

## Research Paper

## Effect of Cognitive Rehabilitation Training on Information Processing Speed, Response Inhibition, Attention, and Perceptual Reasoning in Students With Dyscalculia



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**Citation** Dereili R, Estaki M, Beheshte N. Cognitive Rehabilitation Training on Speed of Information Processing Response Inhibition, Attention and Perceptual Reasoning in Students With Dyscalculia. *Iranian Rehabilitation Journal*. 2024; 22(3):509-518. <http://dx.doi.org/10.32598/irj.22.3.2102.1>

**doi** <http://dx.doi.org/10.32598/irj.22.3.2102.1>

## Article info:

Received: 08 May 2023

Accepted: 05 Sep 2023

Available Online: 01 Sep 2024

**ABSTRACT**

**Objectives:** Children with learning disabilities have problems with processing speed, reaction inhibition, attention and perception, hearing, and visual clarity. Accordingly, this study examines the effects of cognitive rehabilitation on processing speed, response inhibition, attention, and Perceptual Reasoning in students with mathematics learning disabilities.

**Methods:** This was a semi-experimental study with a pre-test-post-test design and a control group. The statistical population included all third-grade students with mathematics problems in Tehran City, Iran, in 2017. They were referred to Roozbeh Counseling and Rehabilitation Clinic for treatment and met the inclusion criteria. A total of 30 students were selected from among these individuals using the purposive sampling method. The participants were assigned to experimental (n=15) and control groups (n=15). The participants in the experimental group underwent a 20-session cognitive rehabilitation program. The Grant and Beck Wisconsin test (1948), the Wechsler intelligence test (2003), the fourth edition, the Sarrold continuous achievement test (1956), and the Toulouse-Piron attention test (1986) were used to collect data. The data were analyzed using the multivariate analysis of variance and the SPSS software, version 22.

**Results:** Cognitive rehabilitation strategies effectively affect information processing speed, responsiveness, attention and perceptual reasoning in children with math learning disabilities ( $P < 0.001$ ). Furthermore, the results showed that learning cognitive rehabilitation strategies had a considerable impact on perceptual reasoning ( $P < 0.001$ ) according to the resulting Eta coefficient ( $\eta^2 = 0.92$ ).

**Discussion:** Cognitive rehabilitation is a practical approach to improving information processing speed, reaction inhibition, attention, and Perceptual Reasoning skills in students with special mathematical learning disabilities.

**Keywords:**

Cognitive rehabilitation training, Speed of information processing, Response inhibition, Attention, Perceptual reasoning, Students with dyscalculia

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## Highlights

- Cognitive rehabilitation strategies are effective in information processing speed, response inhibition, attention, and perceptual reasoning of children with a mathematical learning disorder.
- The training of cognitive rehabilitation strategies had the greatest effect on perceptual reasoning.

## Plain Language Summary

Cognitive rehabilitation provides retraining in thinking, judging, and making decisions. The focus is on correcting deficits in the areas of memory, concentration and attention, perception, learning, planning, sequencing, and judgment.

### Introduction

In its most recent classification, the [American Psychiatric Association \(APA\)](#) classified learning disabilities as specific disorders as disorders of educational skills (math, reading, and writing), speech and language disorders, and motor skill disorders. According to general scientific studies, among learning disabilities, math disability has the lowest rate compared to other forms of learning disability with an estimate of 5% to 10% [1]. This has resulted in less research on this disorder [2, 3]. According to research, children with learning disabilities often have problems with processing speed, the ability to maintain attention, inhibition of reactions, motor coordination, perception, hearing and clear vision, and when children have visual-motor coordination deficits and inappropriate learning styles [1, 3-5].

Information processing speed is considered equivalent to executive function and has been identified as several excellent functions of the cognitive system, including self-management, self-initiation and self-inhibition, planning strategy, cognitive flexibility, time perception, impulse control, and memory [5]. People with math disabilities have various problems in learning mathematical concepts because of difficulties in working memory, attention, and slow processing speed [6]. These children have a slower processing speed than normal children [4, 5]. On the other hand, one of the most critical executive functions is response inhibition and attention retention [7]. Reaction inhibition is the ability to think before acting. This ability allows the situation and behavior to be assessed before taking action [8]. Finally, other important factors that play a role in learning mathematics are the ability to understand spatial relationships and the ability to think logically [9].

Perceptual reasoning reflects an increasing emphasis on the ability to think fluently, as measured by new matrices and intuitive conceptual tests. Flexible reasoning includes thinking skills that are practiced in new and unfamiliar conditions [10]. Regardless of the problem associated with the specific math disorder, the result is poor performance in math, leading to damaged self-esteem, a decline in self-confidence, negative attitudes toward oneself and a decline in educational progress [11]. School performance depends on the amount of learning information acquired in the educational process and is measured by the progress made in this process [12]. Learning experts are looking for ways to reduce the challenges faced by students with special learning disabilities. Many different methods have been developed to improve the achievement of these children; therefore, it is critical to choose a method that can improve learning problems in a particular subject while also being effective.

One of the most important methods currently used to teach appropriate learning strategies to children with learning disabilities is to teach cognitive strategies. Cognitive strategies are sets of actions and thoughts that influence the process of storing information in memory and retrieving the information more efficiently. These strategies help people combine new information with previously learned information. This information is easier to store in long-term memory [13]. In addition, studies of cognitive strategies have shown that the use of such cognitive strategies increases student learning and progress [6, 10, 14]. Hassanvand and Arjamandnia have shown in a study that cognitive flexibility using this approach effectively improves performance in children with impotence [6]. Meanwhile, Khanjani et al. reported similar results in a study of autistic children with learning disabilities [10]. However, to date, a few researchers have investigated the effects of teaching these strategies on information processing speed, response inhibition and cognitive thinking in students with dyscalculia, thereby

confirming the effectiveness of this method in improving the skills of children with dyscalculia. Accordingly, this study examines the effect of cognitive rehabilitation on students' processing speed, reaction inhibition and cognitive thinking, to address gaps in existing research and direct impacts and further improve academic performance in children with learning disabilities.

## Materials and Methods

This was a pre- and post-trial study with a control group. The current study's statistical population included all third grade with math problems in Tehran City, Iran, in 2018, who were referred for treatment at the [Roozbeh Center's Counseling and Rehabilitation Clinics](#). Based on the purposeful sampling method, students who were diagnosed with a math disorder according to the diagnostic and statistical manual of mental disorders, fifth edition criteria were selected as the sample. To select a sample of 32 participants, the Cohen formula with a power of 84% and an  $\alpha$  value of 0.05 was used [15]. A total of 30 students were randomly assigned after signing their parental consent forms to experimental ( $n=15$ ) and control ( $n=15$ ). During the study, two subjects were excluded from the study, and in the end, the study was completed with 30 subjects. The inclusion criteria for the study were having no history of neuropsychiatric disease confirmed by a psychiatrist, no history of limited documented intellectual disability and no history of attention deficit disorder. Meanwhile, the exclusion criteria were absences for over two training sessions, the reluctance of parents or subjects to continue the intervention, and not completing the questionnaires at different stages of the study. To conduct the study, firstly, 30 students with math problems were selected from learning disability treatment centers in [Roozbeh Center](#), district 1, Tehran City, Iran, by the purposeful sampling method and were randomly placed into two experimental groups (with cognitive rehabilitation intervention) and a control group (no intervention). During the next phase of implementation, the control and intervention groups underwent several assessments, including the Wisconsin and Wechsler test, the Toulouse-Piron attention and accuracy test and the continuous performance test, before starting the test. Each pre-test and post-test was administered over one week. The experimental group received two 1 h cognitive rehabilitation sessions per week as part of a five-week exercise program.

However, the control group did not receive any intervention during the therapeutic interventions for the experimental groups and until the end of the post-test stage. Tabrizi [15] created a treatment protocol for cognitive re-

habilitation interventions with a particular focus on children's readiness and motivation levels. The implementation of this intervention follows this protocol. The 20 treatment sessions are summarized in [Table 1](#). The intervention sessions in this study were conducted by the first author who had attended specialized courses and workshops. Following the treatment sessions, all participants were re-evaluated by the instruments (post-test stage). Ethically, there was no relationship between the control and experimental groups during the study. The control group was treated by a specialist according to the current protocol and without any researcher intervention. At the end of the study, the control group received a cognitive rehabilitation protocol in the form of a training package.

The SPSS software, version 20, was used to perform multivariate analysis of variance on the collected data. A statistical test with a significance level of 0.05 was used. Meanwhile, the following instruments were used to collect information.

### The computerized version of the Wisconsin card sorting test

Grant and Berg used the Wisconsin card sorting test in 1948 to evaluate problem-solving and decision-making skills. One of the primary indicators of this test is sensitivity to frontal lobe damage, which is used today as an evaluation of transfer attention and information processing speed [16]. The test comprises two sets of 64 non-similar cards, each based on the shape (triangle, cross, circle, and star). Color distinguishes them (green, blue, red, and yellow) or numbers (one, two, three and four). Each card has one of red, blue, yellow, or green colors, and four shapes of circle, triangle, cross and star are placed on each card. The number of shapes on a card also varies from one to four, so none of the two cards is the same. Evaluating and summarizing the items scored in the studies done with the Wisconsin test identifies the number of ten items recorded for this test. In the present study, the speed of information processing is measured based on the following three subscales: The number of classes, total general errors, and involuntary repetition errors; meanwhile, the scale does not have a total score. The researchers have reported the reliability of the test based on the agreement coefficient of the evaluators equal to 0.83 [17]. In the Iranian version of this test, the internal consistency coefficients were calculated using the Cronbach  $\alpha$  method and the bisection coefficient method. The values of 0.73 and 0.83 have been reported respectively for the number of completed classes, and 0.74 and 0.87 are obtained respectively for the number of remaining errors [18]. In this research, the internal

**Table 1.** A summary of the content of the treatment sessions of the cognitive rehabilitation protocol

Meeting Procedures	Summary
1 & 2	This meeting was for familiarization and initial communication and motivating the child. At the end of the session, according to Seman's table, specific and non-specific problems of the child were identified and the next sessions were planned according to the problems of the child.
3 & 4	Dynamic standing coordination: The child stands on one leg, counts forward and backward, stands on the balance board with eyes closed, throws the ball up and catches it, hits the ball at the target and finds and expresses similarities by seeing pictures.
5 & 6	General dynamic coordination: Jumping rope, walking backward, walking to the rhythm of the therapist's kicks, such as Li Li with both legs, jumping with both feet on both sides of the rope forwards and backward. The therapist provides different objects and compares them.
7 & 8	Manual coordination: Playing pranks with both hands, turning the rod with fingers, crumpling the newspaper and throwing it in the basket, hitting the hand with the child's eyes closed by the therapist. Identify the number of beats, choose something, and ask the student to stare at it for a long time.
9 & 10	Speed of movement: This meeting should be done with time, several jumbled letters are shown in different directions, and the child must connect the word that is asked of him. The therapist says 4-5 commands in a row. The child listens and must do them in order after a 10-s pause. The therapist draws different shapes on a page and asks the child to mark the shapes they want the child to mark. The therapist prepares pictures of several words whose final sounds are the same and asks the child to name them and repeat their final sound after naming each word.
11 & 12	Coordination between limbs, hand-eye coordination games (bilateral superiority, Delacato sleeping position practice, parade walking, butterflying, scissoring, crawling in place-crawling with obstacles-picking up coins and matches. Walking on the balance board, completing the image to pay attention to the constituent members of a phenomenon and image, for example, completing the image of an incomplete house can be useful.
13 & 14	Strengthening the motor vision system: Facial expression, eye expression, expression by pressing hands, imitating the movements of people with different jobs, imitating the movements of animals, imitating movement in space, picking up a light object, imitating the movement of someone who has picked up a very heavy object. Twisting in movement, conveying a message with gestures and pointing, the therapist writes the desired word in large letters on a large piece of paper and pronounces it when the child looks at the word. Then, along with the pronunciation of the word, they touch the letters of it from the beginning to the end with their fingers. After that, the student writes the desired word on a paper and then they are asked to say a sentence or a short story with that word and express it orally.
15 & 16	Exercises of the third stage of Delacato: Walking with an interlaced pattern, hearing exercise, sight exercise, without showing the card, the teacher plays the sound of the desired letter through a tape recorder and the student must tell the teacher the name of the desired letter. At this stage, hearing and speech are used.
17 & 18	With eyes closed, the child should identify the letters and name them, put the writing of one line in front of the furler's eyes and the child should try to read the whole line without moving his eyes. Look at a picture for a minute and then the therapist asks to memorize the details of the picture, use memory cards and complete the unfinished sentences.
19 & 20	The therapist reads similar words in a low voice and the child must write them down, keeping his head steady and looking directly at the child's words, trying to read three words in each line together. The therapist says a word, and the child says a sentence about it and with the other word, the therapist relates another sentence to it. Several rows of numbers are written on a page and the therapist asks the child to read the two side numbers by only looking at the middle number. In addition, in this meeting, the date of implementation of questionnaires for post-test and follow-up was determined.

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consistency coefficients using the Cronbach  $\alpha$  method were reported at 0.68 for the number of completed classes and 0.71 for the number of residual errors.

### Wechsler IQ test, fourth edition

The Wechsler IQ test (fourth edition) is a revised form of the Wechsler IQ test for children, third edition, prepared by Wechsler (2003) for children aged 6-16 years. This scale was prepared and distributed for the first time by Wechsler and standardized in Iran by Razavieh et al.

[18]. This tool has 21 subtests in both verbal and verbal (practical) sections, and the scale has five main sub-tests and one optional sub-test. The scores of each subtest are compared with the averages. In the present study, sub-scales of arithmetic, digit span, letter and number sequence were used to measure perceptual reasoning. The validity and reliability of this version of the Wechsler test have been confirmed in various studies [19, 20]. In Iran, the correlation coefficients of general, verbal and practical intelligence are reported at 0.84, 0.74 and 0.85, respectively. For the revised Wechsler scale the reliabil-

ity by splitting method, for general intelligence, verbal intelligence, and practical intelligence, was reported as 0.94, 0.90 and 0.96, respectively. The reliability of the subtests using the Cronbach  $\alpha$  method was reported between 0.60 and 0.80 [18]. The validity of the subtests in the re-test is reported in the range of 0.65 to 0.95 and the coefficients of partial validity are reported from 0.71 to 0.86 [21].

### Toulouse-Piron attention and accuracy test

The Toulouse-Piron test can be used without factors, such as intelligence level, reading speed, literacy, education, age, and gender. In this test, 236 consecutive squares are drawn on the paper in no specific order (it is made up of several pages of consecutive squares), the examiner must identify the three squares shown on the top of the page at the specified time from among the squares and cross it out. A positive mark is given for each correct choice, half a negative mark is given for each wrong or forgotten answer, and an individual score is obtained from the total. The re-test reliability of Toulouse-Piron is reported as 86%. The researcher has achieved the validity of this test through correlation with the Wilson Golriz accuracy test of 79% [22]. This test is also used and standardized in Iran and the reliability of the test is 0.75 via the Cronbach  $\alpha$  method and 0.81 through the ballad test. Meanwhile, its validity was 0.81 using simultaneous execution with Wechsler's memory test [23]. In this study, the internal consistency coefficient using the Cronbach  $\alpha$  method was 0.78.

### Continuous performance test

The continuous performance test will measure response inhibition variables. Rosvold et al. created this test in 1956 to measure brain damage [24]. In recent research, subjects respond to computer screen visuals by pressing a key. The test measures response inhibition with three subscales as follows: Response, presentation, deletion and time. Test validity and reliability were confirmed [24]. All correlation coefficients were significant at the 0.001 level in this normalized form, and the test's validity was confirmed by comparing the healthy and hyperactive groups with attention deficit using criterion validation. Reliability for different parts of the test ranges from 0.59 to 0.93 [25]. In this study, the internal consistency coefficient according to the Cronbach  $\alpha$  method was 0.88.

## Results

The Mean $\pm$ SD age of the students in the experimental group was 10.10 $\pm$ 1.26 years, while the control group had an average age of 10.52 $\pm$ 1.06 years.

Table 2 shows the Mean $\pm$ SD of information processing speed, response inhibition, attention, and visual perception of the control and experimental groups along with their subtests.

The findings of the Table 2 show that the mean scores of the variables in the subjects of the experimental group improved from the pre-test to the post-test, while the mean scores of the variables in the control group changed slightly from the pre-test to the post-test. To analyze the data, first, the assumption of normality of the distribution of the scores of the research variables in the pre-test and post-test was checked using the Kolmogorov-Smirnov test in the research sample, and the results showed that the distribution of the investigated variables was normal ( $P < 0.05$ ). Verified assumptions supported the homogeneity of variance test. The study found that every variable met the assumption of homogeneity, as the P value was less than 0.05. As a result, covariance analysis is unimpeded. Table 3 shows the information related to the credit indicators of multivariate analysis of variance.

As seen in Table 3, in the variable of information processing speed, the mean number of classes, the sum of total errors, and involuntary repetition errors, after removing the effect of pre-test and post-test, a significant difference was observed between the intervention and evidence groups ( $P < 0.001$ ). In the mentioned variables, the cognitive rehabilitation intervention affected 46%, 66% and 50% of the changes. In the response inhibition variable, a significant difference was observed between the average response presentation, response elimination, and the time spent after removing the effect of the pre-test on the post-test between the intervention and control groups ( $P < 0.001$ ).

The results of the Eta coefficient in Table 3 showed that 33%, 64% and 37% of the changes were related to the cognitive rehabilitation intervention, respectively. Also, in the variable of attention, a significant difference was observed between the average of the intervention and control groups after removing the effect of the pre-test on the post-test ( $P < 0.001$ ) and 70% of these changes were because of cognitive rehabilitation intervention. Finally, based on the analysis performed between the average of perceptual reasoning, between the intervention and control groups after removing the effect of the pre-test on the post-test, a significant difference was observed ( $P < 0.001$ ) and based on the Eta coefficient, the greatest effect of the intervention with 93% was related to this variable.

**Table 2.** Descriptive indices of the scores of the two groups in the pre-test and post-test stages

Variables	Sub Tests	Mean±SD			
		Intervention		Waiting List	
		Pre-test	Post-test	Pre-test	Post-test
Processing speed	Number of floors	2.80±1.08	4.26±1.22	3.06±1.22	3.00±1.13
	Total errors	3.13±0.91	12.33±1.75	3.06±1.22	2.93±1.33
	Involuntary repetition errors	12.33±1.75	8.33±2.63	13.73±2.40	12.86±2.35
Response inhibition	Provide an answer	4.53±1.24	4.60±0.98	4.26±1.03	3.46±0.91
	Delete answer	3.80±1.08	2.26±0.79	3.20±1.14	3.26±1.16
	Time spent	405.53±59.72	311.33±60.45	392.60±56.91	366.26±72.94
Attention span	Attention	15.26±2.40	19.06±2.57	13.33±3.77	13.33±3.99
Perceptual reasoning	Total score of three subscales	95.51±3.96	102.86±3.95	94.20±3.43	94.91±3.64

SD: Standard deviation.

### Discussion

This study examined the effect of teaching cognitive strategies on processing speed, response inhibition, attention, and perceptual reasoning in students with math disorders. The results showed that the intervention was effective and considering that the difference between the two groups is statistically significant, this significant difference is due to the implementation of training and the implementation of the rehabilitation program. Furthermore, the obtained Eta ( $\eta$ ) coefficients showed that the magnitude of this effect was significant. Consistent with the results of this research, previous studies on the

effects of training with cognitive methods have shown that the use of these cognitive rehabilitation strategies increases students' learning scope and academic progress [6, 10, 14].

Regarding the use of cognitive strategies in the education of students with learning disabilities, Moreno and Saldana as well as Solas and Sanjos have shown that learning to use strategies in learning is critical [26-28]. Research conducted by Shiran and Breznitz found that cognitive training effectively affects the recall and speed of information processing in the working memory of children with learning disabilities and increases the

**Table 3.** Information related to credit indicators of multivariate analysis of variance

Variables	Description	F	P	$\eta^2$
Information processing speed	Number of floors	23.50	<0.001	0.46
	Total	53.48	<0.001	0.66
	General errors	27.60	<0.001	0.50
	Involuntary repetition errors	13.78	<0.001	0.33
Response inhibition	Provide an answer	48.94	<0.001	0.64
	Delete answer	16.15	<0.001	0.37
	Time spent	63.47	<0.001	0.70
Attention	Attention span	328.13	<0.001	0.92
Perceptual reasoning	Provide an answer	23.50	<0.001	0.46

ability to store verbal and visual information in working memory [29]. Likewise, Fathi-Ashtiani et al. (2016) found that teaching cognitive strategies improved the speed of information processing in students with learning disabilities [30]. This research result can be explained by considering that students with math disorders have lower awareness and use of cognitive strategies compared to normal students [31]. This topic is essential because cognitive skills are essential for correct information processing and students need to use these strategies to achieve academic success. Given that these strategies have been achieved through regular and planned training, and in the current research, this important thing has been done. This is because high-performing students have improved the speed of information processing.

The results also showed that the index of response inhibition and attention increased significantly after the intervention in the experimental group compared to the control group, thus learning cognitive strategies affects response inhibition in students with math disorders. Although there is no research examining the effectiveness of cognitive strategies on response inhibition in children with math disorders, recent research findings support the findings of this research. Research on cognitive interventions for students with dyslexia showed that teaching cognitive strategies through games can improve attention and retardation in students with math disorders [32].

In explaining this issue, we can point to defects in executive function in students with learning disabilities. Based on Barclay's model of inhibition, the correct functioning of executive functions depends on the correct functioning of inhibition and attention. In other words, when there is a problem with inhibition, the executive functions do not function properly and as a result, children have problems in the learning process, especially in learning mathematics [33]. Most children automatically practice these skills, which are related to inhibition of response and attention, but children with learning disabilities, including children with math disorders, have trouble mastering these skills. Since research has shown that cognitive ability can improve executive function and that attention and response inhibition are the main components of executive function, the intervention improved attention and response inhibition in these students [34].

Regarding the last variable examined in the present study, the results showed that teaching cognitive strategies were effective in improving students' perceptual reasoning and had the largest effect on this variable, even with a coefficient of 92%. Researchers found no agreement or inconsistency study on the effectiveness

of cognitive strategies on cognitive reasoning. However, previous studies support the findings of current research. Studies have shown that the use of cognitive rehabilitation increases the amount of learning and academic progress of students [6, 10, 14]. Research by Hassanvand and Arjamandnia showed that this intervention improves the performance of students with learning disabilities in mathematics [6], Khanjani and colleagues reported a similar finding in a study of autistic children with learning disabilities [10].

To explain this research finding, the teaching of cognitive strategies, the high functions of the cognitive system, and several high-level cognitive processes, including planning, response inhibition, and attention, help a person to plan their activities. Moreover, it improves their organization and allows students to monitor their thoughts and regulate their behavior in the best possible way. By creating these skills, and particularly by strengthening attentional function, processing errors, and improving problems in maintaining and continuing effort, the consecutive failures of students with math disorders have been reduced, due to the apparent importance of accuracy and attention in the four subtests on reasoning. At the perceptual level, training attention and reaction inhibition have also increased the scope of perceptual reasoning.

## Conclusion

The cognitive rehabilitation approach assumes that cognitive strategies select and control the internal processes involved in learning and thinking. A critical point is the expertise that distinguishes cognitive abilities from other mental abilities.

## Study limitations and future research recommendations

In the present study, it was not possible to further assess the continuity of the effectiveness of teaching cognitive strategies due to time constraints. The other current study limitation was the complete non-cooperation of parents in doing homework for students undergoing rehabilitation. Other limitations of this study include the lack of control for several intervention variables, including physical health status when attending meetings and student motivation. In addition, researchers have encountered limitations, such as a lack of accessibility and occasional barriers to attendance at meetings. The uncertainty about compliance with all instructions by subjects in the cognitive rehabilitation training group was beyond the researcher's control. In addition, due to

the limited number of students with math disorders at [Roozbeh Psychology Clinic](#), they were targeted and selected from different grade levels as research samples. Therefore, caution should be exercised in generalizing the results. Finally, the teaching of cognitive strategies should also be carried out in students with other special learning disabilities.

The study recommends making the results available to counselors so that they can recommend or use the best and most effective approach when dealing with children's math problems. Considering the usefulness of cognitive rehabilitation and computer games to improve the skills of students with learning difficulties in math, and considering the short-term nature of this intervention, it seems likely that this approach can be applied to many behavioral and cognitive problems, such as autism, attention deficit hyperactivity disorder, math disorders, and handwriting disorders. It is suggested that play therapy intervention should be applied to children with math difficulties to improve learning skills to avoid its consequences in the future.

## Ethical Considerations

### Compliance with ethical guidelines

This study was approved by the Ethics Committee of [Islamic Azad University, Saveh Branch](#) (Code: IR.IAU.S.REC.1397.082). To address the ethical considerations, before conducting the research, the students and parents completed the research participant satisfaction questionnaire; in addition, the questionnaires were completed and compiled by an independent reviewer.

### Funding

The paper was extracted from PhD Dissertation of [Ronak Dereili](#), approved by the Department of Psychology, Faculty of Humanities, [Saveh Branch, Islamic Azad University](#).

### Authors' contributions

All authors equally contributed to preparing this article.

### Conflict of interest

The authors declared no conflict of interest.

## Acknowledgments

The authors thank and appreciate the research participants who collaborated with the research group at all stages of the work.

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