Semantic Verbal Fluency Predicts Mathematical Learning

Abbey M. Loehr, Michael R. Miller, Marci S. DeCaro, & Bethany Rittle-Johnson

VANDERBILT PEABODY COLLEGE

Background

Differences in young children's cognitive abilities are predictors of later academic achievement (Welsh et al., 2010).

- **Working memory**, the ability to hold information in memory temporarily while inhibiting distractions, is important for performance on mathematical tasks (see Raghubar et al., 2010).
- **Semantic verbal fluency** (i.e., fluency), or the controlled search and retrieval of words from long-term memory (Baddeley, 1996; Ratcliff et al., 1998), may also be important.
  - Associated with the efficiency of working memory functions (Auzma, 2004)
  - Highly correlated with executive functioning and attention capacity (Hurks et al., 2004)
  - Predicts both concurrent and future mathematics performance (Andersson, 2008; Swanson, 2011)
  - Ability to strategically search and retrieve information from memory may help students to better attend to, process, and apply instructional guidance
- However, little is known about the combined influence of working memory and fluency in math learning.

Current Study

***Domain*:** Mathematical equivalence

- Concept that two sides of an equation are the same amount
- Foundational for algebra (Falkner, Levi, & Carpenter, 1999)
- Operational View: View "=" as a command to carry out arithmetic operations
  - 3 + 5 + 6 = __ + 6, most get 14 or 20
- Relational View: View "=" as meaning two sides of an equation have the same value

Participants: 122 2nd and 3rd graders with less than 75% or higher on either a conceptual or procedural knowledge measure at pretest

Design:

- During the intervention, students received instruction on the concept of math equivalence either *before* or *after* being asked to solve and explain challenging problems.
- **Conceptual Instruction**: Children were taught the relational meaning of the equal sign in the context of five non-standard number sentences
- **Intervention Problem Solving**
  - 4 standard arithmetic problems
  - 8 math equivalence problems

    6 + 3 + 4 = 6 + __ 3 + 4 + 8 = __ + 8

Measures

Executive Function Tasks

- **Working Memory**: Backward Digit and Letter Spans (Davis & Pratt, 1995)
- **Semantic Verbal Fluency**: Given 1 minute each to name as many items as possible from two categories (i.e., animals and food; NEPSY II, 2007)

Math Equivalence Assessment

- Rittle-Johnson et al., 2011

Conceptual Knowledge – understanding the principles governing a domain

Explicit – Equal Sign Knowledge

What does the equal sign mean?

Implicit – Equation Structure Knowledge

3 + 5 = 5 + 3 True or False

Procedural Knowledge – knowledge of specific action sequences to correctly solve a problem

Learning Items – Same as those practiced during the intervention

7 + 6 + 4 = 7 + __

Transfer Items – Different from those practiced during the intervention

8 + __ = 8 + 6 + 4 *6 - 4 + 3 = __ + 3*

Table 1: ***Summary of Hierarchical Multiple Regression Analyses for Variables Predicting Overall Math Equivalence Performance (N=118)***

	Posttest				Retention Test			
Predictors	Δ R^2	B	SE B	β	Δ R^2	B	SE B	β
Block 1	.25				.22			
Grade		13.07	6.49	.17*		4.69	5.27	.08
Pretest ME Score		.98	.19	.43**		.82	.16	.45**
Block 2	.09				.06			
Grade		12.49	6.16	.16*		4.37	5.12	.07
Pretest ME Score		.74	.20	.32**		.70	.16	.38**
Working memory		6.19	2.59	.20*		1.92	2.15	.08
Fluency		2.25	.84	.21**		1.90	.70	.22**
Total R^2	.34				.28			
F	14.33**				11.03**			

* p < .05. ** p < .01.

Results

- Controlling for grade and prior math equivalence knowledge, hierarchical regression models indicated that both working memory and fluency predicted students' overall mathematical equivalence knowledge at posttest (see Table 1).
- However, at the retention test, students' working memory was no longer significant, whereas fluency still predicted math equivalence over and above grade, prior knowledge, and working memory.
- Additional analyses indicated that fluency predicted outcomes on both procedural and conceptual knowledge subscales at posttest and retention test, whereas working memory only predicted procedural knowledge at posttest.
  - Findings for **procedural knowledge** show a similar pattern as seen in Table 1 for overall mathematical equivalence knowledge. Both working memory (β = .24, p < .01) and fluency (β = .19, p < .05) predicted students' procedural knowledge at posttest. At retention test, only fluency (β = .26, p < .01) remained significant.
  - For the **conceptual knowledge** subscale, only fluency predicted students' conceptual knowledge at both posttest (β = .48, p < .01) and retention test (β = .15, p = .05) over and above grade, prior ME knowledge and working memory.

Conclusion

- While both working memory and fluency seem to impact immediate learning of math equivalence, only fluency remains important for knowledge retention.
- Similarly, while both working memory and fluency impacted learning of procedural knowledge, only fluency predicted gains in conceptual knowledge.
  - Instruction focused on key concepts, so ability to strategically search and retrieve information from memory (i.e., fluency) may help students to better attend to, process, and apply conceptual instruction.
- Future mathematics studies with young children should account for the dynamic relations between different aspects of cognitive ability.

References

- Andersson, U. (2008). Working memory as a predictor of written arithmetical skills in children: The importance of central executive functions. *British Journal of Educational Psychology*, 78, 181-203.
- Azuma, T. (2004). Working memory and perseveration in verbal fluency. *Neuropsychology,* 18(1), 69-77.
- Baddeley, A. D. (1996). Exploring the Central Executive. *Quarterly Journal of Experimental Psychology*, 49A, 5-28.
- Falkner, K. P., Levi, L., & Carpenter, T. P. (1999). Children's understanding of equality: A foundation for algebra. *Teaching Children Mathematics*, 6(4), 232-236.
- Hurks, P. P. M., J. G. M. Hendriksen, et al. (2004). Verbal fluency over time as a measure of automatic and controlled processing in children with ADHD. *Brain and Cognition,* 55(3), 535-544.
- Korkman, M., Kirk, U., & Kemp, S.L. (2007a). NEPSY II Administrative manual. San Antonio, TX: Psychological Corporation.
- Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences*, 20, 110-122.
- Ratcliff, G., Ganguli, M., Chandra, V., Sharma, S., Belle, S., Seaberg, E. & Pandav, R. (1998). Effects of literacy and education on measures of word fluency. *Brain and Language*, 61, 115–122.
- Rittle-Johnson, B., Matthews, P. G., Taylor, R. S., & McEldoon, K. L. (2011). Assessing knowledge of mathematical equivalence: A construct-modeling approach. *Journal of Educational Psychology*, 103(1), 85-104.
- Rittle-Johnson, B., Siegler, R. S., & Alibali, M. W. (2001). Developing conceptual understanding and procedural skill in mathematics: An iterative process. *Journal of Educational Psychology*, 93(2), 346-362.
- Swanson, H. L. (2011). Working memory, attention, and mathematical problem solving: A longitudinal study of elementary school children. *Journal of Educational Psychology,* 103(4), 821-837.
- Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., Nelson, K. E (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of Educational Psychology,* 102(1), 43-53.

VANDERBILT KENNEDY CENTER FOR RESEARCH ON HUMAN DEVELOPMENT

The author appreciates the graphic services support from the Vanderbilt Kennedy Center for Research on Human Development. The Vanderbilt Kennedy Center mission is to facilitate discoveries and best practices that make positive differences in the lives of persons with developmental disabilities and their families. kc.vanderbilt.edu