Predictors of First Graders' Arithmetic Strategy Choices

Ally Patterson and Robert Pasnak, Ph.D.
George Mason University

Introduction

- Though girls receive higher teacher-reported course grades in all subjects, boys demonstrate equal or slightly superior performance on objective mathematics and science assessments (Cornwell et al., 2013). These gender differences increase throughout the course of elementary school into adolescence, and persist into adulthood (McGraw, Lubienski, & Strutchens, 2006).
- Compared to men, women earn substantially fewer advanced degrees in fields such as engineering, computer science, physics, mathematics, and statistics; and make up less than 30% of those in science/engineering occupations (NSF, 2017).
- Carr and Alexeev (2011) described a general developmental trend in mathematics whereby young students progress from use of manipulatives to use of cognitive strategies in order to perform calculations. The development of these more complex strategies, however, does not progress similarly for boys and girls.
- Researchers have used arithmetic strategy choices (ASCs) to explain individual and group differences in mathematics performance, and have found that females of all ages in the United States are more likely than their male peers to use overt strategies such as counting on their fingers or using manipulatives, and that these differences are present as early as first grade (Carr & Davis, 2001; Fennema, Carpenter, Jacobs, Franke, & Levi, 1998; Imbo & Vandierendonck, 2007).
- Use of overt strategies has been found to predict poorer performance in some aspects of mathematics, particularly complex arithmetic, from kindergarten through adulthood (Carr & Alexeev, 2011; Imbo & Vandierendonck, 2007; Laski et al., 2013; Laski, Schiffman, Vasilyeva, & Ermakova, 2016; Powell, 2016).
- In the short-term, early tendencies toward overt ASCs may be overlooked, as they are not necessarily associated with differences in performance on simple mathematics tasks (Koriaken et al., 2017). However, in the long-term, early habits may create barriers to women's participation in scientific and mathematical fields.
- There are a variety of cognitive and "non-cognitive" factors that may explain development of ASC(Cornwell et al., 2013), including mathematics anxiety and executive functions (Cragg & Gilmore, 2014; Ramirez et al., 2016). Additionally, girls' reliance on low-risk, "perfectionistic" arithmetic strategy choices: counting with blocks or on fingers as if to check the solutions that boys often arrive at through higher-risk insight strategies (Carr & Jessup, 1997; Siegler, 1988), suggests the influence of risk tolerance in the development of ASCs. However, because some boys do display perfectionistic tendencies in arithmetic and some girls display insightful tendencies (Carr & Jessup, 1997), these characteristics and skills may be useful in predicting both boys' and girls' early preferences for strategy.

	Gender					
	Male			Female		
	M	*SD*	*n*	*M*	*SD*	*n*
Counting objects	8.33	5.53	30	11.94	6.17	33
Counting in head	2.37	2.80	30	1.88	2.25	33
Retrieval	6.87	4.61	30	4.67	3.21	33
Decomposition	2.37	3.06	30	1.52	2.67	30

Table 1. Mean numbers of strategies used by gender during 20-problem arithmetic assessment. Counting objects (including fingers and manipulatives) is an overt strategy. Counting in head, retrieval, and decomposition are covert strategies.

Hypotheses

- First-grade boys will be more likely than first-grade girls to use covert strategies.
- Covert strategy use will be associated with accuracy for complex, but not simple, arithmetic problems.
- There will be a positive relationship between executive function skills and covert strategy use, as well as risk tolerance and covert strategy use. There will be a negative relationship between mathematics anxiety and covert strategy use.
- Executive functions will moderate the relationship between gender and strategy use, while risk tolerance and mathematics anxiety will mediate the relationship between gender and strategy use.

Methods and Materials

- *Population*: A multicultural, economically diverse sample of general education first-grade students was recruited and assessed. The 63 participants were between the ages of six and eight, and attended a Mid-Atlantic elementary school.
- *Research Design:* Risk tolerance was measured by Levin and Hart's Cups Task, which has been found to reveal both gender and individual differences in the amount of risky choices children make. Executive function skills were measured by the WISC backward digit span (Wechsler, 1974), the Head Toes Knees and Shoulders cognitive inhibition task (McClelland et al., 2007), and a card sorting task of cognitive flexibility (Bock et al., 2015). Executive function tasks demonstrate no consistent gender differences and are used to explain variance in mathematics performance. Math anxiety was assessed using Ramirez et al.'s (2016) Children's Math Anxiety Questionnaire. Arithmetic strategy choice was measured using an interview procedure originally developed by Carr, Alexander, and Folds-Bennett (1994).

Results

- Boys (M = 11.60, SD = 5.46) were more likely than girls (M = 8.06, SD = 6.17) to use a covert strategy (decomposition, retrieval, counting in head), $t(61) = -2.40$, $p < .05$. See Table 1.
- Covert strategy use was associated with accuracy for complex ($\rho = .25$, $p < .05$), but not simple, arithmetic problems.
- There were positive relationships between working memory and covert strategy use ($r = .39$, $p < .01$), as well as cognitive flexibility and covert strategy use ($r = .33$, $p < .01$). There was not a significant relationship between inhibition and covert strategy use.
- There was a positive relationship between risk tolerance and covert strategy use ($\rho = .33$, $p < .01$).
- There was a negative relationship between mathematics anxiety and covert strategy use use ($r = -.42$, $p < .01$).
- The main effect of gender on covert strategy use ($b = .27$, $p < .05$) remained significant after controlling for all three executive function skills, $F(4,58) = 4.57$, $p < .01$, $R^2 = .24$.
- Gender was a significant predictor of mathematics anxiety, b = -4.08, SE = 1.82, $p < .05$, and mathematics anxiety was a significant predictor of covert strategy use, b = -.30, SE = .10, $p < .01$. Gender was no longer a significant predictor of covert strategy use after controlling for mathematics anxiety, b = 2.33, SE = 1.44. As shown in Figure 1, these results support the mediation hypothesis, $R^2 = .21$.

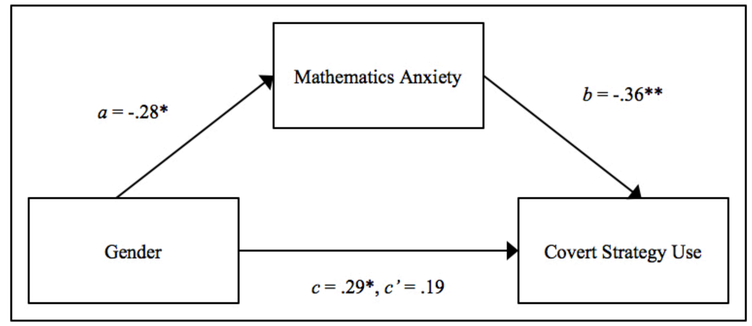

Figure 1. Mathematics anxiety mediates the relationship between first graders' gender and covert strategy use. *$p < .05$, **$p < .01$

Discussion

The current study aims to look beyond gender differences in order to clarify some patterns of cognitive abilities that enable adaptive strategizing in early arithmetic. Our findings suggest that factors besides gender may play an important role in development of arithmetic preferences and ASCs. Applications of this study could help children experience early success in mathematics, particularly by promoting awareness of the roles of both cognitive and "non-cognitive" factors contributing to eventual success in mathematics. However, this study was limited by a small sample size (N = 63) and a single data collection site.

As mathematics anxiety was found to be the strongest predictor of ASC, additional research could also examine other social or cultural variables that contribute to gender differences in mathematics performance, and attempt to determine how early in development these differences in ASCs emerge. Broad implications for this study are relevant to early intervention efforts to diversify the scientific community, particularly by promoting young females' early interest and success in mathematics.

Conclusions

The pathway toward adult participation in mathematics and related fields begins in early development, with research demonstrating the contributions of early childhood influences on later performance. Despite diminishing gender gaps in primary and secondary education across the 20th century, females are still less likely to pursue a career in higher-pay, higher-skill careers such as those in the sciences (NSF, 2017; OECD, 2017). An examination of developmental research identifies patterns of gender-differentiated mathematical behavior that is apparent at the beginning of elementary school and persists into adulthood.

Though ASCs have minimal impact in performance on tasks of geometry or simple calculation, the influences of strategy choice become apparent as children mature and encounter more complex course material (Carr & Alexeev, 2011; Spelke & Grace, 2007; Vukovic et al., 2013). Gender-differentiated habits endure throughout the course of middle childhood and into adolescence and adulthood, as gender gaps in mathematical attitudes, performance, and career intentions widen (NSF, 2017; OECD, 2017).

Contact

Ally Patterson
George Mason University
Department of Psychology
apatte17@gmu.edu

References

1. Carr, M., Alexander, J., & Folds-Bennett, T. (1994). Metacognition and mathematics strategy use. *Applied Cognitive Psychology*, *8*(6), 583-595.
2. Carr, M., & Alexeev, N. (2011). Fluency, accuracy, and gender predict developmental trajectories of arithmetic strategies. *Journal of Educational Psychology*, *103*(3), 617–631. https://doi.org/10.1037/a0023864
3. Carr, M., & Davis, H. (2001). Gender differences in arithmetic strategy use: A function of skill and preference. *Contemporary Educational Psychology*, *26*(3), 330–347. https://doi.org/10.1006/ceps.2000.1059
4. Carr, M., & Jessup, D. L. (1997). Gender differences in first-grade mathematics strategy use: Social and metacognitive influences. *Journal of Educational Psychology*, *89*(2), 318.
5. Cornwell, C., Mustard, D. B., & Van Parys, J. (2013). Noncognitive skills and the gender disparities in test scores and teacher assessments: Evidence from primary school. *Journal of Human Resources*, *48*(1), 236-264.
6. Cragg, L., & Gilmore, C. (2014). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. *Trends in Neuroscience and Education*, *3*(2), 63-68. http://dx.doi.org/10.1016/j.tine.2013.12.001
7. Fennema, E., Carpenter, T. P., Jacobs, V. R., Franke, M. L., & Levi, L. W. (1998). A longitudinal study of gender differences in young children's mathematical thinking. *Educational Researcher*, *27*(5), 6-11.
8. Imbo, I., & Vandierendonck, A. (2007). Do multiplication and division strategies rely on executive and phonological working memory resources?. *Memory & Cognition*, *35*(7), 1759-1771.
9. Koriakin, T., White, E., Breaux, K. C., DeBiase, E., O'Brien, R., Howell, M., ... & Courville, T. (2017). Patterns of cognitive strengths and weaknesses and relationships to math errors. *Journal of Psychoeducational Assessment*, *35*(1-2), 155-167. doi: 10.1177/0734282916669909.
10. Laski, E. V., Casey, B. M., Yu, Q., Dulaney, A., Heyman, M., & Dearing, E. (2013). Spatial skills as a predictor of first grade girls' use of higher level arithmetic strategies. *Learning and Individual Differences*, *23*, 123–130. https://doi.org/10.1016/j.lindif.2012.08.001
11. Laski, E. V., Schiffman, J., Vasilyeva, M., & Ermakova, A. (2016). Arithmetic accuracy in children from high- and low-income schools: What do strategies have to do with it? *AERA Open*, *2*(2). https://doi.org/10.1177/2332858416644219
12. McGraw, R., Lubienski, S. T., & Strutchens, M. E. (2006). A closer look at gender in NAEP mathematics achievement and affect data: Intersections with achievement, race/ethnicity, and socioeconomic status. *Journal of Research in Mathematics Education*, *37*, 129–150.
13. NSF. (2017). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017*. Special Report NSF 17-310. Arlington, VA. Available at www.nsf.gov/statistics/wmpd/.
14. OECD (2013), "Mathematics Self-Beliefs and Participation in Mathematics-Related Activities", in *PISA 2012 Results: Ready to Learn (Volume III): Students' Engagement, Drive and Self-Beliefs*, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264201170-8-en
15. Powell, S. M. (2016). *Exploring strategy use for multiplication problem solving in college students* (Unpublished doctoral dissertation), Fordham University, New York, New York.
16. Ramirez, G., Chang, H., Maloney, E. A., Levine, S. C., & Beilock, S. L. (2016). On the relationship between math anxiety and math achievement in early elementary school: The role of problem solving strategies. *Journal of Experimental Child Psychology*, *141*, 83–100. https://doi.org/10.1016/j.jecp.2015.07.014
17. Siegler, R. S. (1988). Individual differences in strategy choices: Good students, not-so-good students, and perfectionists. *Child Development*, 833-851.
18. Spelke, E. S. & Grace, A. (2005). Sex differences in intrinsic aptitude for mathematics and science?: A critical review. *American Psychologist*, *60*(9), 950. doi: 10.1037/0003-066X.60.9.950.
19. Vukovic, R. K., Kieffer, M. J., Bailey, S. P., & Harari, R. R. (2013). Mathematics anxiety in young children: Concurrent and longitudinal associations with mathematical performance. *Contemporary Educational Psychology*, *38*(1), 1-10. doi: 10.1016/j.cedpsych.2012.09.001.