

The Effect of Mathematics Anxiety on Math Performance

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Abstract: Mathematics anxiety has long been a hotly debated topic of research in education and psychology, and studies have confirmed the prevalence of mathematics anxiety among learners of different ages and its impact on learners' mathematics performance. This literature review attempted to organize the discuss two research points under the topic of mathematics anxiety. The first part focuses on analyzing the mediating factors between mathematics anxiety and outcomes in order to clarify the mediators of their effects and the process of mediation. The second part is related to the differences of mathematics anxiety in different age groups and describes the causes of mathematics anxiety in different groups to provide strategies for learners to improve their mathematics performance and directions for educators to improve their teaching. Based on these arguments, a foundation for subsequent research on math anxiety is provided. However, more empirical studies are needed to justify the findings and hypotheses.

Keywords: mathematics anxiety, mathematics performance, control-value theory, students

1. Introduction

Mathematics anxiety (MA) has been experienced by most students more or less in their lives. The reasons why people produce math anxiety and the impact of MA on mathematics achievement are topics that have come under debate and are worth reflecting on in current years. Mathematics anxiety, as a type of academic emotion, brings changes to people's lives, especially for those who are in the process of mathematics learning and their mathematics performance. There is much literature that reveals the connection between MA and math proficiency. However, it is relatively fragmented and lacks a framework for this topic. Therefore, this literature review article will be intent on extracting insights into the relationship between the two factors based on the control-value theory [1]. The following aspects will be discussed: (1) an overview of MA; (2) the causes of MA; (3) the age characteristics of MA; and (4) how MA impacts math achievement.

2. Methods

The use of the academic databases Google Scholar and Web of Knowledge were involved in the process of extensive literature search. The following search terms were input together with their derivatives: math anxiety, anxiety, mathematics performance, age, and mediating. Studies included that explanation of anxiety, causes of anxiety, relationship between math anxiety and math performance, age-stage differences in math anxiety, mechanisms influencing the relationship

between math anxiety and math outcomes. There are some empirical researches were identified from the literature.

3. Literature Review

3.1. Definition

Math anxiety is one of anxiety as a feeling and emotion, and it would have an impact on students' performance in mathematics, which can be discussed and clarified based on control value theory. Anxiety is seen as a type of emotion that contains several elements, namely affective, cognitive, motivational, expressive, and physiological, corresponding to expressions of tension, worry, avoidance, anxious facial expressions, and peripheral physiological activation [1]. Synthesizing the literature on the definition of mathematical anxiety, it has been defined as: 'Stress and worry affect one's capacity to cope with numbers and come up with math problems in a range of academic and real-world contexts' [2]. The theory of control-value implies that emotions are one of influencing factors on the social atmosphere in classrooms and educational institutions, as well as student interest, engagement, accomplishment, and personality development [1]. Therefore, for the mathematically anxious group, their mathematical performance is influenced by their mathematical anxiety.

3.2. The Mediating Mechanism of Maths Anxiety and Maths Performance

As a type of anxiety, maths anxiety arises when facing maths or maths-related situations, and it affects one's maths performance. Math performance and math anxiety may be related by various of psychological factors, such as working memory (WM), state anxiety, motivation, self-efficacy, beliefs, gender stereotypes, teacher feedback and parental expectations. These factors can interact with each other, forming a complex dynamic system that influences one's attitude and outcome in maths.

The most widely accepted hypothesis named WM interference explains that there is a direct connection between math anxiety and math achievement. WM is a cognitive system that enables us to store and process information in a short period of time. WM is crucial for many cognitive tasks, especially for maths, which requires keeping and manipulating numbers, symbols and procedures in mind. According to the WM interference hypothesis, maths anxiety consumes WM resources that could otherwise be used for maths processing. Therefore, maths anxiety reduces the efficiency and accuracy of maths performance.

The WM interference hypothesis is supported by empirical evidence from various studies. For example, Ashcraft and Kirk [3] found that high-MA individuals performed worse than low-MA individuals on complex arithmetic problems that required more WM resources. Additionally, they discovered that during mathematical activities, high-MA individuals displayed greater activity in the region of brain linked to emotion regulation and decreased activation in brain areas associated with WM. Similarly, Ma and Xu stated that maths anxiety had a negative impact on maths performance only when the task difficulty was serious, and the WM demand was high. They also found that mathematical anxiety negatively affect on WM capacity evaluated by a digit span task [4].

The WM interference hypothesis also suggests some possible interventions to alleviate the vitiating impact of maths anxiety on maths performance. For example, one could try to reduce the WM load by simplifying the maths problems or providing external aids such as calculators or notes. One could also try to increase the WM capacity by training the WM skills or using mnemonic strategies. One could also try to reduce the maths anxiety level by using relaxation techniques or cognitive reappraisal.

Another hypothesis that explains how maths anxiety negatively affects on maths outcomes is the state anxiety hypothesis. State anxiety is a type of transient anxiety that occurs in specific situations, and it affects one's emotions, cognition and behaviour. The state anxiety hypothesis emphasises the distinction between maths anxiety and state anxiety and the direct impact of state anxiety on maths performance. Based on the state anxiety hypothesis, when facing maths, people who are high in maths anxiety experience heightened state anxiety, and this state anxiety interferes with their attention, concentration and decision-making in maths. The state anxiety hypothesis is also supported by empirical evidence from various studies. For example, Hembree [5] figured out that high-MA individuals reported more negative affect and more physiological arousal before and during maths tests than low-MA individuals. He also found that high-MA individuals showed more errors of omission and commission on maths tests than low-MA individuals. Similarly, Beilock et al. [6] found that high-MA female teachers transmitted their state anxiety to their female students during maths instruction, which resulted in lower maths achievement for these students. The state anxiety hypothesis also suggests some possible interventions to alleviate the negative impact of state anxiety on maths performance. For example, one could try to reduce the state anxiety level by using relaxation techniques or cognitive reappraisal. One could also try to increase coping skills by using problem-solving strategies or seeking social support. One could also try to change the situational factors by creating a positive and supportive learning environment or reducing evaluative pressure.

A further hypothesis that explains the negative relationship between maths anxiety and maths performance is the motivation-self-efficacy-beliefs hypothesis. Motivation refers to one's interest, value and desire for a goal or activity. Self-efficacy refers to one's confidence in their ability to successfully complete a task or activity. Beliefs refer to one's views or attitudes towards themselves, others or the world. The motivation-self-efficacy-beliefs hypothesis suggests that maths anxiety affects one's motivation, self-efficacy and beliefs about maths. According to this hypothesis, people who are high in maths anxiety might lack interest, confidence and value in maths learning, leading them to invest less effort and resources in maths. The motivation-self-efficacy-beliefs hypothesis is also supported by empirical evidence from various studies. For example, Gunderson et al. [7] found that maths anxiety was negatively impacted by intrinsic motivation and self-efficacy in maths for both boys and girls. They also found that maths anxiety was negatively impacted by maths achievement for girls but not for boys. They explained that girls may be more vulnerable to the negative effects of maths anxiety due to their lower self-efficacy and higher stereotype threat in maths. Similarly, Ma and Xu [4] found that maths anxiety had a negative effect on maths performance only when the motivation level was low, and the self-efficacy level was low. They also found that maths anxiety had a negative effect on motivation and self-efficacy measured by a questionnaire. The motivation-self-efficacy-beliefs hypothesis also suggests some possible interventions to alleviate the negative impact of maths anxiety on maths performance. For example, one could try to increase the motivation level by enhancing the interest, value and relevance of maths learning. One could also try to increase the self-efficacy level by providing positive feedback, modelling and mastery experiences in maths. One could also try to change the beliefs level by challenging the negative or irrational beliefs about maths, such as fixed mindset, helplessness or stereotype threat.

Finally, the social-environmental factors are also considered as a hypothesis explaining the negative relationship between the maths anxiety and maths achievement. Social-environmental factors are external conditions or pressures that influence one's behaviour and psychology. The social-environmental hypothesis suggests that maths anxiety is influenced by social and environmental evaluations of maths ability, such as gender stereotypes, teacher feedback and parental expectations. According to this hypothesis, people who are high in maths anxiety may be

exposed to negative evaluations or pressures on their maths ability from society and environment, which may undermine their self-esteem and self-concept in maths. The social-environmental hypothesis is also supported by empirical evidence from various studies. For example, Beilock et al. [6] realized that female teachers with high-MA transmitted their stress from mathematics to their female students through their implicit attitudes and explicit behaviors in maths instruction. In addition, they discovered that this effect of transmission was influenced by the students' acceptance of the gendered belief that boys excel girls in maths. Similarly, Gunderson et al. [7] found that parental expectations were positively related to maths anxiety for both boys and girls. They also found that parental expectations had positive relation with maths achievement for boys but negative relation with maths achievement for girls. They explained that parental expectations might create pressure or a challenge for children depending on their gender and self-efficacy in maths. The social-environmental hypothesis also suggests some possible interventions to alleviate the negative impact of social-environmental factors on maths anxiety and maths performance. For example, one could try to reduce exposure to negative evaluations or pressures by avoiding or confronting the sources of criticism or stigma in maths. One could also try to increase the exposure to positive evaluations or support by seeking or creating sources of praise or encouragement in maths. One could also try to change the social norms or expectations by promoting or advocating the diversity and equality of maths ability among different groups.

These four hypotheses are not mutually exclusive but rather complementary and interrelated. They can be integrated into a comprehensive model that explains the mechanism of maths anxiety and maths performance. The model can be summarized as follows: maths anxiety is influenced by social and environmental factors, such as gender stereotypes, teacher feedback and parental expectations. Maths anxiety affects one's motivation, self-efficacy and beliefs about maths, which in turn affects one's effort and resource allocation in maths. Maths anxiety also consumes WM resources and induces state anxiety, which impairs one's attention, concentration and decision-making in maths. These cognitive and affective processes mediate the negative relationship between maths anxiety and maths performance. The model also implies that there may be individual differences in susceptibility and vulnerability to maths anxiety and its consequences, depending on one's personality, coping strategies and learning styles.

3.3. Manifestations of Math Anxiety in Different Age Groups

Math anxiety is a common phenomenon among students of different age groups. It refers to the emotional state of tension, worries, fear and so on, that individual experiences when encountering numerical challenges, applying mathematical principles, acquiring mathematical skills or undergoing mathematical assessments. Stress from mathematics is able to negatively impact on students' math motivation, performance, creativity and development. However, the causes and consequences of math anxiety may vary depending on the age group of the students. From a psychological perspective, this paper will discuss the differences and impacts of math anxiety for three age groups: early childhood learners and elementary school students, adolescents and higher education students.

Low-age students involving early childhood learners and elementary school students are in the stage of developing their basic mathematical skills and concepts. The extent of their mathematics anxiety is affected by several factors; these include their self-concept, self-efficacy and interest in mathematics, which are derived from their previous learning experiences and outcomes. Math self-concept is the cognitive evaluation of one's own math ability, which is formed by internal and external feedback. Mathematics self-efficacy denotes one's perception of their ability to perform mathematics tasks successfully, which is shaped by their prior experiences and expectations of achievement. Math interest is the degree of preference for math activities, which is affected by

intrinsic and extrinsic factors. These three psychological constructs influence children's math motivation and math achievement. Research has shown that children with low math self-concept, low math self-efficacy and low math interest tend to have higher levels of math anxiety, which in turn impair their math performance and math development [8-10].

Adolescents are in the stage of expanding their mathematical knowledge and skills. Their cognitive style, emotion regulation, and social comparison may influence their math anxiety. Cognitive style is the way and strategy that individuals use in information processing, which can be classified into two types: analytic and holistic. Analytic cognitive style is characterized by focusing on details, rules and logic, while holistic cognitive style is characterized by focusing on patterns, intuition and context. Emotion regulation is the ability to control and manage one's own emotions, which can be divided into two types: adaptive and manipulative. Adaptive emotion regulation is characterized by using positive strategies such as reappraisal, problem-solving and seeking support, while manipulative emotion regulation is characterized by using negative strategies such as suppression, avoidance and rumination.

Social comparison is the process of mutual evaluation between oneself and others, which can be divided into two types: upward and downward. Upward social comparison is characterized by comparing oneself with someone who is superior or more successful, while the downward social comparison is characterized by comparing oneself with someone who is worse or less successful. Research has shown that adolescents with holistic cognitive style, manipulative emotion regulation and upward social comparison tend to have higher levels of math anxiety, which in turn impair their math interest and math creativity [3, 5, 11].

Higher education students are in the stage of applying their mathematical knowledge and skills to various domains. Their math anxiety may be influenced by their meta-cognition, goal orientation and feedback sensitivity. Meta-cognition is the monitoring and regulation of one's own cognitive processes and strategies, which can be divided into two types: meta-cognitive knowledge and meta-cognitive skills. Meta-cognitive knowledge is the awareness of one's own strengths and weaknesses, task demands and available resources. Meta-cognitive skills are the ability to plan, monitor and evaluate one's own learning process. Goal orientation is the outcome or value that individuals pursue when engaging in an activity, which can be divided into two types: mastery and performance. Mastery goal orientation is characterized by focusing on learning for its own sake, understanding the material and improving oneself. Performance goal orientation is characterized by focusing on demonstrating one's ability, obtaining favorable evaluation or avoiding unfavorable evaluation. Feedback sensitivity is the degree of reaction to external evaluation or reward and punishment, which can be divided into two types: feedback-seeking and feedback-avoiding. Feedback-seeking is characterized by actively soliciting feedback from others to improve one's performance or confirm one's competence. Feedback-avoiding is characterized by avoiding feedback from others to protect one's self-esteem or avoid negative consequences. Research has shown that higher education students with low meta-cognitive knowledge, low meta-cognitive skills, performance goal orientation and feedback-avoiding tend to have higher levels of math anxiety, which in turn impair their math confidence and math achievement [1, 12, 13].

In conclusion, this paper has discussed the differences and impacts of math anxiety for different age groups from a psychological perspective. It has shown that math anxiety may be influenced by various psychological factors such as self-concept, self-efficacy, interest, cognitive style, emotion regulation, social comparison, meta-cognition, goal orientation and feedback sensitivity. It has also shown that math motivation, performance, creativity and development from students might be negatively impacted by math anxiety. Therefore, it is crucial to comprehend the causes and consequences of math anxiety for different age groups and to provide appropriate interventions to reduce math anxiety and enhance math learning.

4. Implications

As a negative emotional reaction to maths, Maths anxiety is can interfere with maths performance and learning [3]. Maths anxiety is prevalent among students of different age groups and can have detrimental effects on their maths motivation, achievement, creativity and development [5, 8, 10]. Therefore, it is important to understand the causes and consequences of maths anxiety for different age groups and to provide appropriate interventions to reduce maths anxiety and enhance maths learning. There will be some strategies for reducing maths anxiety and improving maths achievement for different ages of learners should be considered.

As for preschool and elementary school children, Providing positive and supportive feedback is important to enhance their maths self-concept and self-efficacy. Their curiosity and exploration of maths activities should be encouraged to foster their maths interests. Concrete and visual materials should be used to help them understand maths concepts and skills. Maths should be made fun and meaningful by connecting it to their daily life and interests, and negative stereotypes and labels about maths ability or gender should be avoided.

Adolescents should be helped to develop an analytic cognitive style by teaching them how to use logic, rules and details in maths problem-solving [11]. Adaptive emotion regulation strategies including reappraisal, problem-solving and seeking support should be taught to cope with maths anxiety. A healthy social comparison should be promoted by emphasizing self-improvement rather than competition or evaluation. Opportunities for creative and collaborative maths learning should be provided to enhance their maths interests and creativity [11, 14].

Considering higher education students, their meta-cognitive knowledge and skills should be enhanced by teaching them how to plan, monitor and evaluate their own maths learning process. A mastery goal orientation should be fostered by emphasizing learning for its own sake, understanding the material and improving oneself rather than demonstrating one's ability or obtaining favourable evaluation [12]. Feedback-seeking behaviour should be encouraged by providing constructive and timely feedback to improve their performance or confirm their competence. Various resources and support should be provided to help them overcome maths difficulties or challenges [13, 15].

The literature review was compiled not only to provide different ages learners and educators with methods to improve students' mathematical performance, but also to further sort out the mechanism of the role between mathematical anxiety and mathematics performance to provide more support and basis for the study in the future.

5. Conclusion

Math anxiety has always been a hot topic in education and academia. For learners, it has been confirmed that their final math performance is affected by their math anxiety. This paper discussed learners who cannot be with their age group and provides directions and strategies for educators and learners to improve their teaching and math performance. The summary found that students of different age stages generally have math anxiety. The anxiety of young children mainly comes from their self-math concept, self-efficacy and math interest. Adolescents are mainly affected by cognitive style, emotion regulation and social comparison. Higher education students are impacted by meta-cognition, goal orientation and feedback sensitivity. Therefore, based on the influencing factors of different age stages, the article further discussed the mediating mechanism of math anxiety and mathematics performance, comprehensively analyzes it, and finally provides more evidence for further research on math anxiety.

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