Does Cognitive Strategy Training on Word Problems Compensate for Working Memory Capacity in Children with Math Difficulties?

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Abstract

Cognitive strategies are important for tools for children with math difficulties (MD) in learning to solve word problems. The effectiveness of strategy training, however, depends on working memory capacity (WMC). Thus, children with MD but with relatively higher WMC may be more likely to profit from strategy training, whereas children with lower WMC may have their resources overtaxed. In this Goal 2 study, children in grade 3 (N = 146) were randomly assigned to 1 of 4 conditions: (a) verbal strategies (e.g., underlining question sentence), (b) visual strategies (e.g., correctly placing numbers in diagrams), (c) verbal + visual strategies, or (d) an untreated control. In line with the predictions, children with MD and higher WMC benefited from visual-spatial strategies relative to the control conditions on post-test measures of problem solving accuracy, calculation accuracy, and operation span. In contrast, cognitive strategies decreased problem solving accuracy in children with low WMC. Thus, improvement in problem solving and related measures, as well as the impact in learning outcomes was mediated by WMC.

Introduction

Research on children with math difficulties (MD) has focused in the area of calculation processes (Anderson, 2010; Geary, 2001, 2010) but more recently has expanded to include those children who experience difficulty solving word problems (e.g., Anderson, 2010; Fuchs et al., 2010). Word problem solving constitutes a critical addition because through word problem solving children learn to apply strategies for coping with everyday problems beyond the classroom. Evidence suggests cognitive processes involved in calculation difficulties are not the same as those involved in problem solving difficulties (e.g., Fuchs et al., 2008). This is supported by studies indicating word problem solving deficit cannot be accounted for across the elementary school years even when calculation and reading skills remain at grade level (e.g., Swanson et al., 2008). Recent studies have found support for teaching cognitive strategies to enhance children with MD with their problem solving skills particularly with models using verbal strategy instruction (Montague, 2004; Montague, Wagner, & Morgan, 2003), visual-spatial strategies (e.g., Kellolfel, Eysenck, de Jong, & Wilhelm, 2009) or visualization categorization methods (Simms et al., 1998) and diagramming (van Garderen, 2007), identifying keywords (e.g., Mastropietro, Scribner, & Skidder, 1997), and other verbal and visual-verbal strategies.

We hypothesize that the availability of ample working memory (WM) resources is an important prerequisite in determining whether this strategy training will be successful in a child with MD. Particularly as children with MD experience more working memory difficulties (e.g., Fuchs et al., 2010; Swanson, Keller, Jerger, 2010); in line with cognitive load theory (e.g., Sweller, 1988, 2005), poor problem solving skills plus low WM capacity (WMC) may have direct consequences on the effectiveness of such cognitive strategy interventions while higher WMC may allow spare resources to benefit

Research Objectives

Random Assignment

Participants

Participants were 146 (84 with MD, 62 non-MD), 3rd grade students from a public elementary school in southern California. Criteria for defining MD was a score between the 35th and 95th percentiles on a measure of fluid intelligence: reading, and calculation, and a score below the 25th percentile on measures of word problem solving accuracy. Subjects were randomly assigned to treatment conditions (Verbal Strategies-only, Visual Strategies-only, Verbal + Visual Strategies, and Control). This was an experimental pretest/post-test design, with an i-as intervention that lasted for 8 weeks, 2-3 times a week, for 30 minutes each session. Lessons were presented in 4 parts: warm up basic math skills, instruction on cognitive strategy (visual-spatial only, verbal only (a.k.a. diagramming), or visual + verbal), guided practice (1 question), and independent practice (3 questions). Number of relevant and irrelevant sentences increased across lessons.

Methods

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Clustering: MANOVA was significant for risk status (MD/non-MD) but not interaction, and the pretest operation span score. In control condition, Low WMC MD had a significant advantage over non-MD. In treatment condition, significant treatment effects occurred for non-MD. Within the two tasks, Tukey tests showed significance for the Visual-only condition, particularly for High WMC children.

Effect Sizes (20-mo, 50-mo, 80-g): MD - Problem solving, calculation accuracy, and operation span were in the mid to high range in the Visual-only (diagramming) condition. All treatments enhanced calculation accuracy relative to control. Non-MD - Only operation span scores were in the mid to high range, but only for Visual-only. MD - Low WMC - No significant differences. MD - High WMC - Large effect sizes in favor of Visual-only (diagramming) across problem solving, calculation, and operation span.

4 models assessed WMC role on cognitive strategy training outcomes for children with MD:

1. WMC is a Limiting Factor Model – children with MD will vary in their responsiveness to strategy assistance with those with MD with low WMC benefitting less.
2. Basic Skills Model - all children show benefit with greater math ability and not WMC. If basic reading and computational skills are intact, then strategy instruction will provide a helpful procedure for improving efficiency in using these skills on word problem solving ability without making additional demands on WMC.
3. General Resource Model - WM as underlying several problem solving tasks, WM has a general effect (non-specific or specific) effect on problem solving outcomes.
4. Compensatory Model - WM interacts with strategy training, those children with low WMC are more likely to benefit more than with high WMC from strategy intervention.

Effect Sizes for Adjusted Post-Test Scores as a Function of Treatment x Ability Group

Results

Classification: MANOVA was significant for risk status (MD/non-MD) but not treatment groups. All covariates were significant for risk status, but not treatment.

Post-test Criterion Measures: Problem Solving yielded a significance for risk status and the WMC covariate. No other significant effects or interactions. Calculation accuracy yielded a significant effect for the WMC covariate. Operation Span ANOVA was expected to covary with WMC, a significant effect emerged for risk status on operation span. No significant treatment effects occurred for operation span.

Discussion

This study investigated the role of strategy instruction, working memory (WM) load and WM capacity (WMC) on word problem solving accuracy in children with math difficulties (MD).

- WMC does play a role in post-test performance especially on visual-spatial conditions.
- Children with high WMC, especially with MLS, benefited more from visual-only diagramming than those with low WMC on problem solving, calculation, and operation span.

- Using cognitive strategies decreased problem solving accuracy in children with low WM relative to the control condition.

- 4 models were assessed as possible predictors for how WMC would impact strategy training outcomes for children with MD. The Compensatory Model was not found to be the best fit, rather the results suggested that cognitive strategy training improved problem solving outcomes for children with relatively larger WMC because these children have more WMC resources available to utilize the strategies.

Implications: WMC level may account for why some benefit from strategy instruction in class and others do not. Visual-spatial strategies, more so than verbal strategies, assisted problem solving in children with MD and may help to close the math performance gaps in classrooms. Could moderating effects of WMC change with longer intervention? Perhaps WMC becomes less important with greater strategy practice. This might reduce the disadvantage found for Low WMC children with MD using strategies. Non-MD children only benefited from cognitive strategy conditioning on operation span but not problem solving or calculation. Did operation span potentially benefit from a practice or novelty effect?

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Data Analysis

Random effects were measured for: 1) MD/non-MD risk & task interacted with treatment 2) Treatment nested within classroom.

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