been proposed about the underlying components of mathematical performance, there is consensus that early numerical abilities and difficulties are closely linked to the brain's core number systems, particularly the approximate number system (ANS) (Wolf & McCoy, 2019). Research shows that infants and young children gradually develop numerical understanding and spontaneously acquire foundational skills, such as number correspondence (Siegler & Lortie Forgues, 2014).

Executive functions refer to a set of higher-level brain abilities, including organization, decision-making, planning, working memory, initiation, inhibition, and attention. This term encompasses the complex cognitive processes essential for performing challenging or novel goal-directed tasks. Executive functions involve the ability to delay actions and maintain a mental representation of tasks through working memory (Demehri et al., 2020). Research indicates that executive functions play a significant role in predicting numerical abilities in children. Skills such as cognitive flexibility, inhibition, and working memory show marked improvement in children after the age of 5 (Gashaj et al., 2019). However, another study found that executive function skills do not have a direct impact on mathematical progress across different ages (Wilkey et al., 2020).

In educational settings, individuals may experience various forms of test anxiety and performance anxiety, with math anxiety being one of the most prevalent. Math anxiety is a widespread issue that affects people of all ages globally. According to international assessments, including the Program for International Student Assessment (PISA) studies, many adolescents report feeling worried and stressful during math classes and while completing mathematical tasks.

Environmental factors, such as teaching methods and classroom management by teachers can also play a significant role in the development of math anxiety and negative attitudes toward math among students (Alanazi, 2020).

Cognitive rehabilitation refers to a set of interventions aimed at enhancing a person's ability to perform cognitive tasks by retraining previously learned skills and teaching compensatory strategies. These interventions include memory exercises, problem-solving games, and mental exercises designed to improve cognitive functions (Resch et al., 2018). Ample evidence supports the efficacy and effectiveness of cognitive rehabilitation, which has become the treatment of choice for cognitive impairments, leading to improvements in both cognitive and psychosocial functioning (Feinstein et al., 2023). Cognitive rehabilitation has been shown to positively impact executive functions in students with special disorders (Sheykholeslami et al., 2023), improve focused/sustained attention, reduce scattered attention, and enhance reaction time in students with specific learning disabilities (Norozbakhsh et al., 2021). Additionally, applied behavior analysis can be used as a therapeutic method to improve executive functions in children with intellectual disabilities (Demehri et al., 2019). Specific mental training practices, such as attention training, can also induce plasticity in various mental functions, improving attentional performance (Trautwein et al., 2020). In this study, we combined cognitive rehabilitation with the I-Math program.

I-Math is a method designed to teach basic math concepts to children aged 3 to 7, developed by the International UC-Mass Institute under the supervision of Professor Dinowang in Malaysia in 2003. Its goals include eliminating math anxiety, removing barriers to creativity, teaching and strengthening thinking skills, conveying fundamental math concepts, and enhancing practical understanding and inference (Zahediannasb et al., 2020). The I-Math educational method aims to create an environment that facilitates the teaching of fundamental math concepts in early childhood through play and storytelling. It emphasizes a greater focus on mathematical language, enriches the learning environment, and fosters conditions that strengthen divergent thinking. One study conducted in Iran demonstrated that learning mathematical concepts through I-Math leads to positive outcomes in various cognitive performance domains in young children (Zahediannasb et al., 2020). On the other hand, the effect of mathematical education through the I-Math program on the creativity and basic skills of preschool children was examined. The results indicated that the I-Math program positively and significantly affected two components of creativity: expansion and fluidity. However, it did not have an impact on the components of originality and flexibility (Hajitabar Firouzjaee et al., 2017).

Math anxiety creates conditions that negatively impact academic performance and future career prospects. While there are many behavioral studies on math anxiety, the underlying cognitive and neurological mechanisms are not well understood. Therefore, in this study, it was aimed to see if

cognitive rehabilitation using the I-MATH educational program can improve executive functions and math performance of first-grade children with math anxiety.

Materials and Methods

Design and Participants

The present study was a quasi-experimental and applied type research conducted using a quantitative method. The statistical population included all first-grade elementary school students in both genders (male and female) with math anxiety, who were referred to the counseling center of Yazd school in 2024. Convenience sampling method was used in this research. The sample size consisted of 30 students with math anxiety who were randomly assigned to two groups of 15: one for cognitive rehabilitation and one control group. There were 16 girls and 14 boys, with an average age of 7 years and their average intelligence was 94. The sample size was determined based on Cohen's table for experimental research, considering an alpha of 0.05, a relatively large effect size (0.04) and medium power (0.5) for each group 15, totaling 30.

Instruments

Mathematical Anxiety Test: Chiu and Henry (1990) developed Mathematics Anxiety Scale for Children (MASC), a measure based on a shortened version of the Mathematics Anxiety Rating Scale, developed and administered to 562 children in Grades 4–8. This scale has 22 items with four underlying factors: mathematics evaluation anxiety, mathematics learning anxiety, mathematics problem solving anxiety and mathematics teacher anxiety. The lowest score is 22 and the highest score is 88. The MASC showed good internal consistency. Evidence for its construct validity included significant relationships with math grades, test anxiety, achievement motivation, and academic ability. The Cronbach's alpha was reported 0.90 (Deniz, 2008). In Iranian sample, the Cronbach's alpha was reported as 0.88 (Ahmadi, 2021).

Behavior Rating Inventory of Executive Function (BRIEF): It is a questionnaire for parents and teachers to measure executive functions at home and in the school environment. This questionnaire is designed for a wide range of children aged 5 to 18 years. It has two report forms for teachers and parents, both of which have 86 questions. This questionnaire evaluates 8 components of executive functions including inhibition, attention transfer, emotion control, initiation, working memory, planning, organization and control. The retest reliability of the questionnaire was reported as 0.81 for the parent form and 0.86 for the teacher form (Gioia, 2000). In Iranian's research, the reliability and validity of the questionnaire was measured using the test-retest reliability coefficients of the subscales of the behavioral rating test of executive functions were as follows: .90 in inhibition function, .81 in orientation, .91 in emotional control, .80 in initiation, and .80 in memory. Also it was .71 in active, .81 in planning, .79 in organizing components, .78 in monitoring, .90 in behavior

adjustment index, .87 in metacognitive index and the overall score of executive functions was obtained to be .89. The internal consistency coefficient for this questionnaire ranges from.87 to.94, which indicates the high internal consistency of all subscales of the questionnaire (Alimohaid, 2023).

Procedure

I-Math program is a unique program to enrich the environment in order to promote and strengthen basic skills such as observing, thinking, reasoning, removing obstacles to creativity, etc. in children from 3 to 7 years old. All the activities of this program are child-oriented and according to the child's cognitive development stage, they are presented in the form of games, creative performances, poems and stories. Also, this program has three courses with red, green and blue books.

In this research, the cognitive rehabilitation sessions combined with I-Math program and from I-Math's red and blue package (www.imathsworhd.com), were performed for 2 months, two sessions per week for students of the experimental group (16 sessions of 60 minutes). Classroom was divided into different fun activities using the flash cards, numbers and listening exercises which would enhance the Visual Auditory and Tactile Learning (VAT). Students earn and collect points as a group or individually for their participation and performance which creates a fulfilled energetic and competitive learning environment for the students. In order to comply with the ethical aspect of this research, a written consent form was obtained from the parents of volunteer children and that their information will remain confidential.

This educational program is carried out in three areas. Introduction to creative functions, Application of concepts, and Mastery mathematical skills. Here are the main goals of I-Math package:

- Fun with Flash Cards Activities are done with flash cards flashing the bead image or numbers; these activities are done as a group and individually where students score and collect points. This helps trigger and improve the visual learning skills in children;
- Fun with numbers: Fun activities where students recognize, listen and write numbers. It includes different ways of doing speed writing (SW), jumble dictation (JD), listen recall and write (LRW). Students collect points as a group or individually. These activities will help enhance the auditory learning skills in children;

Fun with beads: Hands on abacus and finger movements performing basic arithmetic operations on abacus, quantifying the beads to numbers and relating different numbers to the place value on abacus activate the neural system. It facilitates tactile learning and the connection of the fingers to the brain helping the child enhance the working and stimulation of the brain cells.

Table 1. The I-Math session combined with cognitive rehabilitation

	Purpose	Activities
1	Introduction to creative functions	The concepts of sequence of numbers

	Purpose	Activities
2	Introduction to creative functions	Observation and classification
3	Introduction to creative functions	Basic communication
4	Introduction to creative functions	Quantity recognition
5	Introduction to creative functions	Shape recognition
6	Application of concepts	Familiarity with numbers 11-14
7	Application of concepts	Hand-eye coordination
8	Application of concepts	Descending concept and ascending
9	Application of concepts	The concept of probabilities using with I-math method
10	Application of concepts	Familiarity with geometric shape
11	Application of concepts	Familiarity with numbers 15-20
12	Mastery mathematical skills	Concepts of bigger and smaller, visualization. Concept of weight, development of divergent thinking by I- math method
13	Mastery mathematical skills	Identifying symmetry, mirror reflection
14	Mastery mathematical skills	Concept of balance, the concept of time
15	Mastery mathematical skills	Familiarity with numbers 20-50
16	Post-test	

Data Analysis

All data were described as means and standard deviation (SD). Covariance analysis was conducted to determine whether two groups had a statistical difference in the study variable. Leven's test was carried out to assess the quality of variances. MANCOVA was employed to control for initial differences in pre-test scores, isolating the effect of the intervention. The statistical analysis was carried out in SPSS 22. The significant level was set at 0.05. This study was approved by the Ethics committee of Jahad university of Mashhad (IR.ACECR.JDM.REC.1401.015).

Results

In the present study, 8 female and 7 male students were in the experimental group, while the control group included 9 female and 6 male students. The average of grade of their course was 16.45 in experimental and 15.45 in the control groups. The results show the mean of math anxiety scores in the pre-test of the experimental group was 61.86 (SD=12.45) while it appeared to be 41.46 (SD=9.23) in the posttest.

Table 2. Descriptive Statistics

Variable		group	SD	M
Attention	Pre-test	experimental	2.31	16.08
		control	1.48	15.75
	Post- test	experimental	1.92	12.08
		control	2.44	14.58
Working memory	Pre-test	experimental	2.06	16.58
		control	2.46	16.67
	Post- test	experimental	2.12	11.83
		control	2.42	14.67
Planning	Pre-test	experimental	2.53	17.42
		control	2.52	18
	Post- test	experimental	1.27	11
		control	2.92	14.25
Inhibition	Pre-test	experimental	2.68	15.05
		control	2.37	15.25
	Post- test	experimental	2.81	10.08
		control	2.54	12.50
Emotional control	Pre-test	experimental	2.19	13.50
		control	1.74	13.17
	Post- test	experimental	1.83	10.08
		control	2.06	10.75
Self-monitoring	Pre-test	experimental	1.65	12.42
		control	1.40	12.17
	Post- test	experimental	1.56	5.91
		control	1.56	10.41
organization	Pre-test	experimental	1.49	11.75
		control	1.37	11.92
	Post- test	experimental	1.56	10.92
		control	1.56	10.42
Flexible Thinking	Pre-test	experimental	2.09	11.25
		control	1.93	10.50
	Post- test	experimental	1.86	5.25
		control	1.94	8.84
Math scores	Pre-test	experimental	5.34	12.50
		control	4.23	12.80
	Post- test	experimental	4.76	16.25
		control	5.81	14.23

As observed in Table 1, the mean scores for executive functions and math functions were changed from pre-test to post-test compared to the control group. Before analyzing the data with the multivariate analysis of Covariance method, its assumptions were checked. Based on Kolmogorov Smirnov and Shapiro-wilks test, the assumption of normal distribution for all of the variables in both groups during pre-test and pro-test phases was met, as the significance was greater than 0.05. Furthermore, based on the Levine's test values, the assumption of homogeneity of variance for executive functions and math anxiety variables was met, due to significance greater than 0.05. The assumption of homogeneity of covariance was met based on the Box's M test,

(Box's M=4.17, F=12,1) with significance greater than 0.05. Therefore, using the Multivariable analysis of covariance method is permissible.

Table 3. Covariance analysis test finding for executive functions, math anxiety and math score

Variable to Assess The Impact of Cognitive Rehabilitation	Source Of Variation	Sum of Squares	df	Mean of Squares	F	Sig	Effect Size
Executive functions	Pre-test	651.304	1	651.304	39.14	0.0001	0.89
	Group	84.23	1	54.23	43.12	0.0001	0.69
	Error	46.91	21	1.707			
	Total	32140	24				
Math anxiety	Pre-test	551.55	1	551.55	19.23	0.0001	0.67
	Group	98.5	1	98.5	32.18	0.0001	0.59
	Error	32.9	21	2.13			
	Total	3678	24				
Math score	Pre-test	201.300	1	201.300	34.57	0.0001	0.67
	Group	44.051	1	44.051	26.12	0.0001	0.58
	Error	11.42	21				
	Total	4231	24				

The results of multivariate analysis of covariance (MANCOVA) to compare executive functions, math anxiety, and math test score in the experimental and control groups show a significant difference between the experimental group's executive functions ($p \leq 0.05$, F=43.12, Eta=0.69), math anxiety ($p \leq 0.05$, F= 32.18, Eta=0.59) and math score ($p \leq 0.05$, F=44.51, Eta=0.58). (Table 3)

Discussion

The general purpose of this research was to investigate the effectiveness of cognitive rehabilitation using the I-Math educational program on executive functions and math anxiety of first-grade children with math anxiety. The results of covariance analysis indicate that I-Math education program had a significant effect on the improvement of executive functions, and decrease the math anxiety. The result of this research is in line with the results of Zahediannasb et al. (2020) which showed I-math program had a positive effect on increasing the distinct cognitive performance in young children. Also, the result is in line with the results of Orki (2018) reporting that cognitive rehabilitation can improve the educational achievement.

The results of this study showed that cognitive rehabilitation exercises improved the planning and organizational abilities of students with math anxiety. Planning ability requires conceptualizing changes in the current environment and moving forward based on identifying various options (Dai et al., 2020). Therefore, it can be suggested that the presence of educational exercises in each session, along with increasing the student's awareness of the steps involved in performing math tasks through the I-MATH program, has enhanced their planning and

organizational skills. As a result, the child experiences less anxiety when completing math assignments.

The study results indicated that cognitive rehabilitation based on the I-Math program can improve the working memory of students with math anxiety. For working memory to function effectively, information must be consistently received, processed, and then stored to be recalled later (Almarzouki, 2024). In this study, the I-Math program was used, which includes tailored exercises along with positive reinforcement. It is likely that these exercises, combined with cognitive rehabilitation exercises, have enhanced the working memory of the students, thereby improving their problem-solving abilities.

On the other hand, teaching numerical counting as a skill in operating with numbers is a strong predictor of mathematical competence in the early years of elementary school (Viesel-Nordmeyer et al., 2022). Therefore, in this study, teaching students how to work with numbers and use creative thinking, as taught in the I-Math sessions, can explain the improvement in the students' math performance. According to Piaget's theory, for a child to learn mathematics, they must have acquired the skills from the previous stage and engage in exploration and experimentation during the learning process, which requires a rich physical environment (Lefa, 2014). Therefore, it can be explained that in this study, as the students' executive functions improve during cognitive rehabilitation, they are mentally prepared for learning mathematics and experience less math anxiety.

Conclusion

One of the factors influencing learning is cognitive strategies, which serve as a bridge between behavior and brain structure and encompass a range of abilities, including planning, attention, response inhibition, and problem-solving (Muwonge et al., 2019). Thus, we can infer that as students acquired cognitive strategies during cognitive rehabilitation better, their performance in mathematics improved. When presenting functional activities to students, it is crucial to consider individual differences, needs, and interests, ensuring that the student can connect with and become interested in the content of the lesson. The I-Math program helped students with math anxiety establish a connection with their teacher and discuss mathematics. Therefore, it can be concluded that the cognitive rehabilitation program, combined with the I-MATH program, can improve executive functions and reduce math anxiety in students who suffer from this condition.

Despite the positive findings, several limitations should be considered. One limitation is the relatively small sample size of 30 participants, which may restrict the generalizability of the results. Future studies should aim to include larger and more diverse samples to validate the findings and ensure their applicability to broader populations. Another limitation is the short duration of the intervention; while the I-Math program is ideally followed for three months, this

study utilized the program over a period of two months. Longitudinal studies are needed to assess the durability of cognitive rehabilitation using the I-Math program and to determine the optimal duration and frequency of training sessions for maximum benefit.

Additionally, the study relied on students' math scores to measure math performance. In Iran, there is currently no comprehensive and validated test for assessing math performance. It is suggested that future research develop a tool for measuring mathematical performance. Building on the findings of this study, future research should explore the long-term effects of cognitive rehabilitation with the I-Math program through follow-up assessments to provide valuable insights into the need for ongoing training to maintain improvements.

The findings of this study provide strong evidence for effectiveness of I-Math program for enhancing math performance for students with math anxiety. Therefore, teachers and psychologists can use this method in their clinic for improvement of math scores in their students. Cognitive rehabilitation programs that consist of many plays with focus on improving of attention can prepare mind for learning.

Authors' Contributions

All authors significantly contributed to this study.

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Declaration of Interest

The authors report no conflicts of interest.

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Ethical Considerations

In this study, to observe ethical considerations, participants were informed about the goals and importance of the research before the start of the interview and participated in the research with informed consent. The study was confirmed by the Ethics committee of Jahad university of Mashhad (IR.ACECR.JDM.REC.1401.015)

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