METAANALIZY
BADAŃ
EDUKACYJNYCH

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Regulating Math Anxiety and Improving Math Performance: A Review of Intervention Research

Abstract

Math anxiety as a stressful reaction to interacting with mathematics is a common problem in education and is highly prevalent across the globe. Moreover, math anxiety is negatively correlated with math performance. Researchers are looking for promising ways to mitigate its negative association by designing and testing various interventions. This article presents a review of intervention research aiming at regulating students' math anxiety. The findings revealed that interventions may be classified into two types: (1) behavioral interventions, and (2) interventions focusing on improving math knowledge and skills. The article further provides an overview of interventional studies that examined the effect on both math anxiety and math performance. It includes the identification of primary characteristics of the studies, and also the effects of interventions. The findings are discussed in terms of the present state in the field of math anxiety, particularly its potential regulation or treatment.

Keywords: math anxiety, math performance, interventions, treating anxiety, improving math.

Introduction

There is no doubt that the quality of math education determines the scientific and technical development of each country. Math education has a meaningful role for every individual as well. A meta-analytical study of six longitudinal data sets, which estimated the relationship between school readiness and later school performance, shows that early development of math abilities is a correct prerequisite for a child not only being good at math in the future but also excelling in other school subjects (Duncan, et al., 2007). However, the importance of math skills does not disappear after graduation. Competence in math opens up many career opportunities in science, technology, engineering, and math (STEM). However, people deliberately avoid choosing majors in math-related areas (Ahmed, 2018). One of the reasons for this is math anxiety.

Math anxiety is defined as "a feeling of tension, apprehension or fear that interferes with math performance" (Ashcraft, 2002, p. 181). This state manifests itself directly when interacting with math or with numbers. Math anxiety prevents from concentrating on current mental activity, and may also cause feeling restless and tense, sweating, having a rapid heartbeat, and other symptoms.

Many studies indicate that math anxiety is consistently associated with poor math performance (Wigfield & Meece, 1988; Hembree, 1990; Ma, 1999; Namkung et al., 2019; Zhang et al., 2019; Barroso et al., 2021). In some works math performance is understood as a measure of student achievements in math or subjects with high math content. Wherein measuring achievement uses overall classroom performance and results from standardized tests.

Whether math anxiety is a precursor or a consequence of cognitive problems is difficult to answer (Carey et al., 2015; Namkung et al., 2019). One thing is clear – the math curriculum is hierarchically organized, and the level of complexity is constantly increasing. Therefore, studies show that as a child grows up, as the knowledge load increases then math anxiety and math performance begin to have the most significant correlation (Wigfield & Meece, 1988; Hembree, 1990; Ma, 1999; Zhang et al., 2019). This trend is observed concerning interest and attitude toward math which also tend to deteriorate over time (Hidi & Harackiewicz, 2000). Recent studies have

indicated that math-related unpleasant emotions are also common in elementary school children (Dowker et al., 2012; Wu et al., 2012; Namkung et al., 2019; Zhang et al., 2019). However, the relationship between math anxiety and math performance at an early age has not been established. Therefore, it can be assumed that students who are anxious about math try to avoid situations related to math, and as a result, they receive less practice (Hembree, 1990; Meece, et al., 1990; Ashcraft, 2002; Choe et al., 2019). However, other studies indicate that initial low math abilities are the cause of subsequent high levels of math anxiety among students (Ma & Xu, 2004), and increasing the complexity of the curriculum only contributes to a clearer manifestation of this effect.

Despite the difficulties in understanding the full picture of the development of math anxiety, much attention is paid to the design of interventions in this matter. While there are not many studies, there are already some results that may shed light on which direction to move in and what research still needs to be done.

This review article has two primary purposes. The first is to attempt to find out what types of interventions researchers suggest for the regulation of math anxiety. The second aim is to summarize the main findings of recent intervention studies that examined the effect on both math anxiety and math performance. This article begins with a brief description of the main controversies raised in discourses on the causal relationship between math anxiety and math performance. Following that, an overview of the methods for reducing math anxiety is provided, which are grouped into two main types: (1) behavioral interventions, and (2) interventions focusing on improvement of math knowledge and skills. Finally, some recent interventions are described in terms of their effectiveness in the regulation of math anxiety and improvement of math performance.

Theoretical background

Math anxiety and math performance
Students with high levels of math anxiety are not motivated and unsure of their math skills, they try to avoid math lessons. Thereby they do not give themselves a chance to get higher education and build a career that requires

math knowledge (Hembree, 1990; Meece et al., 1990; Ashcraft, 2002; Choe et al., 2019). Various studies support the fact that math anxiety is consistently associated with poor math performance (Wigfield & Meece, 1988; Hembree, 1990; Ma, 1999; Namkung et al., 2019; Zhang et al.; 2019; Barroso, et al., 2021). Students from grades 6–12 participated in the research of Wigfield and Meece (1988). Authors found that math anxiety is almost uncommon for 6th graders and reaches its peak around the 9th grade, and after that, it stabilizes. A meta-analysis of Hembree (1990) that included participants from grades 6 to 12 and college students showed similar results. In a meta-analysis by Ma (1999), it was found that starting from grade 4, if the level of math anxiety is lower, then the performance in math is better, and vice versa. The level of math anxiety rises with age when children move from childhood to adolescence. A longitudinal study found that two-thirds of 11-year-olds consider math as their favorite subject, but only a few 16-year-olds like it (Blatchford, 1996). Blatchford (1996) points out that these kinds of results were observed since math was considered a difficult subject and students felt incompetent.

A more recent meta-analysis by Namkung and colleagues (2019) that included elementary and middle school students showed that math anxiety can go hand in hand with math performance from early childhood. However, other research (Zhang et al.; 2019) indicates that the negative association between math anxiety and math performance is stronger in middle and high school and the weakest in elementary school. A meta-analysis by Barroso and colleagues (2021) is consistent with earlier findings – there is a significant correlation between math anxiety and math performance that begins in childhood and continues into adulthood. Research claims that anxiety is inherent even in children of elementary school age. These results are a reflection of the fact that earlier research was carried out with older students (middle and high school, university level), and only recently there has been an increase in interest in defining this phenomenon at early school age. However, the results are contradictory, and cannot assert if there is a connection between math anxiety and math performance at the elementary school level.

It is very difficult to determine in what sequence math anxiety manifests itself and the performance deteriorates. Is it the case that poor performance in math leads to math anxiety? Or does math anxiety lead to poor performance? There are competing theories on this issue: deficit theory (Tobias, 1986),

debilitating anxiety model or cognitive interference theory, and reciprocal theory (Carey et al., 2015; Namkung et al., 2019).

The idea behind deficit theory is that poor performance in math leads to higher levels of math anxiety (Tobias, 1986). Support for this theory has mainly been demonstrated in studies with students experiencing learning disabilities (for instance, dyscalculia, attention deficit hyperactivity disorder (ADHD)), and also in longitudinal studies (Carey et al., 2015). According to this theory, math anxiety develops gradually and affects this difficulty in understanding mathematical concepts or/and memories of poor results in math, etc.

The debilitating anxiety model, also known as cognitive interference theory, has the opposite meaning – precisely having math anxiety affects subsequent performance in math (Carey et al., 2015). In this case, students with high levels of anxiety try to reduce or eliminate various math-related situations (Hembree, 1990; Ashcraft, 2002). This causes the students to deprive themselves of the opportunity to study math which decreases their performance.

Cognitive interference theory is associated with working memory theory (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Eden et al., 2013). Working memory (WM) is a short-term memory system that is needed to process current tasks. With a high level of anxiety, working memory resources can be used not for solving a specific problem, but for thinking about worries. For instance, thoughts about what others might think if the problem will be solved incorrectly, etc.

Overall, studies provide mixed results on the causal relationship between math anxiety and math performance. Therefore, Carey and colleagues (2015) suggested that instead of trying to choose between the two previous theories, the most plausible theory seems to be the reciprocal theory (Carey et al., 2015). The idea behind this theory is that poor performance triggers math anxiety, and math anxiety leads to poor performance in a task-related situation.

Methods for regulating math anxiety
Nowadays, interventions are being developed to reduce math anxiety and its negative impact on math performance. In general, interventions can be classified into three main categories: (1) behavioral interventions or methods

for treating anxiety; (2) interventions focusing on improvement of math knowledge and skills; (3) neuropsychological stimulation methods (Sarkar et al., 2014). This article covers the first two categories.

Treating anxiety

The first attempts at regulating math anxiety were made by Suinn and Richardson in 1971. They presented the results of a study on the introduction of specific training to treat math anxiety and improve results in math-related tasks (Suinn & Richardson, 1971). The first group underwent treatment by anxiety management training (AMT). AMT is a treatment based on the reduction of anxiety reactions through relaxation and positive emotions. The second group of students underwent treatment by standard desensitization (SD). SD is a type of behavioral therapy developed by Joseph Wolpe (1968). The results showed a significant decrease in the level of math anxiety in the first and second groups of students. However, only the group treated by SD showed more positive dynamics in math-related tasks.

SD treatment has shown good results in studies of math anxiety (Hembree, 1990; Zettle, 2003; Akeb-urai et al., 2020). Zettle (2003) tested the effectiveness of two methods: (1) acceptance and commitment therapy (ACT), and (2) SD. The author concluded that indeed the level of math anxiety decreased with both treatments. However, no improvement in math performance was found with any treatment. Akeb-urai and colleagues (2020) obtained significant results in both reducing the level of math anxiety and increasing the level of math performance when using DS behavioral therapy.

Samuel and Warner (2021) tested the effectiveness of two mixed methods mindfulness and growth mindset on regulating math anxiety and evaluating the self-effectiveness of college students (Samuel & Warner, 2021). The results of the study showed that this combined approach not only reduced math anxiety, but also increased students' confidence in their self-effectiveness when interacting with math. Another study also lead to a multi-component intervention that included: self-directed learning, mindfulness breathing, humor, comic strips, and the use of self-coping statements when solving math problems (Collingwood & Dewey, 2018). Twelve 45-minute sessions over 4 weeks of this intervention improved math performance and self-regulation, but did not significantly affect students' math anxiety and math self-concept.

The creation of comic strips as a cognitive-behavioral intervention was also tested in a later study (Fernandez & Lina, 2020). A comic strip is a form of art therapy used in the treatment of anxiety disorders. This qualitative study involved a 14-year-old student with very low grades in math and significant anxiety during quizzes and tests. With the help of comic strips, the student had to describe the scenario of passing the test in math. Such therapy allowed the student to become aware of his sensitivity to time, describe his feelings of anxiety, and identify specific strategies at certain stages of the test.

Studies have found that controlling negative feelings about math can be achieved through expressive writing. Park and colleagues (2014) conducted an experiment in which university students were asked to write openly about their thoughts and feelings about an upcoming math test (Park et al., 2014). The results showed a significant improvement in math scores for students with high levels of math anxiety that effectively narrowed the performance gap (measured by test scores) between them and students with low math anxiety levels. The authors point out that the positive effect of expressive writing is to free up working memory (WM), the resources which are spent on thinking about the worries about the upcoming test or exam. However, Ganley and colleagues (2021) did not find similar results by testing the effectiveness of several well-known methods, one of which is also writing an expressive letter. The authors even noted that students in the expressive writing condition reported higher levels of anxiety (Ganley et al., 2021).

Integrating writing and math, or more specifically journaling, in math courses, has also been tested as a tool to reduce math anxiety and improve the ability to learn calculus (McCarty & Faulkner, 2020). The Writing Across the Curriculum (WAC) program was offered to university students in a calculus course as an aid for summarizing topics learned and asking questions. Overall, the weekly entries during one semester were positively received by the students; it also helped most students learn calculus and worry less. In general, this experiment could be attributed to the category of methods for improving math as well. However, in the study, the journals were precisely "reflexive", concerning the students' experiences, rather than mathematical concepts.

Improving math

One effective method for reducing math anxiety is to strengthen basic math skills. Studies show that strengthening basic skills can not only reduce math anxiety, but also improve math performance. It is an important point since the problem of math anxiety is considered precisely in the context of poor math performance. The experiment of implementation of an intensive eight-week one-to-one cognitive tutoring program (Supekar et al., 2015) is a prime example. The experiment involved elementary school students (3rd grade), who for eight weeks studied with a tutor according to an adapted math program MathWise (Fuchs et al., 2013). This program aims to improve the knowledge of numbers and increase the speed of the efficiency of counting and the application of computational strategies. The results showed that children with high levels of math anxiety experienced significant reductions in anxiety after tutoring.

Another study examined the impact of peer tutoring on students' math anxiety levels (Moliner & Alegre, 2020). The study involved 420 students in grades 7–9. The authors concluded that peer tutoring for middle school students is very beneficial. Precisely, because mutual learning took place in a group of students of the same age, this contributed to a decrease in the level of their math anxiety. Also, the authors noted that such mutual learning is easier to organize since the students study in the same class.

Tok (2013) in his study tested the know-want-learn (KWL) strategy on 6th graders' to improve their math achievement, metacognitive skills and math anxiety. This strategy was developed by Ogle (1986) and aimed at teaching students to read and work with text. Later it began to be used in teaching various school subjects. KWL strategy was used as an auxiliary tool for solving math problems. Expectedly, the author has found that applying the KWL strategy in the 6th grade math class is effective in improving student achievement in math. However, the KWL strategy has little effect on math anxiety and was no more effective than traditional teaching methods.

As presented above, previous research has demonstrated the efficiency of cross-subject connections (reading and math) in improving academic performance. Another example of the use of this method is the introduction of the history of mathematics in the classrooms of math (Lim & Chapman, 2015). Students of the 11th grade took part in this experiment. History of

mathematics was presented as a tool to improve students' math performance, motivation, and attitude, and to reduce math anxiety. Analysis of the results of the intervention showed a minimal short-term effect on affective measures and a significant long-term positive effect on math performance.

The use of computer technology is being studied in terms of improving math abilities and developing motivation and interest in learning. The impact of tools such as video games, mobile apps, e-books, etc. on the regulation of math anxiety is also being investigated. Researchers used an adapted educational game Number Sense Game (NSG) to develop early computational abilities in elementary school children (Vanbecelaere et al., 2021). This study also involved a second group of children that engaged in a similar educational game but in a non-adaptive version. A three-week intervention showed interesting results. Math anxiety decreased in children who used an adaptive version of the game, and similar results were demonstrated by students from the group with a non-adaptive educational game. In terms of academic performance, adaptive learning turned out to be more effective for students whose knowledge was already at a high level. Conversely, the non-adaptive method helped those students whose level of knowledge was low in the preliminary testing.

Research finds a link between the math anxiety of parents and the subsequent academic performance of their children. Berkowitz and colleagues (2015) presented the interventional study of learning math at home with parents using a specially designed mobile application (Berkowitz et al., 2015). The idea is to improve students' performance in school and reduce parents' anxiety about math. Researchers suggested that joint math classes of a child and a parent at least once a week can improve student performance. As was shown by the results of an experiment conducted during one academic year, the abilities of students using this application improved significantly. The researchers also noted that when parents study math with their children, they can overcome their math anxiety. The authors point out that a short, high-quality communication between parents and children in math at home helps to break the vicious circle of low achievement in math, passed down from generation to generation. However, the improvement in math performance can be seen as an effect of additional exercises that have helped students perform better and parents understand that they do not have to worry about the math.

Methods

Since math anxiety affects math performance, the purpose of this part of the study is to summarize the main findings of recent intervention studies that have examined their effectiveness in the reduction of math anxiety and improvement of math performance. Thus, a description of the basic features of the included studies and the effects of the intervention were presented here. Moreover, the papers were also evaluated for methodological quality using assessment criteria proposed by Dalemans et al. (2008).

Search strategy
According to a bibliometric analysis of publications in various databases of the Web of Science, the growth of interest in the issue of math anxiety occurred in 2012 (see Figure 1, Ersozlu & Karakus, 2019). Therefore, to explore recent research, it was decided to include interventional studies published from the beginning of 2012 to August 2021 (the time of the search in the electronic databases).
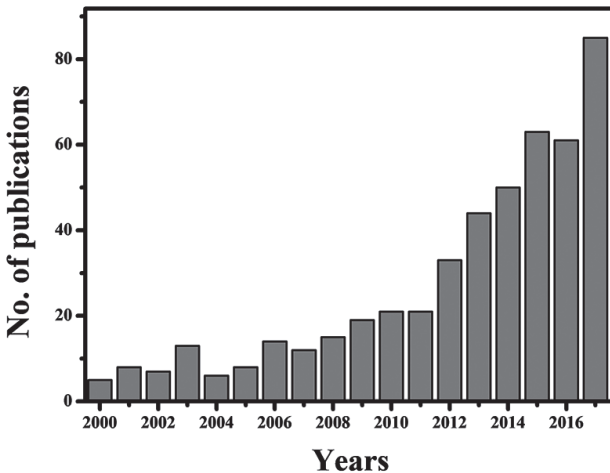
Figure 1. Records of Publications [Ersozlu & Karakus, 2019]
Source: Inspired by Ersozlu & Karakus, 2019.

To identify all relevant studies, a search was performed using the following combinations of terms: ("math anxiety" OR "mathematical anxiety" OR "mathematics anxiety") AND ("treatment" OR "intervention" OR "regulating" OR "reducing" OR "teaching method" OR "teaching strategy" OR "instructional design") in databases such as Web of Science and Scopus.

Inclusion/exclusion criteria
Not every paper with those keywords was suitable enough for this study. Therefore, all found articles were additionally checked against the following criteria: (a) math anxiety and math performance were measured. Studies that measure only math anxiety or only performance in math were excluded, as well as their measurement with other variables such as motivation, learning behavior or self-efficacy, etc.; (b) interventions using neuropsychological stimulation methods were excluded since their use in the educational process is not possible; (c) participants' educational level was from elementary school to university. All theoretical and review articles were excluded. The studies published in a language other than English were excluded. Finally, 15 experimental studies were included in this study.

Coding procedure
The articles that met the criteria were then systematically coded, using a coding sheet developed for the aim of this part of the study. First, the general information about the studies, such as author(s), year of publication, and country were described. Second, each article was analyzed based on sample size and educational stage, interventions (duration and type), and their effectiveness in the regulation of math anxiety and improvement of math performance. Moreover, all studies were divided regarding intervention approach (behavioral interventions, interventions focusing on improving math knowledge and skills).

Results

A complete summary of the included studies' characteristics and outcomes (author(s), year of publication, country, sample, interventions, and their effects on math anxiety and math performance) are shown in Table 1.

Table 1. Summary of basic characteristics and outcomes of the included studies

| | Studies | | | Participants | | Interventions | | | Effectiveness | |
| | | | | | | Behavioral Interventions | | | | |
No.	Author(s)	Publication Year	Country of Study	No. of Participants	Educational Stage	Duration	Type	Math Anxiety	Math Performance
1.	Brunyé, et al.	2013	USA	36	University	2 hours for each test session	(1) Focused breathing; (2) unfocused breathing; (3) worry exercise.	Focused breathing reduced distressing feelings and frees up cognitive resources.	All exercises helped highly anxious students perform a little better on arithmetic tasks. The more significant results were found after performing a focused breathing exercise.
2.	Park, Ramirez & Beilock	2014	USA	80	University	7 min	Expressive writing	Expressive writing helped to free up WM from anxious thoughts.	The method contributed to improving math-anxious students' test scores.
3.	Akeb-urai, Kadir & Nasir	2020	Malaysia	65	College	Six weeks	Systematic desensitization	The intervention demonstrated a significant reduction in math anxiety.	Treatment increased the level of students' math performance.
4.	McCarty & Faulkner	2020	USA	30 (20 analyzed)	University	One semester	Writing across the curriculum (WAC)	6 students found it helped them to be less anxious (5 students gave a negative answer, and the rest were neutral or did not answer).	17 students felt it helped them to learn (3 answered negatively).
5.	Passolunghi, De Vita & Pellizzoni	2020	Italy	224	Elementary school (4th grade)	Eight weeks	Math anxiety training	Math anxiety training helped to reduce math anxiety.	Training did not affect students' math performance.

Table 1. (continued)

No.	Author(s)	Publication Year	Country of Study	No. of Participants	Educational Stage	Duration	Type	Math Anxiety	Math Performance
	Studies		**Participants**				**Interventions**		**Effectiveness**
							Behavioral Interventions		
6.	Ganley, et al.	2021	USA	300	College	5 min or less for one of the intervention	(1) Reappraisal as a challenge; (2) reappraisal as excitement; (3) expressive writing; (4) look ahead.	None of the interventions affected reports of state anxiety. Students in the expressive writing condition reported higher levels of state anxiety.	The interventions did not affect math performance.
					Interventions Focusing on Improving Math Knowledge and Skills					
1.	Jansen, et al.	2013	Netherlands	207	Elementary school (3th–6th grades)	Six weeks	Computer-adaptive practice with a pre-set success rate (Math Garden)	Math anxiety decreased equally for children in experimental groups and control group.	Math performance increased more for the experimental group in the condition with the highest success rate.
2.	Tok	2013	Turkey	55	Elementary school (6th grade)	Eight weeks (4h/week and a total of 32h)	Know-Want-Learn (KWL) strategy	The strategy was not effective in reducing students' math anxiety.	The strategy was effective in increasing students' math performance.
3.	Lim & Chapman	2015	Singapore	103	High school (11th grade)	Seven months	History as a tool to teach math	The intervention demonstrated short-term minimal effects.	A highly significant short and long-term effects were observed.
4.	Núñez-Peña, Bono & Suárez-Pellicioni	2015	Spain	166	University	Academic year	Formative assessment system	The authors concluded that highly math-anxious students gained confidence in their ability to learn the subject after the intervention.	Students who consider feedback classes to be useful received higher exam grades.

Table 1. (continued)

	Studies			Participants			Interventions		Effectiveness	
							Behavioral Interventions			
No.	Author(s)	Publication Year	Country of Study	No. of Participants	Educational Stage	Duration	Type	Math Anxiety	Math Performance	
5.	Supekar, et al.	2015	USA	28	Elementary school (3rd grade)	Eight weeks	One-to-one cognitive tutoring	The intervention obtained a significant reduction in math anxiety.	Students' math performance was improved after the tutoring.	
6.	Tok, Bahtiyarb & Karalök	2015	Turkey	42	Elementary school (6th grade)	Six weeks (4h/week and a total of 24h)	Teaching math creatively	The intervention had a positive result in a reduction of math anxiety	The applied method increased students' math performance.	
7.	Turel & Sanal	2018	Turkey	94	University	Four weeks	ARCS based e-book	The e-book had a significant effect on reducing students' math anxiety.	Students using the e-book performed significantly better on the math test.	
8.	Chen	2019	Taiwan	82	Elementary school (6th grade)	Six weeks	Mobile Augmented Reality (AR)	Students who used mobile AR had less anxiety than those who did not use mobile AR.	AR improved students' ability in math (algebra and geometry).	
9.	Passolunghi, De Vita & Pellizzoni	2020	Italy	224	Elementary school (4th grade)	Eight weeks	Math strategy training	Math strategy helped to reduce math anxiety.	The strategy contributed to the improvement of math performance.	
10.	Vanbecelae-reet al.	2020	Belgium	84 (78 analyzed)	Elementary school (1st grade)	Three weeks	Number Sense Game (NSG) (1) adaptive digital educational game; (2) nonadaptive digital educational game.	In both conditions, children's math anxiety scores were lower after the training.	The first condition was more effective than the second. In particular, (1) effective for children with high prior knowledge, and (2) effective for children with low prior knowledge.	

Source: Author's research.

Table 2. Studies' quality assessment

No.	Study/Author	Informativity							External Validity					Internal Validity						Overall
		a	b	c	d	e	f	sum	g	h	i	j	sum	k	l	m	n	o	sum	
1.	Jansen, et al. (2013)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	+	5	14
2.	Tok (2013)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	+	5	14
3.	Lim & Chapman (2015)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	+	5	14
4.	Supekar, et al. (2015)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	+	5	14
5.	Tok, Bahtiyarb & Karalök (2015)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	+	5	14
6.	Passolunghi, De Vita & Pellizzoni (2020)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	+	5	14
7.	Ganley, et al. (2021)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	+	5	14
8.	Brunyé, et al. (2013)	+	+	+	+	+	+	6	–	+	+	+	3	+	–	+	+	+	4	13
9.	Núñez-Peña, Bono & Suárez-Pellicioni (2015)	+	+	+	+	+	+	6	–	+	+	+	3	+	–	+	+	+	4	13
10.	Turel & Sanal (2018)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	–	4	13
11.	Chen (2019)	+	+	+	+	+	+	6	–	+	–	+	2	+	+	+	+	+	5	13
12.	Akeb-urai, Kadir & Nasir (2020)	+	+	+	+	+	+	6	–	+	+	+	3	+	+	+	+	–	4	13
13.	Vanbecelaere, et al. (2020)	+	+	+	+	+	+	6	–	+	+	+	3	+	–	+	+	–	3	12
14.	Park, Ramirez & Beilock (2014)	+	+	–	+	+	+	5	–	+	–	+	2	+	+	+	+	–	4	11
15.	McCarty & Faulkner (2020)	+	+	+	+	+	+	6	–	+	–	+	2	+	–	+	–	–	2	10

Note: a – the purpose of the study is clearly described; b – the method of the data collection is clearly described; c – the main outcomes to be measured are clearly described in the introduction or methods section; d – the description of the characteristics of the population is clearly described; e – the response rate is ≥ 70%, or the information of the no responders is sufficient; f – the main findings of the study are clearly described: simple outcome data should be reported for all major findings; g – the subjects asked to participate are representative for entire population from which they were recruited; h – the inclusion and exclusion criteria are described; i – the age range is specified; j – the study period is described; k – the data are prospectively collected; l – a comparison group is used and properly described; m – the measurement instrument(s) is/ are described; n – the main outcome measures used are accurate (valid and reliable); o – age specific and gender specific outcomes are reported.

Source: Author's research inspired by Dalemans et al., (2008).

Table 2 presents the quality assessment of the selected studies ranging from higher quality to lower quality on the assessment, in order of the year. Assessment consists of 15 items corresponding to 3 aspects of studies: informativity (6 items), external validity (4 items), and internal validity (5 items) (Dalemans et al., 2008).

Across the 15 studies, the sample sizes ranged from 30 to 300. Depending on the number of methods examined in some research, the participants were divided into groups. Since almost all studies use different treatments or teaching methods, we cannot say anything about the relationship between an intervention's effectiveness and its sample size.

As mentioned before, a search of studies was conducted across the level of elementary school and university. It can be noted that interventions to reduce anxiety responses were most often carried out at the university or college level. Whereas, strategies to improve math skills were mostly applied in elementary school. Overall, more interventional studies that were found employed math-improvement strategies.

Considering the country where the research was conducted, it must be recognized that the leader in the study of the phenomenon of "math anxiety" is the United States, which presented 5 interventions. According to the review results, it can be observed that Turkey has conducted three intervention studies. In general, this area of research has become quite popular nowadays, however, it is still novel in some countries.

The duration of the interventions also varied across studies. In particular, based on the information provided by the researchers, the duration of the interventions ranged from 5 minutes or less to one academic year. Behavioral interventions were generally less time-consuming than methods of improving math knowledge and skills. Methods that focus on improving math are generally time-consuming, but differ depending on the instruments used.

An analysis of the researchers' findings showed that most interventions are effective in reducing math anxiety and improving math performance. However, some results are contradictory, for instance, expressive writing in one study had a positive effect on both reducing the level of math anxiety and improving the results of the math test (Park et al., 2014). In another study, the same method, on the contrary, led to an increase in the level of anxiety among students (Ganley et al., 2021).

The quality assessment of studies that met the search conditions showed that all 15 articles are quite informative. The sample size in all studies is rather small, thus participants are not representative of the entire population from which they were recruited. In general, the quality of studies does not differ depending on the year of publication.

Conclusions

One of the purposes of this study was to find out what types of interventions researchers suggest for the regulation of math anxiety. The results of the review of articles showed that interventions can be divided into two categories: (1) behavioral interventions, and (2) interventions focusing on improving math knowledge and skills. The first category of methods is aimed at treating anxiety or reducing anxiety reactions through a change of state of mind, relaxation, breathing exercises, expressive writing, etc. The second category of methods is aimed at improving knowledge in math through the use of cognitive training programs, teaching strategies, mobile applications, adapted digital books, educational digital games, etc.

The second purpose of the study was to summarize the impact of recent intervention research on math anxiety and math performance. The main finding demonstrated that the first category of interventions may not always have a positive effect on math performance, but may reduce math anxiety among students. The second category of interventions is mostly equally beneficial in improving math performance as well as reducing math anxiety.

Each category has its strengths and weaknesses. Interventions focusing on math ability require more resources. Intensive cognitive programs with a tutor are rarely possible to organize for each student experiencing math anxiety. Excessive use of computer technology steals a lot of time and sometimes distracts from the main idea of the lesson being studied. Therefore, those interventions that can be used in the natural educational process are of the greatest interest to researchers and math teachers. Behavioral interventions, on the contrary, most often do not require a lot of resources. Many techniques can be used just before taking a math test to free up anxious thoughts from working memory. However, if a student has problems with understanding

mathematical concepts, then behavioral interventions will not help to improve his or her math knowledge and skills.

Considering these results, and the fact that the second category of methods was used more often, it can be assumed that the effect of math performance on math anxiety seems to be more pronounced. However, we still cannot clearly state which intervention was most effective for students. Nevertheless, this literature review can demonstrate the main results of the present state in the field of math anxiety, particularly its potential regulation or treatment.

Future research should pay attention to pre-existing instructional methods that had a positive effect on students' math achievements but were considered only in the context of academic performance, increasing cognitive interest, or improving attitude towards math. A combination of focusing on developing math abilities (interest and attitude) and using behavioral treatment may be perhaps the most promising intervention.

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