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Math Anxiety – A Literature Review on Confounding Factors

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Abstract: Math anxiety presents adverse psychological effects, inducing feelings of dread, panic, helplessness, and mental disorganization. Researchers hypothesize that feelings of anxiety are highly influential on a student's working memory during mathematical computations, coupled. with over-reliance on high-stakes diagnostic math exams which strengthen negative mindsets, ultimately presenting math as a high-risk subject. Researchers question why and how an individual develops math anxiety, though an agreed-upon answer has yet to be accepted. This purpose of this paper is to investigate global literature through themes commonly associated to a person's math anxiety. The paper includes one' innate predisposition to mathematical problem solving, the effects of one's previous math performance, as well as environmental impacts such as education systems, familial relationships, and resources, as well as society-held viewpoints and clichés a student faces while approaching math. The paper concludes with tactics for a student's success in alleviating math anxiety and draws conclusions on future work needed academia, which centers around data driven research on social stereotypes, the impacts of support in learning environments, and the impacts of math-anxiety in future education and career paths.

Keywords: *Math Anxiety; Math-anxious; Math Education.*

Introduction

Math anxiety is defined as the increased psychological response and the negative emotions an individual faces when manipulating numerical problems or evaluating numerical solutions (Paechter et al., 2017) (Luttenberger et al., 2018). Math anxiety proves to be a widespread problem, impacting adolescents and adults worldwide. The Organization for Economic Co-operation and Development (OECD) is a meeting of 37 democratic and market-based economy governments who cooperate forming policy standards aimed towards sustainable economic growth. Students in the 34 out of 37 reporting countries find 59% of students ages 15 – 16 describe feelings of worry regarding the level of difficulty of their math class. Thirty-three percent of these students report feelings of tenseness when working on math homework, with an additional 31% experiencing nervousness when practicing math problems (OCED, 2013). An estimated 93% of adults in the United States face some level of math anxiety (Blazer, 2011), with an estimated 17% percent of the United States population experiences a high level of math anxiety (Ashcraft & Moore, 2009). While research and practice acknowledge that math anxiety is a trending international issue, mathematics is more than just a school subject, but a relationship between self-discipline and problem-solving skills as people face predispositions, stereotypes, and environmental factors which sway their confidence (Tobias, 1995). Math anxiety presents adverse psychological effects, as one's faces feelings of fear and panic while trying to problem solve. Current research hypothesizes the anxiety produced during mathematical computations is highly influential on a student's working memory. Educational systems are over-reliance on high-stakes diagnostic math exams. Students face the grave consequences of poor exam marks, while navigating the mental disorganization brought on by math anxiety. This environmental strengthens negative mindsets, ultimately presenting math as a high-risk

subject. Available research questions why and how an individual develops math anxiety, with an agreed-upon answer yet to be accepted, and as such requiring further investigation.

Literature Review

Math anxiety has many adverse psychological effects, inducing feelings of dread, panic, helplessness, and mental disorganization. Those who experience math anxiety also face physiological symptoms including increased heart rate, clamminess, nausea (Luttenberger et al., 2018). Math anxiety can also lead to behavioral impacts as students avoid advanced math classes and procrastinate homework. In the educational setting, these symptoms encourage a student's apprehension toward the subject, only to be reinforced by poor performance in math classes (Luttenberger et al., 2018) (Taleyarkhan et al., 2020). Thus, math anxiety produces serious obstacles for students, impacting overall learning, reaffirming personal doubts and impacts personal and professional opportunities (Tobias, 1995) (Luttenberger et al., 2018).

Researchers question why and how an individual develops math anxiety, though an agreed-upon answer has yet to be accepted. Theorized origins for the development of math anxiety commonly revolve around the complex relationships between a person's personality and environmental factors (Blazer, 2011).

Predispositions to Math Anxiety

Students who face predispositions towards generalized anxiety, those who struggle with temperament and anger management, and those who have low-self-esteem may face an increased challenge in their approach to math (Blazer, 2011). These students are prone to negative learning behaviors showing avoidances and devoting less time to practice and study. Predispositioned students may also face issues effectively organizing their learning environments, may face difficulties in time management, and may lack self-discipline and concentration during a study session (Luttenberger et al., 2018). Mathematical intuition and fluency depend strongly upon consistent practice and perseverance (Lucietto et al., 2020). Individuals who show these predispositions likely fall into a cyclical pattern as they struggle to study and prepare properly, resulting in poor performance during examinations (Luttenberger et al., 2018). Research reports a strong negative relationship between a student's math anxiety and examination scores (Taleyarkhan et al., 2020). Over-reliance on high-stakes diagnostic math exams strengthens negative mindsets, increases testing stress, and reinforces the subject being a high-risk activity (Blazer, 2011).

Effects on Math Performance

Math anxiety is accepted as a non-intellectual-based performance factor; students have shown complete understanding of mathematical concepts, though, during testing, anxiety limits their ability to produce quality answers (Blazer, 2011). The Attention Control Theory states that the cognitive processing required in mathematical fluency depends on a top-down goal-driven system influenced by expectations and a stimulus-driven system influenced by prominent environmental stimulants. The anxiety a student feels disrupts the balance of these two systems, as the stimulus-driven systems become dominant. This reduces one's ability to focus on the task-focused goal of mathematical computation, as cognitive processing becomes impaired by irrelevant environment stimuli (Luttenberger et al., 2018). Researchers hypothesize

that feelings of anxiety are highly influential on a student's working memory during mathematical computations. These impairments decrease the fluency, or one's ability to approach computations efficiently and systematically (Paechter et al., 2017). Math anxiety also compromises reading processes and speed as the student can no longer ignore distractions or irrelevant information (Luttenberger et al., 2018).

Personal Impacts of Math Performance

Outside of antecedents such as high-stress levels and preexisting anxieties, personal and environmental characteristics also have evidence of influence on increased rates of math anxiety. While the indication that gender inequality in United States math performance has faded societal partiality has lasting effects, as it once stereotyped men were superior in math (Paechter et al., 2017) (Lucietto et al., 2020). Testing at secondary and tertiary levels of education find females score higher on generalized math anxiety when compared to males, though content-specific results are more ambiguous (Luttenberger et al., 2018). While testing at a secondary level, gender bias is confirmed, holding true for all grades (Carey et al., 2017). PISA results show females (ages 15 - 16) test higher in math anxiety, numerical fluency, testing, and math classroom settings (OCED, 2013). University level testing shows mixed evidence, as results show females have higher testing anxiety, while finding males score higher in numeric anxiety (Balogˇlu & Koçak, 2006). Other studies show significant variability between the genders in all aspects tested of math anxiety (Cipora et al., 2015) (Paechter et al., 2017) (Lucietto et al., 2017). Varying results in the literature suggest that further research is necessary. Higher math anxiety for females in secondary education may be attributed to society's persuasive messages relate to women's inferiority in science, technology, engineering, and math (STEM) (Paechter et al., 2017). The long-lasting effects of math woes emerge as female students internalize this stereotype, and may carry math anxiety into adulthood, although the climate and psychology around females and math is changing. (Taleyarkhan et al., 2020).

Internalized stereotypes influence math anxiety, as children overestimate the difficulty of a task due to lowered self-esteem (Luttenberger et al., 2018). These self-deprecatory thoughts and actions negatively impact learning behaviors as children become anxious and avoidant (Lucietto et al., 2020). Self-efficacy and self-concept, influenced by stereotypes, are also contributing factors in feelings of anxiety as related to math. Mathematics is a relationship between one's self-discipline and tier problem-solving skills (Tobias, 1995) A person must believe that they are capable of numeric problem solving and that this success is measurable in the academic realm (Luttenberger et al., 2018) (Lucietto et al., 2020). The PISA demonstrates the positive relationship between self-efficacy, self-concept, and performance and their negative relationship to math anxiety (OCED, 2013). Still, self-efficacy and self-concept are variable and do not provide accurate details for a person's math competency. Prior knowledge and motivation in math can strongly influence one's self-efficacy. High self-efficacy can boost a student's performance, leading to a higher self-concept and reducing anxiety (Luttenberger et al., 2018). However, as discussed previously, math anxiety affects a person's working memory. Despite one's competency in the subject, math anxiety can distract one's task focus and lower performance. Lower self-efficacy can have lasting

effects, expectations and persistence dwindle (Lucietto et al., 2020).

Environmental Impacts for Increased Math Anxiety

Environmental characteristics are also a significant contributor to a child's attitude towards math. Examples of environmental characteristics include educational values, influences of culture, and significant role models in one's life (Blazer, 2011). Educational values can incorporate schooling types, such as public, private, or homeschooling. People of significance can also play significant roles in education, such as family structure, marital status, siblings, and extended family (Lucietto et al., 2020).

Educational Environment

Teachers, faculty, and staff in the school environment play a vital role in shaping a child's perception of math. A teacher's approach and attitude towards math provide the foundations for a child to grow. As teachers personify their own bias, they may spread the false idea that math is a natural ability or that mathematical success depends on gift and intellect (Luttenberger et al., 2018). Elementary school teachers must be mindful in their approach, as their math anxiety and approach to numerical problem solving proves significantly influential (Blazer, 2011). Research suggests teachers encourage critical thinking and conceptual understanding (Haralson, 2002) (Geist, 2010). Evidence also suggests that math instruction should place less emphasis on receiving the correct answer and computation speed but emphasize the procedure and work needed for the result (Woodard, 2004) (Geist, 2010). Education should highlight math as a decision-making tool, as students understand and learn theory. Studies show that children taught in the practices on memorization and speed show less confidence in problem-solving skills and higher rates of math anxiety (Haralson, 2002) (Geist, 2010).

Parental Education

Parents and family structure shape a child's perception and self-efficacy towards math using their educational values and attitudes. Research shows family characteristics significantly impact student motivation and overall academic achievement as parental encouragement impacts a child's self-confidence and abilities, objective and subjective alike (Luttenberger et al., 2018) (Lucietto et al., 2020). A parent's attitude towards math is also a foundation of reference for how a child views his or her math skills. Family members offer children additional resources, sharing their knowledge, and driving the child to compete (Lareau, 2002) (Chiu & Xihua, 2008). Henceforth, family members with more education, knowledge, and experience offer a child more learning opportunities and academic resources to capitalize upon (Lareau, 2002).

Family Environment

Education affects the availability of future opportunities, and children raised in disadvantaged families show evidence of lower-income and socioeconomic classes, as a guardian's economic and education difficulties later impact their child's future (Chiu & Xihua, 2008). Children from two parents often have a higher socioeconomic status and have more access to educational recourses such as books (Lareau, 2002). Research shows children of two parents' households are also more involved in the child's education, such as communication with the

teacher, and spend more time as a family. In contrast, children from single-parent households face more significant challenges for educational opportunities. Parents may have less opportunity to provide additional educational resources, have a challenge finding childcare, and the child may receive less parental attention (Lareau, 2002). Additionally, children in separated families may suffer from emotional issues, making them less likely to have the academic motivation and thus have lowered performance (Lareau, 2002) (Chiu & Xihua, 2008).

Blended and multigenerational households have impacts on a child's educational upbringing. Grandparents and siblings may offer competition for attention, reducing the available parental resources (Hampden-Thompson, 2012). Parents may have less time to help a child with homework, should a grandparent be ill, or when helping other children in the household. However, a child may also benefit from blended and multigenerational household's added physical, emotional, social, and economic resources (Hampden-Thompson, 2012). Immigrant households, especially those who primarily speak a country's nondominated language, are also less likely to have cultural possessions and educational material to provides learning opportunities (Portes & MacLeod, 1996).

Family Investment

In social cognitive theory, academic motivation stems from value, expectancy, and affect. A child's attitude towards math impacts the engagement and effort put forth in learning. Children who enjoy math have higher self-confidence in the subject, often resulting in higher performance. When a family has more resources to invest in education, a child's intrinsic motivation also increases (Chiu & Xihua, 2008). As families encourage reading, help with homework, and push critical thinking at home, children are more likely to enjoy learning (Lucietto et al., 2020). As self-efficacy increases, children are more likely to view math as a tool for success, adding extrinsic value to the subject. Families from higher socioeconomic classes emphasize educational investment and involvement, thus having higher expectancy beliefs (Chiu & Xihua, 2008). Higher expectancy drives children to strive for higher performance. As they work harder, they learn more. Previous success drives children to maintain or increase their success as they are rewarded by meeting and surpassing expectations. In higher socioeconomic environments, families have more resources to lend to academic failure (Lareau, 2002). Emotional support, homework aid, and parent-teacher involvement provide a network for a child to grow academically, correcting and learning from mistakes (Lareau, 2002).

Country and Cultural Values

Culture and country values affect student achievements, such as average income, education levels, and social inequalities. Children from countries with higher gross domestic product (GDP) per capita have higher academic performance (Chiu & Xihua, 2008). Countries with economic resources directly impact student achievement by providing academic resources such as books, laboratory equipment, teacher training, and curriculum planning. Indirectly, higher GDP impacts overall health and wellbeing (Appiah, 2017). Children born in developing countries may lack access to proper nutrition, health care, or exposure to harmful environments, all of which are associated with learning difficulties (Chiu & Xihua, 2008).

Research indicates that parental education is a substantial and distinctive predictor of a child's achievement, as mentioned previously. In higher-earning countries, publicly mandated schooling begins at younger ages and offers more subsidized and tertiary education programs (Chiu & Xihua, 2008). Thus, parents in higher-earning countries often have more years of schooling and can offer higher-quality academic involvement as they read, discuss, and teach their children. Moreover, children from richer countries spend more one-on-one time with their parents (Chiu & Xihua, 2008). Families in higher-earning countries tend to have fewer children per family and greater disposable resources (Appiah, 2017). In turn, parents can outsource household duties such as repairs, cooking, or cleaning, allowing for more parental involvement and intangible educational opportunities.

Outside of wealth and social equality, countries have varying approaches to societal issues and differing central values. Children's behaviors and values can be shaped through formal socialization from teachers and parents and informally, such as daily exposure, lows, and cultural practices (Chiu & Xihua, 2008). A country's societal foundation often shapes its cultural values and approach to education. For example, a hierarchical society may maintain order by assigning clear, fixed tiered roles to teach citizens obedience (Chiu & Xihua, 2008). Children raised in a hierarchical society will have social interactions strongly influenced by age and gender (Gheorghita, 2006). These children are less likely to step forward in group leadership in an educational setting or express opinions and comments (Gheorghita, 2006). Societies may also take on an egalitarian structure as they teach citizens to view, act, and value people as equals (Chiu & Xihua, 2008). In an egalitarian society, a child will view themselves as more similar, often leading to companionship and friendship. Students with more friends have better access to shared resources, support systems and show higher self-efficacy and academic achievement (Crosnoe, Cavanagh, & Elder, 2003). Individualist societies value individuality and personal opinions. Children raised with an individualist mindset are encouraged to be free-thinking and work independently (Chiu & Xihua, 2008). In collectivist societies, students are more likely to cooperate and learn, boosting morale and achievement. Children from collective societies may also depend on family and people of significance for success, more likely to benefit from greater availability of resources (Gheorghita, 2006). Countries such as Russia, Hungary, or China have a collectivist mindset, and therefore, stress collective accomplishments as opposed to personal successes (Gheorghita, 2006).

According to PISA reporting, the level of math anxiety, self-assessment, and performance differ significantly across countries, with considerable distinctions seen between Asian and Western European nations (OCED, 2013). While PISA reporting shows a stronger association between math anxiety and math performance in Western European countries, students in Austria, Germany, Sweden, and Switzerland report high self-efficacy, self-concept, and low math anxiety (OCED, 2013). Students of Korea, Japan, and Thailand show high anxiety levels while reporting low values of self-concept and self-efficacy in the subject (OCED, 2013). The Asian cultural values emphasize high academic performance. These children tend to set lofty educational goals while striving to meet society's high educational standards (Luttenberger et al., 2018).

Research shows Asian students perceive their parents and themselves as less contented by their scholastic achievements than students outside of Asian countries (Whang & Hancock, 1994). These countries, parental and self-set aspirations create a high risk, low reward environment surrounding personal, educational achievement, and these are critical components attributed to high math anxiety.

The American education system uses individualist teaching styles, promoting independent work and problem solving without constant attention. Personal achievement holds high importance, and encouragement that poor performances can be followed by improvement and excellence is obtainable (Gheorghita, 2006). This approach presents a challenge for educators, as many minority students value the importance of collectivism at home (Gheorghita, 2006). For example, Hispanic cultures emphasize community hierarchy and group affiliation. American education encourages individual assertiveness and leadership, while at home, children are taught to think modestly and foster cooperation (Gheorghita, 2006). The dichotomy these children face presents a challenge, as they are expected to conform to their environment, presenting inevitable losses.

Strategies to Combat Math Anxiety

An estimated 93% of adults in the United States face some level of math anxiety (Blazer, 2011), giving rise to navigating, reducing, and avoiding the fear of math. Math anxiety is accepted as a non-intellectual-based performance factor as students have shown complete understanding of mathematical concepts, though during testing face performances difficulties while dealing with anxiety (Blazer, 2011). Research indicates that self-efficacy and confidence in mathematical problem solving seem to have origin in the overarching problem, suggesting that educational communities and people of influence can take measures towards prevention and mediation (Lucietto et al., 2020).

Academic Settings

In academic settings, teachers significantly influence the way their students approach mathematics and problem-solving skills. Teachers can adjust instruction and lesson planning to enhance a student's confidence and motivation in math. The school curriculum should approach mathematical operations from real-life situations such as counting change or grocery, showing that math is a valuable tool in the world (Blazer, 2011) (Luttenberger et al., 2018). Teaching approaches should encourage critical thinking and problem-solving. Instructors should also focus on their students understanding the fundamentals, steps, and theory of a math concept instead of grading for correct answers (Haralson, 2002).

School environments should dispel stereotypes and misconceptions about math difficulties and one's abilities (Luttenberger et al., 2018). Stereotypes about men having better problem skills or on an induvial being good or bad at math no matter the effort put in is simply fiction. A supportive environment should also encourage and incorporate various learning styles within the classroom (Blazer, 2011). As mentioned previously, the societal approach to learning may not always be communicated at home. Suggestions for teaching math in the classroom incorporate a number of learning styles and suggest cooperative learning groups, visual aids, hands-on activities, and discussion groups to help all children learn and develop and

reinforce mathematical problem-solving (Woodard, 2004). Finally, a proper performance and execution of problem-solving skills can be disrupted by the fear and anxiety one faces during the actual testing itself (Cavanagh, 2007). Teachers can help mitigate the fear of math tests by exposing students to diverse testing situations. Teaching strategies may include timed practice tests, oral questioning, student-led presentation or observations (Blazer, 2011) which introduce new stimuli and environments to practice problem solving.

Parental Support

Parents and caretakers can also help to relieve math anxiety at home. As children tend to mimic seen behaviors, parents who fear math themselves may unknowingly instill their feelings on their children (Geist, 2010). Caretakers can model patience and self-discipline when problem-solving at home, as children watch them pay bills, balance checkbooks, or follow recipes (Curtain-Phillips, 2016). Helping with homework and studying can also help parents relearn and reduce their math fears with consistent practice and persistence. One can also help children practice problem-solving skills at home in everyday activities, such as playing numeric games or doing puzzles. Finally, parents should ultimately monitor their child's progress and understanding of math concepts (Blazer, 2011). Parent's expectations strongly influence a child's approach to math and self-efficacy (Cavanagh, 2007) (Lucietto et al., 2020). If parents notice their child developing math anxiety, it is essential to discuss with teachers and instructors to pinpoint struggles and provide support and encouragement at home (Blazer, 2011).

Student Strategies

Students can also help themselves mediate the irrationalities of their math anxiety. Research suggests that daily practices and repetitions help build confidence and improve one's perception of their abilities (Cavanagh, 2007). Daily practices also help students understand the theory and concepts instead of memorization (Blazer, 2011). Setting good study techniques such as timed breaks to increase retention and studying in areas clear of distraction also proves vital (Haralson, 2002). Studying can also be improved by exploring one's preferred learning style (Lucietto et al., 2017) (Lucietto et al., 2020). For example, visual learners will benefit from pictures, diagrams, and textbooks, while auditory students will succeed in lectures, discussions, and group work (Woodard, 2004). Finally, students can also ease their worries and frustrations by seeking help from teachers, parents, and peers. One on one attention and tutoring can often help students grasp complex concepts.

Conclusions and Future Work

Math anxiety is a globalized problem (Hampden-Thompson, 2012) (OCED, 2013). Children who lack confidence and educational support face life-long challenges in mathematics. As fear surrounding the subject becomes overwhelming, children become math avoidant, falling victim to self-deprecating thoughts towards their math abilities. While the effects of math anxiety, math performance, and self-perception have been widely studied, deeper investigation still perpetuates the need for further research. While math anxiety is accepted as a non-intellectual-based performance factor (Blazer, 2011), research still questions origins as to why and how an individual develops math anxiety.

Theorized sources commonly revolve around the intricate relationships between personality and environmental factors (Blazer, 2011). For example, researchers hypothesize that feelings of anxiety are highly influential on a student's working memory during mathematical computations. These impairments decrease the fluency, or one's ability to approach computations efficiently and systematically (Paechter et al., 2017). Thus, a concern surrounding math anxiety should delve into the long-term effects of math anxiety, development, and memory-based tasks. As the origin and development of math anxiety are still unknown, more information into these relationships can aid in prevention and treatment, mainly if acknowledged during a formative stage in a child's life.

A person's predispositions for generalized anxiety, behavioral and learning challenges, and those working on self-efficacy and math anxiety relationship also beg for future research (Lucietto et al., 2017). The associations and relationships between preexisting or developed challenges versus one's intrinsic motivation and perseverance also have the potential for methodological or statistical study, especially when approached in a long-term study (Lucietto et al., 2020).

Math anxiety testing at the secondary level presents uniform results, confirming a gender bias in the effects of math anxiety in favor of boys. However, at the university level, studies show significant variability between the genders in all aspects tested of math anxiety, be it numeric calculations, self-perceptions, or testing (Cipora et al., 2015) (Paechter et al., 2017) (Luttenberger et al., 2018). As previous math anxiety research indicates, the feelings of dread, fear, and self-concepts around the subject impact students internationally. Thus, standardized testing and defined measurement units may lead to a deeper understanding of the causes and effects of math anxiety (Lucietto et al., 2017).

Future research offers various approaches to math anxiety exploration, as experts aim to understand and support those who experience this feeling. Coping strategies and curriculum development prove to offer relief and support to students facing math anxiety. Discovering and understanding the psychological and physiological connections students experience when presented with mathematical concepts is invaluable. Findings related to a student’s self-perception, predispositions, worldly experiences in mathematical problem solving offer a path for continued investigation. Teachers, parents, and people of significance have a noticeable and robust impact on a child's self-efficacy and perception of math (Cavanagh, 2007). These individuals have a variety of influence, be it their own predispositions to math, education levels, socio-economic status, and approach to education support for a student (Gheorghita, 2006) (Luttenberger et al., 2018). The relationship between math-anxious students, and their experience with influential educators needs furthered investigation. Finally, varying results in the literature suggest the need for more profound research into society's approach and influences on education (Gheorghita, 2006). The environment and social pressures a student faces show evidence of impact on one’s relationship to mathematics. As the feelings of math anxiety permeate globally, continued research into social conceptions such as gender bias, stereotyping (Paechter et al., 2017), social hierarchies, or a student's choice in

university major or career path beg for correlation and causation.

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