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Influence of reading and calculation on children at risk and not at risk for word problem solving: Is math motivation a mediator?☆

Wenson W. Fung *, H. Lee Swanson, Michael J. Orosco

Graduate School of Education, University of California, Riverside, CA, USA

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ABSTRACT

The purpose of this study was to examine whether two motivational constructs (attitudes/beliefs and effort toward math) acted as mediators between reading or calculation skill and word problem solving accuracy in children with and without math difficulties (MD). The sample consisted of 264 children, separated into children with MD ($N = 179$) and without MD ($N = 85$), ages 7 to 10 years ($M = 8.06$, $SD = 0.52$; 134 males, 130 females) from 2nd, 3rd, and 4th grade classes. The results showed that both reading and calculation skills had direct effects on word problem solving accuracy for both children with and without MD but the two motivational constructs did not mediate this relationship in either group. The results suggest that motivational constructs related to attitudes/beliefs and effort toward math have little meditational influence between basic reading/calculation skills and problem solving accuracy.

Current categories of learning disabilities include specific disabilities, including calculation and math problem solving [see IDEA reauthorization, 2004, Sec. 300.8(c)(10)], but the majority of the research on math disabilities (MD) focuses on cognitive processes related to calculation (Andersson, 2010; Geary, 1993, 2010; Gersten et al., 2009; Mazzocco, Devlin, & McKenney, 2008; Stock, Desoete, & Roeyers, 2009; Swanson & Jerman, 2006). This focus is unfortunate because math word problem solving (WPS), which involves math exercises where background information is presented as texts rather than math notations and equations, constitutes one of the most important mediums through which students can learn to select and apply strategies for coping with everyday problems. In addition, studies have shown that deficits in WPS are persistent across the elementary school years even when calculation and reading skills are at grade level (e.g., Swanson, Jerman, & Zheng, 2008).

One factor that may play a role in WPS is motivation. Since many children perceive math as more difficult than other subjects, it has been suggested that higher motivation is beneficial and is correlated with math achievement (e.g., Eccles, Adler, & Meece, 1984; Gottfried, 1990; Middleton & Spanias, 1999). However, the role of motivation in linking basic skills in such area as calculation and reading to WPS remains unclear since some studies found that motivation have an association (e.g., Aunola, Leskinen, & Nurmi, 2006) whereas other have not (e.g., Lu, Weber, Spinath, & Shi, 2011). This study provided a clearer understanding of the role of motivation by examining two aspects of motivation, attitudes/beliefs and effort, on WPS and its mediating role among children with and without MD.

1. Reading and calculation

It is no surprise that numerous studies have found reading and calculation performance have a large influence on WPS in children with and without MD, as every word problem requires children to read and comprehend it and then do the necessary calculations. Vilenius-Tuohimaa, Aunola, and Nurmi (2008) examined the relationship between reading comprehension and WPS in a group of 4th graders and found that poor readers had significantly lower scores on WPS than good readers. Although reading has a large influence on WPS, it does not completely account for WPS performance. Calculation performance also has an influence. Andersson (2008) examined 3rd and 4th graders with reading difficulties (RD), math difficulties (MD), and comorbid RD-MD. They found that children with RD had similar performance in WPS to the control group, but that children with MD or RD-MD had lower performance. Andersson

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* Corresponding author at: University of California, Graduate School of Eduction, 1207 Sproul Hall, Riverside, CA 92521.
E-mail address: wfung002@ucr.edu (W.W. Fung).

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(2007) found that calculation had a larger influence on WPS ($\beta = .33$) than reading ($\beta = .21$). Thus, reading performance alone does not completely account for WPS performance, but calculation is also a contributing influence.

2. Motivation

Motivation may have an important role in mediating the relationship between problem solving and basic skills in reading and math. Because many children perceive math as more difficult and demanding than other subjects, it has been suggested that higher motivation is needed to succeed when compared to other subjects, and motivation correlates strongly with math achievement (Eccles et al., 1984; Gottfried, 1990; Middleton & Spanias, 1999). Lepola, Niemi, Kuikka, and Hannula (2005) found that motivation (persistent effort, becoming absorbed in the task) influenced children's reading comprehension and calculation from grade 1 onwards, even when controlling for prior linguistic and math skills. Another study found that higher math performance in 1st grade influenced subsequent math motivation (interest or liking of math), which in turn, influenced math performance at the beginning of 2nd grade (Aunola et al., 2006). Magi, Lerkanen, Poikkeus, Rasku-Puttonen, and Kikas (2010) examined teacher-rated student classroom effort in a sample of 2nd and 3rd graders and found that effort was positively associated with math grade. Furthermore, Gottfried (1990) found that that overall intrinsic motivation was positively associated with math achievement among children ages 7 to 9. Lepola et al. (2005) found that from grade 1 onwards, motivation made unique contributions to decoding accuracy, reading comprehension, and calculation performance. Viljaranta, Lerkkanen, Poikkeus, Aunola, and Nurmi (2009) examined a sample of 5- and 6-year-olds and found that prior motivation yielded small to moderate correlations between concurrent and subsequent calculation testing, but not for literacy performance. In sum, some studies have found that higher motivation in various forms is associated with higher math achievement, including calculation performance.

However, other studies have found that motivation has little effect on achievement (Areepattamannil & Freeman, 2008; Halawah, 2006). Areepattamannil and Freeman (2008) found that overall intrinsic and extrinsic motivation did not predict overall GPA or math GPA in a sample of 11th and 12th graders. Furthermore, Halawah (2006) found no significant correlation between general academic motivation and overall GPA in high school students. These inconsistent results seem to suggest that motivation may or may not act as a mediator between WPS and basic reading and calculation skills.

The purpose of the present study is to examine the effect of attitudes/beliefs and effort on WPS and whether it mediates the relationship between reading, math skills, and WPS performance in children with and without MD. Given that many children perceive math to be more difficult and demanding than other school subjects, that higher motivation in various forms may be needed for math achievement (Eccles et al., 1984; Gottfried, 1990), and that children with MD have been reported as having lower scores than normally achieving children (Andersson, 2008), there is reason to suspect that reading, calculation, and attitudes/beliefs and effort may act differently among children with MD. It should be noted that the concept of motivation is broad term and can mean a number of concepts, including task orientation, absorbed in a task, interest/liking/enjoying a subject, attitudes/beliefs about a subject, effort, etc. In this study, only two aspects of motivation are examined: (a) attitude/belief, which is closely related to intrinsic motivation, and (b) effort.

This study addresses two questions. First, does attitudes/beliefs and effort mediate the relationship between basics math/reading processes and WPS? Second, are the effects of attitudes/beliefs and effort on problem solving more pronounced in children with MD than children who are average achievers?

3. Methods

3.1. Participants

The sample consisted of 264 children ages 7 to 10 years ($M = 8.06$, $SD = 0.52$; 134 males, 130 females) from 2nd to 4th grades in six Southern California public schools. The ethnicity makeup of the sample was as follows: 52% Caucasian, 33% Hispanic, 6% African American, 5% Asian, and 4% other (e.g., Native American). One child did not have ethnicity information. The mean SES of the sample was primarily low to middle SES based on free lunch participation, parent education, or occupation. However, the sample varied from low-middle class to upper middle-class.

3.1.1. Definition of risk for serious math difficulties (MD)

While there is controversy over the definition of math disabilities, this study adheres to the growing consensus among researchers that it is best to use an absolute definition of specific learning difficulties (cutoff score on achievement) rather than a discrepancy between achievement and IQ. In determining the cutoff for MD, we consider that previous studies using a math cutoff score below the 25th percentile (Geary, Hoard, Nugent, & Bailey, 2012; Mazzocco et al., 2008). Because the focus of this study is on children with math difficulties and not disabilities, children who scored below the 25th percentile on a WPS measure were our sample for MD.[1] The Story Problem subtest from the Test of Math Ability (TOMA, Brown, Cronin, & McEntire, 1994) was used to identify children below the 25th percentile.

Based on the above criteria, the sample consisted of 179 children with MD (86 males, 93 females) and 85 children (48 males, 37 females) without MD. Table 1 shows the descriptive statistics of the two groups. Performance on standardized measures of WPS for the MD sample was well below the 25th percentile, whereas their norm-referenced scores on calculation, reading comprehension, and fluid intelligence were above the 25th percentile. There were no differences between MD and non-MD children in terms of gender, $\chi^2(1, N = 264) = 1.64, p > .05$, and ethnicity, $\chi^2(5, N = 263) = 10.63, p > .05$.

3.2. Classification measures

3.2.1. Word problem solving

The Story Problems subtest from the Test of Mathematical Abilities (TOMA; Brown et al., 1994) was administered. The assessment involved children reading a short story problem that ended with a computational

[1] We acknowledge that dichotomizing the data is not recommended compared to analyzing continuous measures (see MacCallum, Zhang, Preacher, & Rucker, 2002; for an extensive discussion on the limitation of dichotomizing). That is, creating discrete variables from continuous variables has been shown to decrease power, weaken reliability and increase Type I error. However, the vast majority of studies on MD have used the dichotomization of normed referenced achievement measures as a means to study children classified as at risk. For example, Fuchs, Fuchs, Stuebing, Fletcher, Hamlett, and Lambert (2008) provided a justification for dichotomization (cutoffs) in the study of MD (math in this case, see p. 37) to determine risk status by using common cutoff score designations. In terms of common cutoff score designations for MD, the 25th percentile is commonly used to designate risk and it is useful to use cutoff scores as practiced in the schools. In Table 1, we show the scores for nationally normed math measures. It is important to note that extreme groups (removing children close to the cutoff scores in our comparisons) were not created in our analysis. The removal of children to create extreme groups has come under criticism because it creates several artifacts and unwarranted assumptions about linearity, group membership, and the reliability of the findings are more likely to be reduced rather than increased related to these procedures (Preacher, Rucker, MacCallum, & Nicewander, 2005). However, Preacher et al. suggest that subgrouping (creating groups) is appropriate to determine if an effect exists (i.e., direction of the effect, but not the magnitude, p. 188), if the data appear skewed, and/or the researcher wants to optimize their chances of finding interactions. Further, our a priori creation of subgroups is well suited for use in the exploratory stage of research “when the exact function form of a relationship is unknown but there is reason to make conjectures about the existence and direction of an effect” (p. 189). Because we have a priori defined our two groups and “not engaged in post-hoc subgroups” or removed middle values (thereby decreasing the power of our analysis), we assume our subgrouping is justifiable for exploratory purposes.