



Sex Differences in Solving Algebra Word Problems



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INTRODUCTION

The study of sex differences in learning and cognition has been an intensive and heavily debated topic, specifically in the area of mathematics. The magnitude of the differences in mathematics vary across content and grade level (Hyde et al., 1990). Overall, the differences are small and typically favor boys, but larger differences are found at the high end of ability and in more complex areas of mathematics. During adolescence, sex differences favoring males in mathematical ability have been found and are larger in some areas than others. The latter includes the solving of algebraic word problems but not in all algebra outcomes (Geary, 1996, Hyde et. al, 1990).

VISUOSPATIAL ABILITIES AND MATHEMATICS

Boys typically have advantages on various visuospatial tasks, such as skill at generating and mentally manipulating images and in visuospatial working memory. This might provide them with an advantage on word problems, because spatially representing (e.g., drawing) the relations noted in the problem reduces problem-solving errors.

ANXIETY AND MATHEMATICS

Internalized beliefs and attitudes have been proposed as an explanation for sex differences involving math because of varying socialization factors that influence educational preferences and eventually careers. Anxiety when doing math makes it more difficult to concentrate and thus can undermine math performance and alter attitudes about math, leading to avoidance. Additionally, masculine associations with math and self-perceptions of efficacy are factors that can be internalized by both sexes and potentially contribute to differences in algebra performance. The important sex difference here favors boys, because they report feeling less anxiety and having more positive attitudes about math than girls.

CURRENT STUDY

The current study assessed the algebra ability of 171 ninth grade students (87 boys, 84 girls; M =14 years, 8 months old, SD= 4.81 months) who are all participating in an on-going longitudinal study from 6th to 9th grade, inclusive. Mathematics anxiety was assessed at the end of 8th grade, visuospatial abilities in 7th and 8th grade, and a general test of algebra abilities, an algebraic word problem test, and an anxiety survey occurred in 9th grade. The goals were to determine if there was a sex difference related to both math anxiety and visuospatial ability.

HYPOTHESES

- Hypothesis 1 → We hypothesized that a sex difference, favoring boys, would be found for solving algebra word problems.
- Hypothesis 2 → We hypothesized that boys would have better visuospatial abilities and lower mathematics anxiety than girls.
- Hypothesis 3 → The sex difference in solving algebra word problems would be mediated by some combination of the sex differences in visuospatial abilities and mathematics anxiety.

MATERIALS AND METHODS

Participants	n=171
Sex	87 boys, 84 girls
Age	M = 14 years, 8 months (SD = 4.81 months) (at time of the Algebra assessments)
Race/Ethnicity	White (70%) Black or African American (15%) Multiracial (10%) Asian (4%) American Native or Alaskan Native (1%)

INTELLIGENCE MEASURES

Vocabulary and Matrix Reasoning subtests of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999).

ACHIEVEMENT OF MATHEMATICS AND READING MEASURES

Numerical Operations and Oral Reading Fluency subtests from the Wechsler Individual Achievement Test–Third Edition (Wechsler, 2009)

COGNITIVE MEASURES

- Spatial Span*: Corsi Block Tapping Task (Kessels et al., 2000)
- Spatial Ability*: Judgment of Line Angle and Position Test (JLAP; Collaer et al., 2007) and Mental Rotation Task (MRT-A; Peters et al., 1995)
- Algebra Ability*: Concepts and Procedures in Algebra Test (CaPA, abbreviated; Rittle-Johnson and Starr, 2007) and Algebra Word Problem test (AWP)

NONCOGNITIVE MEASURES

- Attitudes*: Attitudes and Beliefs about Math and English survey (<http://garp.education.uci.edu/msalt.html>)
- Anxiety*: Abbreviated Math Anxiety Scale (AMAS; Hopko et al., 2003)

PROCEDURE

The three cognitive tests were given during seventh and eighth grade, and the two algebra tests along with the Attitudes and Anxiety survey were given toward the middle of ninth grade. Tests were administered in the participants’ schools during45 minute one-on-one sessions.

Parents provided informed written consent, and assent was obtained from adolescents for all assessments. The University of Missouri Institutional Review Board (IRB; Project 2002634, “Algebraic Learning and Cognition”) approved all methods included in this study.

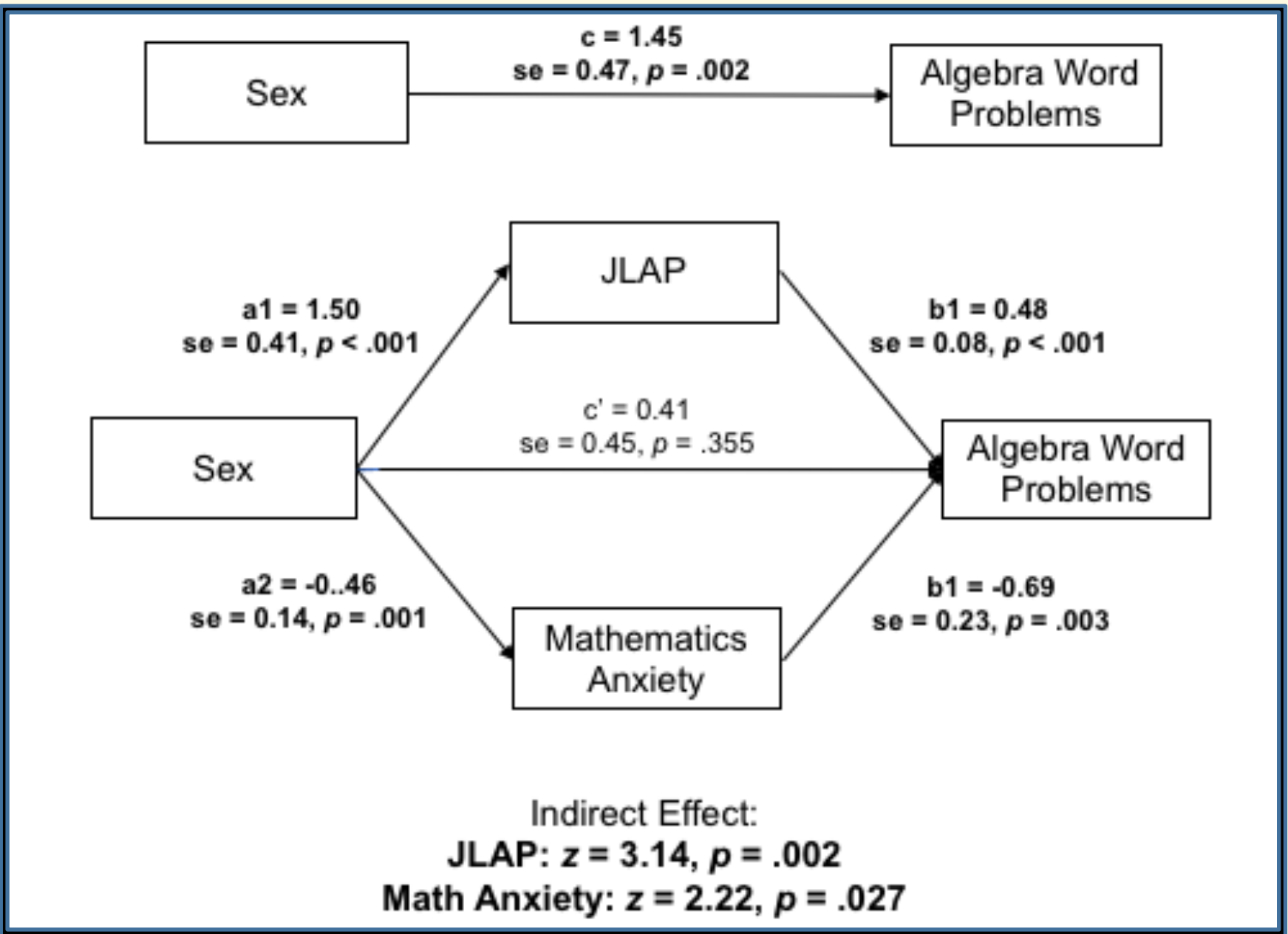
RESULTS

Independent two-sample t-tests were used to assess sex differences for key measures. As shown in the table below, there was a moderate sex difference in the ability to successfully complete algebra word problems, favoring boys ($t_{169} = -3.09$, $p = .002$), but no difference in overall algebra ability ($t_{169} = -.25$, $p = .80$). Boys also had significantly higher scores than girls on the JLAP ($t_{169} = -3.62$, $p = .0004$) and lower mathematics anxiety for evaluations ($t_{169} = 3.29$, $p = .0012$) and mathematics anxiety in general ($t_{169} = 2.12$, $p = .04$). The remaining t-tests rendered smaller differences.

	Male			Female			Effect Size	
	N	Mean	SD	N	Mean	SD	d	p
Numerical Operations Standard Score	87	98.1	16.3	84	98.7	17	-0.04	0.83
Oral Reading Fluency SS	87	103.0	12	84	105.2	11.2	-0.19	.
Oral Reading Accuracy	87	92.1	11.7	84	93.4	12.6	-0.11	.
Algebra Word Problems (AWP)	87	5.1	3.1	84	3.6	3.0	0.49	<.01
Algebra Test (CAPA)	87	7.0	4.5	84	6.8	4.7	0.04	0.8
IQ Scores	87	106.3	12.2	84	104.5	13.9	0.15	0.34
Corsi Blocks	87	8.65	1.5	84	8.2	1.8	0.27	0.09
Judgement of Angle and Line Position (JLAP)	87	14.2	2.5	84	12.7	2.9	0.55	<.01
Mental Rotation Task	87	10.1	4.3	84	9.1	3.9	0.24	0.11
Evaluations Anxiety	87	2.5	.8	84	2.9	1	-0.44	<.01
Learning Math Anxiety (AMAS)	87	1.5	.6	84	1.8	0.9	-0.39	0.04

MEDIATION

Based on the finding of sex differences on the JLAP and mathematics anxiety for evaluations, these measures were included as potential mediators of the sex difference on the algebra word problems test, using the *lavaan* package in R (Rosseel, 2012); these measures were all significantly correlated ($ps < .001$). The sex difference on the algebra word problems test is represented by the *c* path in the top section of the figure below. The *a* paths show the sex differences for JLAP and mathematics anxiety and the *b* paths show that higher JLAP and lower mathematics anxiety scores are associated with higher word problem scores. Once the sex differences on the JLAP and mathematics anxiety are controlled, the sex difference on the algebra word problems is no longer significant (*c'* path, $p = .355$), indicating full mediation of the sex difference. The indirect (mediated) relation between sex and algebra word problems was significant for both JLAP, $z = 3.14$, $p = .002$, and mathematics anxiety for evaluations, $z = 2.22$, $p = .027$.



DISCUSSION

Following previous studies, boys had advantages in the solving of algebra word problems but not algebra more broadly. Boys also had more-developed visuospatial skills and were less math-anxious than were girls; again, consistent with previous studies. These findings confirmed our first two hypotheses.

The novel contribution here is demonstrating that the combination of visuospatial abilities and mathematics anxiety fully mediated the sex difference on the algebra word problem test. The latter finding confirmed our third hypothesis.

The overall pattern suggests that the sex difference in high school algebra is found in some but not all algebraic domains. The results here suggest that any such differences are most likely to emerge for content in which visuospatial abilities help in problem solving (word problems, in this case). The sex difference in mathematics anxiety might contribute to differences with this type of content but did not appear to undermine performance in all areas of algebra, given no sex difference on the general algebra test.

Future Direction: When teaching algebra, specifically word problems, teachers can use spatial diagrams to assist understanding of word problems which can decrease error rates and has been found to reduce the sex difference in solving word problems (Johnson, 1984).

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