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THE INTERPLAY BETWEEN MATH PERFORMANCES, SPATIAL ABILITIES AND AFFECTIVE FACTORS: THE ROLE OF TASK AND SEX

Sarit Ashkenazi
Department or Learning Disabilities, The Seymour Fox School of Education,
The Hebrew University of Jerusalem (Israel)

Abstract

Science, technology, engineering and mathematics (STEM) fields are very important to modern society. Careers in STEM fields involve larger salaries than in all the other domains, and there is underrepresentation of females in STEM related fields. Hence, understanding the cognitive and affective foundation of math abilities, a core part in all STEM related careers, has central educational and social significance.
Over the last two decades, many studies have suggested that cognitive and affective factors explain individual differences in math. One of the central cognitive factors is spatial abilities. However, recent studies suggest that spatial abilities (real or spatial anxiety) affect emotional factors such as math anxiety.
A large body of research has found stronger math anxiety in females and suggests that inferior spatial abilities in females compared to males are the origin of sex differences in math anxiety.
To fully explore the complex relationship among math anxiety, spatial abilities, spatial anxiety on math performance and sex differences, the current set of studies examined spatial skills, working memory skills, math anxiety, spatial anxiety and math self-efficacy as predictors of math performance in different math contents, in college students.
The results showed sex differences in a few domains: math anxiety was higher in females compared to males, males outperformed females in number line performance and spatial skills. The relationships among spatial abilities, math performance, and math anxiety were stronger in males than in females. By contrast, the relationship between math self-efficacy and performance was stronger in females compared to males.
Moreover, the results indicated that the interplay between math performances and cognitive and affective factors is related to task demand. Math anxiety and spatial abilities had a direct effect on math performances regardless of task. Spatial anxiety had only an indirect effect on math performances via mathematical anxiety, regardless of task. Math self-efficacy had an indirect effect on math performances via MA, and in the one case, also had a direct effect on math performances.
Few implications can be drown from the current findings:
First, this finding demonstrated fundamental differences between the sexes, even with similar performances in curriculum-based assessments. Second, for math performances, contrary to math anxiety, real spatial abilities rather than spatial anxiety play a significant role in explaining individual differences. Additionally, math anxiety is a very important factor in explaining individual differences in complex math. Hence, the present result dissociates cognitive and emotional factors.

Keywords: *Mathematical anxiety, mathematical self-efficacy, spatial abilities, individual differences in mathematical performances, sex differences.*

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1. Introduction

Science, technology, engineering and mathematics (STEM) fields are very important to modern society. Careers in STEM fields involve larger salaries than in all the other domains, and there is underrepresentation of females in STEM related fields (Bloodhart, Balgopal, Casper, Sample McMeeking, & Fischer, 2020; Botella, Rueda, López-Iñesta, & Marzal, 2019; López-Iñesta, Botella, Rueda, Forte, & Marzal, 2020). Hence, understanding the cognitive and affective foundation of math abilities, a core part in all STEM related careers, has central educational and social significance.

Over the last two decades, many studies have suggested that cognitive and affective factors explain individual differences in math. It has been suggested that spatial abilities are one of the cognitive building blocks of math abilities (Cornu, Schiltz, Martin, & Hornung, 2018; Geer, Quinn, & Ganley, 2019; Lauer & Lourenco, 2016). However, recent studies suggest that spatial abilities (real or spatial anxiety) affect emotional factors such as math anxiety (MA) (Delage, Trudel, Retanal, & Maloney, 2022; Sokolowski, Hawes, & Lyons, 2019). A large body of research has found stronger MA in females and suggests that inferior spatial abilities in females compared to males are the origin of sex differences in MA (Dowker, Sarkar, & Looi, 2016;Dowker, Sarkar, & Looi, 2016; Ferguson, Maloney, Fugelsang, & Risko, 2015).

To fully explore the complex relationship among MA, spatial abilities, spatial anxiety on math performance and sex differences, the current set of studies examined spatial skills, working memory skills, MA, spatial anxiety and math self-efficacy as predictors of math performance in diffrent math contants (Ashkenazi and Velner, submitted; Danan and Ashekanzi, 2022).

2. Methods and results experiment 1

The first study explores the interplay between MA, math self-efficacy, spatial anxiety and spatial abilities in explaining individual differences on two complex math tasks: math problem solution and computational estimation. Ninety-three college students took part in the experiment online, and completed 3 questionnaires 1) MA 2) math self-efficacy and 3) spatial anxiety, in addition to 3 tasks: 1) math problem solution (see Figure 1) 2) computational estimation (see Figure 2) and 3) a mental rotation task, to test spatial abilities. The results indicated that the interplay between math performances and cognitive and affective factors is related to task demand. MA and spatial abilities affected math performances directly, regardless of task. Spatial anxiety had only an indirect effect on math performances via MA, regardless of task. Math self-efficacy had an indirect effect on math performances via MA, and in the case of math problem solution, also had a direct effect on math performances (see Figure 1 and 2).

Figure 1. A) The results of the stractural equasion model (SEM) analysis with accuracy rates in complex verbal math problems as the dependent variable.
*Note. MR = mental rotation; SA = spatial anxiety; Math = accuracy in complex math problem; MA = math anxiety. * = p < .05, ** = p < .01, *** = p < .001*
B) example for complex math problems.

A.

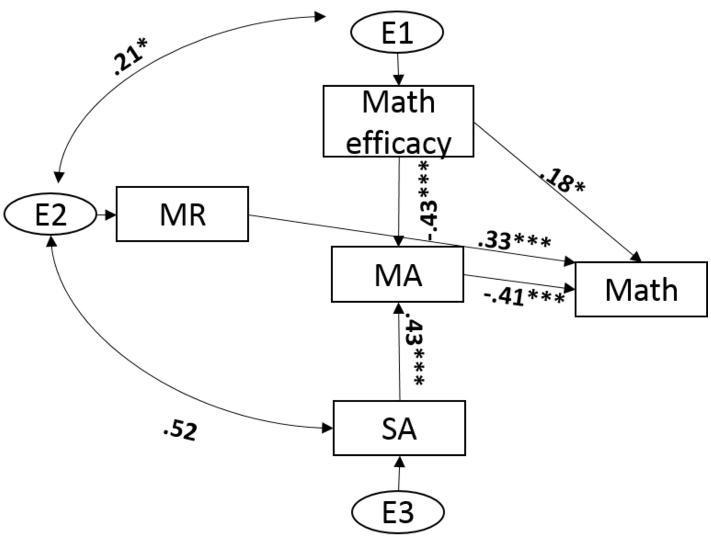
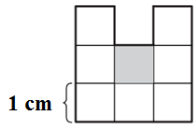
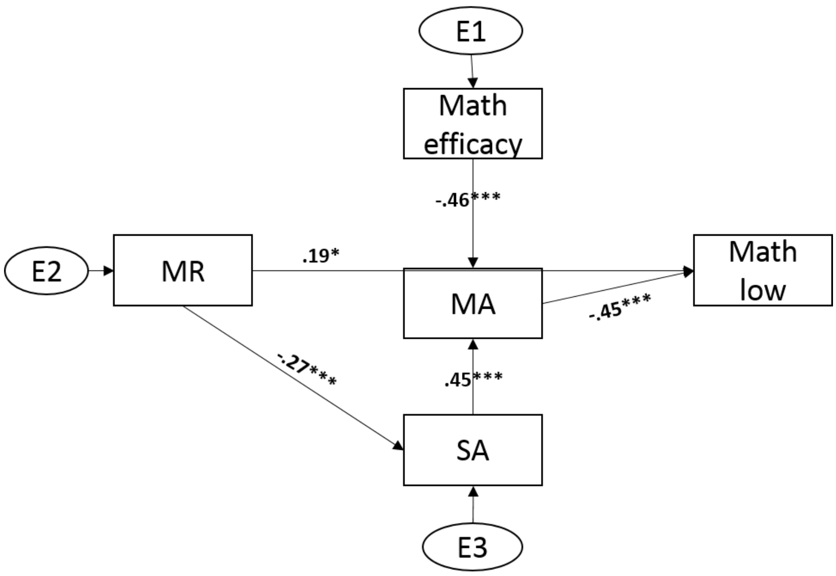


Figure 1. B) The drawing is composed of overlapping squares. Each Square rib is 1 cm. If you remove the dark square from the shape, the perimeter of the shape____in ________cm.



(1) *Decrease ; 3 ;*
(2) *Decrease ; 2*
(3) *Increase ; 3*
(4) *Increase ; 2*

Figure 2. The SEM analysis with accuracy rates in estimations of below problems as the dependent variable. Math low indicated accuracy in estimation were the reference number is lower or below the exact answer (e.g., 23 X 34 = 156).
*Note. MR = mental rotation; SA = spatial anxiety; Math = accuracy in complex math problem; MA = math anxiety. * = p < .05, ** = p < .01, *** = p < .001*



3. Methods and results experiment 2

To fully explore the complex relationship among math anxiety, spatial abilities, math performance and sex differences, the current study examined spatial skills, working memory skills, math anxiety, and self-efficacy as predictors of math performance. Participating in the study were 89 undergraduate Israeli students (44 males and 45 females).

The result showed sex differences in a few domains: MA was higher in females compared to males, males outperformed females in number line performance and spatial skills. The relationships among spatial abilities, math performance, and math anxiety were stronger in males than in females. By contrast, the relationship between math self-efficacy and performance was stronger in females compared to males (see Figure 3).

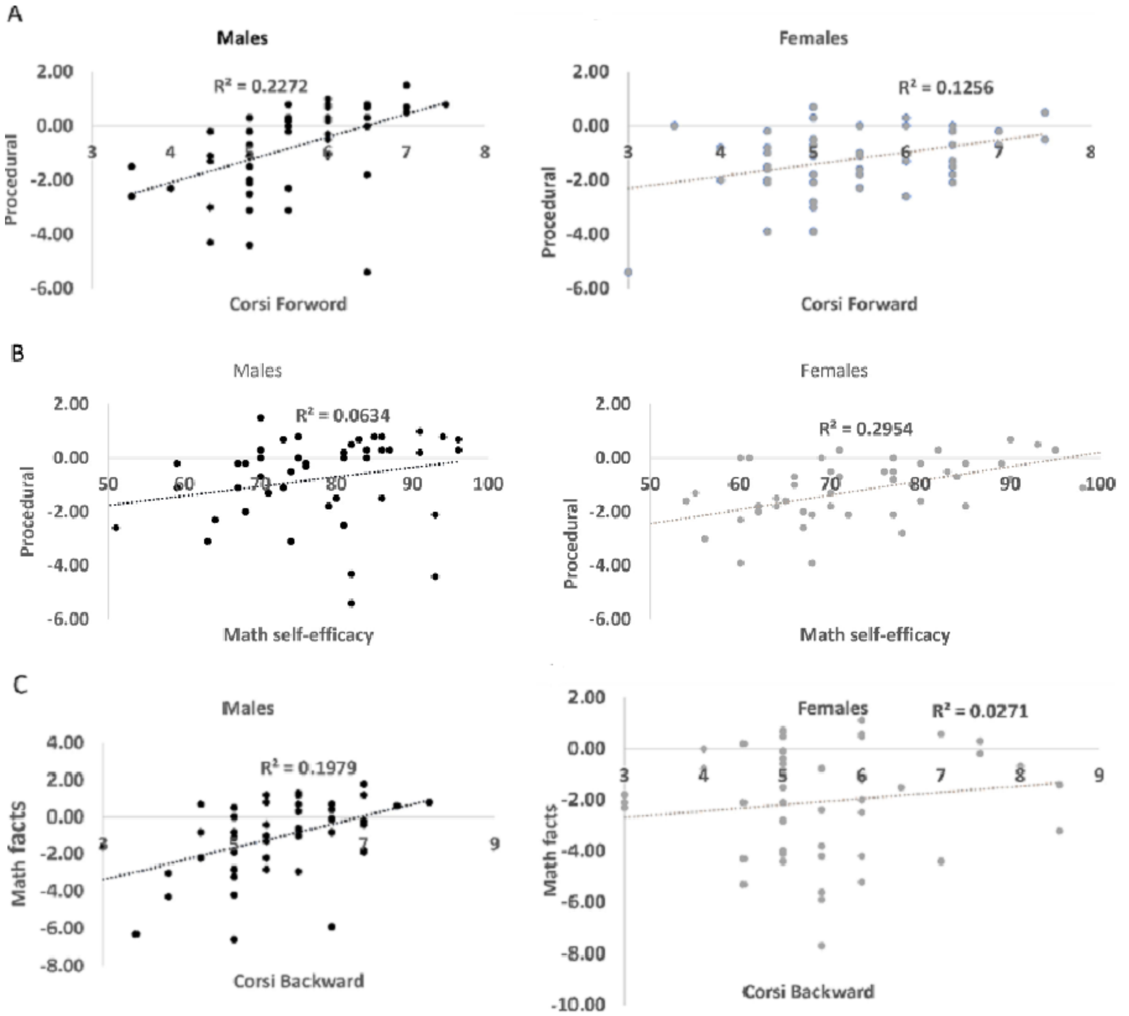
4. General discussion

These finding suggest that for math performances, contrary to MA, real spatial abilities rather than spatial anxiety play a significant role in explaining individual differences. Additionally, MA is a very important factor in explaining individual differences in complex math. Hence, the present result dissociates cognitive and emotional factors (Ashkenazi and Velner, submitted).

Moreover, the results indicated that the interplay between math performances and cognitive and affective factors is related to task demand (Ashkenazi and Velner, submitted).

Moreover, psychological factors, such as math self-efficacy can be the origin of sex differences since self-efficacy was more correlated to curriculum-based math tasks in females than in males. This demonstrated fundamental differences between the sexes, even with similar performances in curriculum-based assessments (Danan and Ashekanzi, 2022).

Figure 3. Correlation approached discovered that males have stronger associations between procedural math performances and visuospatial working memory than females (A). However, the associations between math self-efficacy and procedural math performances is stronger in females than males (B). Last, males have stronger associations between math facts performances and visuospatial working memory than females.



References

Ashkenazi, The Hebrew University of Jerusalem, & Velner, The Hebrew University of Jerusalem (Submitted). The Interplay between Math Performances, Spatial Abilities, and Affective Factors: The Role of Task. *Journal of Numerical Cognition*.

Bloodhart, California State university, Balgopal, Colorado State university, Sample McMeeking, Colorado State university & Fischer, Colorado State university (2020). Outperforming yet undervalued: Undergraduate women in STEM, *PLOS ONE, 15(6),* e0234685.

Botella, Universitat de València, Rueda, Universitat de València, López-Iñesta, Universitat de València & Marzal, Universitat de València (2019). Gender Diversity in STEM Disciplines: A Multiple Factor Problem, *Entropy, 21(1), 30*.

Cornu, University of Luxembourg, Schiltz, University of Luxembourg, Martin, University of Luxembourg & Hornung, University of Luxembourg (2019). Visuo-spatial abilities are key for young children's verbal number skills, *Journal of Experimental Child Psychology, 166, 604-620.*

Danan, The Hebrew University of Jerusalem, & Ashkenazi, The Hebrew University of Jerusalem (2022). The influence of sex on the relations among spatial ability, math anxiety and math performance. *Trends in neuroscience and education*, 29, 100196.

Delage, University of Ottawa, Trudel, University of Ottawa, Retanal, University of Ottawa & Maloney, University of Ottawa (2022). Spatial anxiety and spatial ability: Mediators of gender differences in math anxiety. *Journal of Experimental Psychology: General*, 151(4), 921-933.

Dowker, University of Oxford, Sarkar, University of Oxford & Looi, University of Oxford (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in psychology, 7, 508*.

Ferguson, University of Waterloo, Maloney, University of Chicago, Fugelsang, University of Waterloo, & Risko, University of Waterloo (2015). On the relation between math and spatial ability: The case of math anxiety. *Learning and Individual Differences, 39, 1-12*.

Geer, Florida State University, Quinn, Florida State University, & Ganley, Florida State University (2019). Relations between spatial skills and math performance in elementary school children: A longitudinal investigation. *Developmental Psychology*, *55(3), 637-652*.

Lauer, Emory University, & Lourenco, Emory University (2016). Spatial Processing in Infancy Predicts Both Spatial and Mathematical Aptitude in Childhood. *Psychological Science, 27(10), 1291-1298*.

López-Iñesta, Universitat de València, Botella, Universitat de València, Rueda, Universitat de València, Forte, Universitat de València & Marzal, Universitat de València (2020). Towards Breaking the Gender Gap in Science, Technology, Engineering and Mathematics. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje, 15(3), 233-241*.