

Executive Function and Academic Outcomes

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Agenda

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- Summary of my Research
- What can EF and academic outcomes research tell us?
- What can't it tell us?
- Promising Directions for Education Research and Practice

What are Executive Functions?

- Viewed as the “air traffic control system” of the mind.
- They control our thoughts, behaviors, and our emotions.



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What are Executive Functions?

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- Dimensions of executive functions:
 - Inhibitory control: our ability to ignore distractions and pay attention
 - Working memory: our ability to hold information in mind and manipulate it for later use
 - Cognitive Flexibility: our ability to shift between tasks, goals, or strategies

What are Executive Functions?

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Shopping at
grocery store

Solving a math
problem

Organizing your
clothes by color
and season

Driving

Executive Function and Academic Outcomes

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Executive functions are highly related to a host of academic outcomes:

- Reading and mathematics skills
- Learning disabilities
- Language ability
- Attention hyperactivity disorders

Individuals who perform well on executive function tasks often do well in many aspects of school

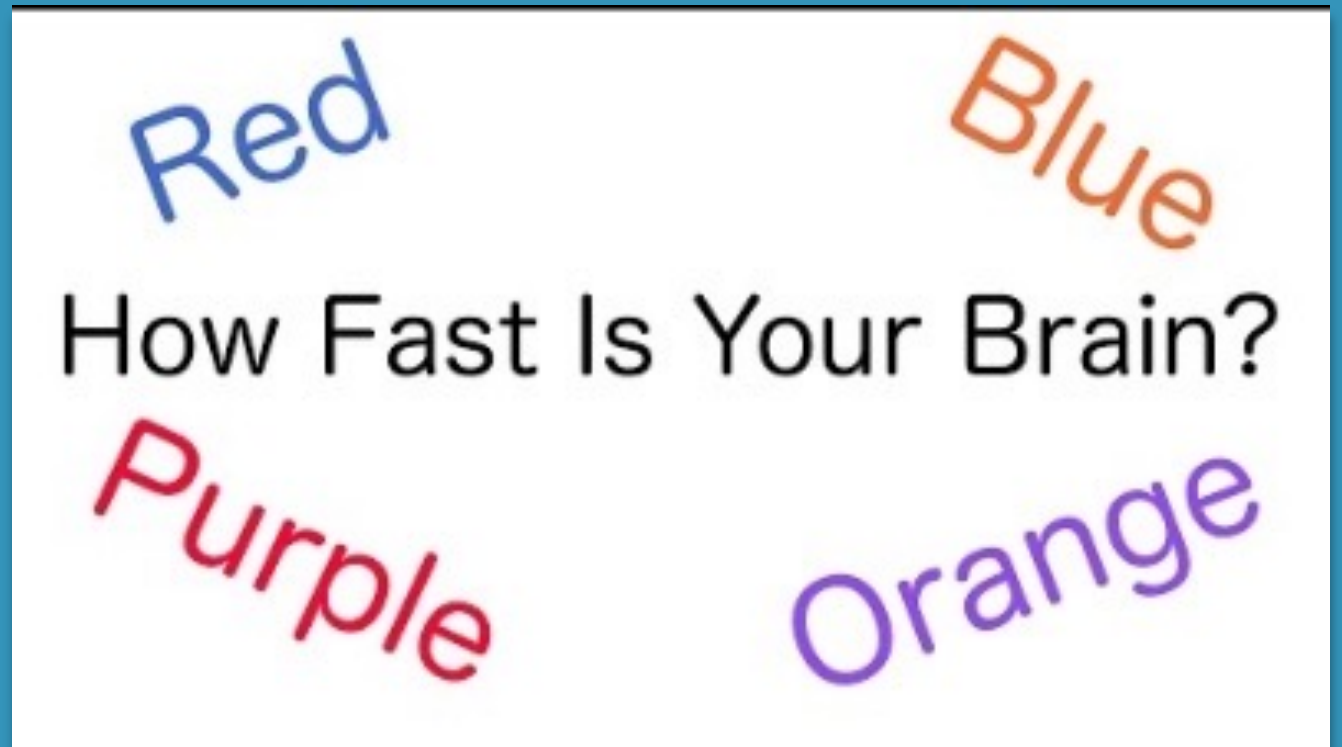
Executive Function Assessments

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- Stroop Task
- Numbers Reversed

Stroop Task

Measures Inhibitory Control and Cognitive Flexibility



Stroop Task

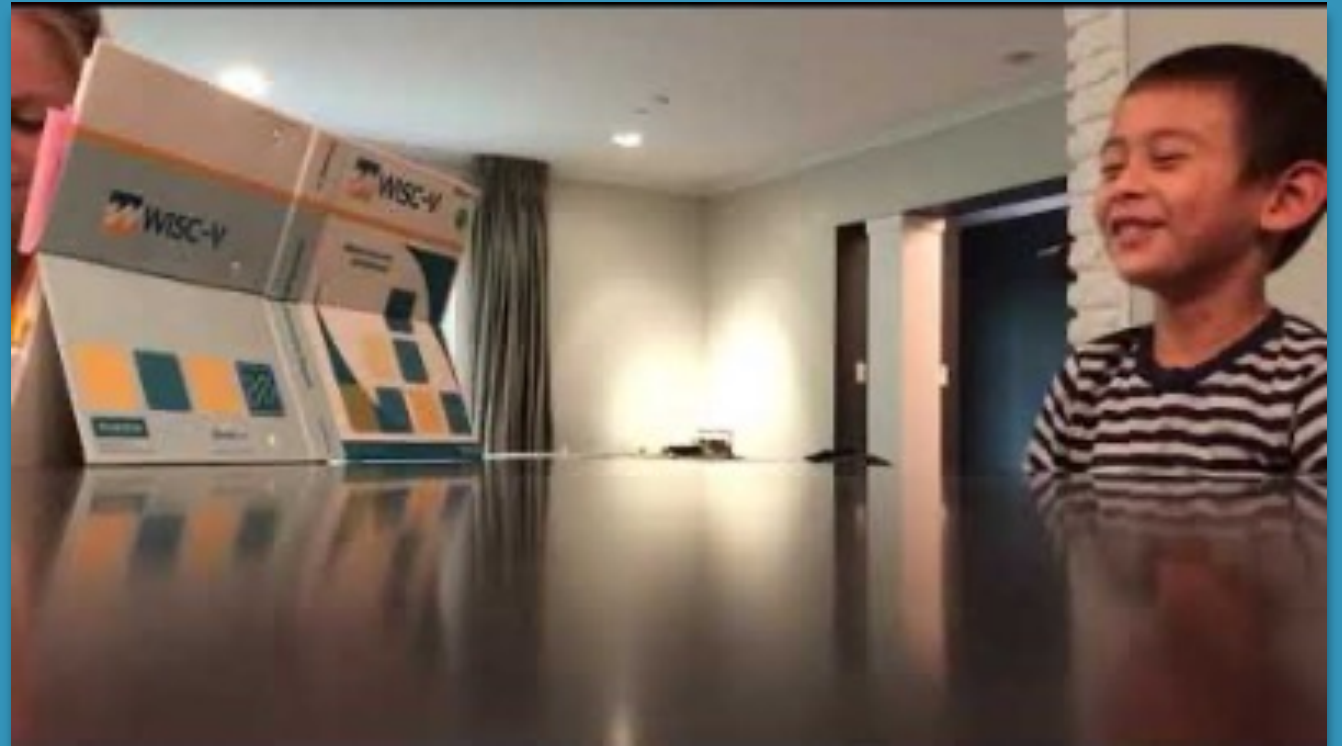
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Ignore the
color, say the
word (inhibit)

Ignore the
word, say the
color (switch
and inhibit)

Numbers Reverse

Measures Working Memory



Numbers Reverse

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- Remember the numbers, manipulate them in another order (working memory)

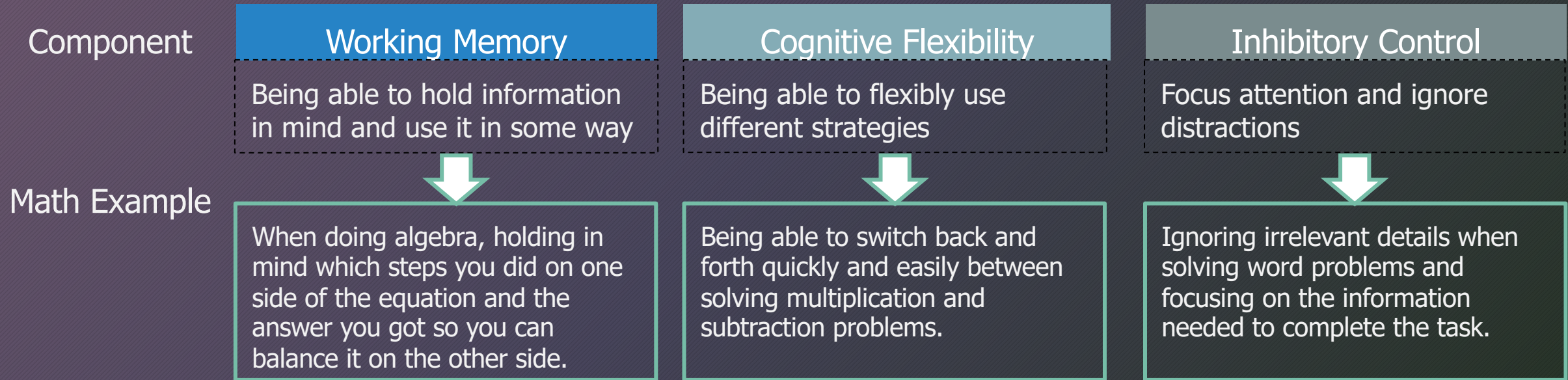
How are executive functions at work
in my students?

What might EF struggles look like?

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- Struggles to plan or organize for long-term goals
- Trouble controlling behaviors or emotions (i.e., poor emotion regulation)
- Concentrating on a specific task
- Trouble remembering details

EFs in a Mathematics Classroom



Working Memory

Component

Working Memory

Being able to hold information in mind and use it in some way

Math Example

When doing algebra, holding in mind which steps you did on one side of the equation and the answer you got so you can balance it on the other side.

Cognitive Flexibility

Component

Cognitive Flexibility

Being able to flexibly use different strategies



Math Example

Being able to switch back and forth quickly and easily between solving multiplication and subtraction problems.

Inhibitory Control

Component

Inhibitory Control

Focus attention and ignore distractions



Math Example

Ignoring irrelevant details when solving word problems and focusing on the information needed to complete the task.

Why are executive
function skills and
mathematics skills
related?

Testing Theories of EF and Math

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- Examined three theories of working memory and math/reading skills
 - Are WM and these skills the same?
 - Does WM help take information from our mind? (processing)
 - Does WM act like a filter?

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What's the Best Way to Characterize the Relationship Between Working Memory and Achievement?: An Initial Examination of Competing Theories

Dana Miller-Cotto
University of Pittsburgh

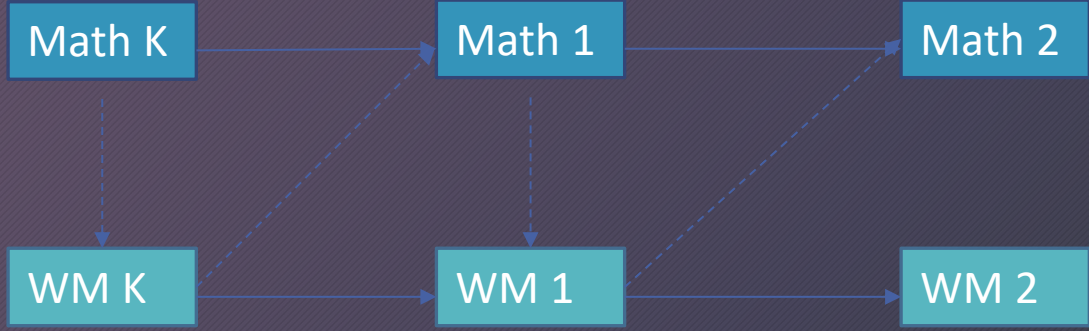
James P. Byrnes
Temple University

Although studies have demonstrated a relationship between working memory and achievement in math and reading, it is still unclear *why* working memory might be related to these abilities. In the present article, we examined the viability of several possible theories in 2 separate analyses of math and reading. In each case, we contrasted the predictions of a cognitive filter model, a transactional model, and a positive manifold model using data from the 2011 Early Childhood Longitudinal Study Kindergarten (ECLS-K). Results of path analyses in a structural equation modeling (SEM) framework indicated an excellent fit for the transactional model, while a poor fit was shown for the other 2 models for both math and reading. Findings across these analyses suggested that working memory and achievement interact in a reciprocal, recursive manner over time. Findings are discussed in terms of their implications for theory, practice, and future research.

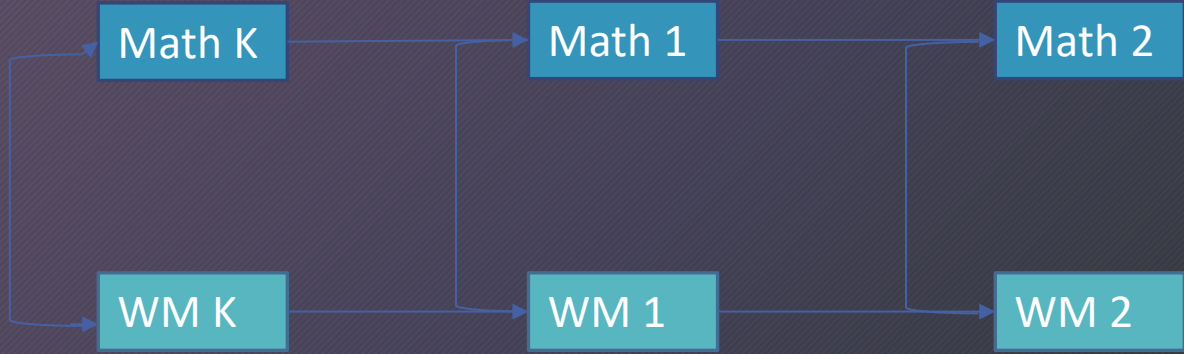
Educational Impact and Implications Statement
The current study demonstrated support for prior theories that suggested that working memory and prior knowledge work together in an interactive nature over time. That is, the relationship between working memory and achievement may be explained by an individual's ability to retrieve information from long-term memory. This was the case for both math and reading, two domains that have often been seen as very distinct. Findings highlight the importance of understanding the mechanisms underlying the associations between working memory and math or reading ability to improve these skills.

Keywords: mathematics, reading, working memory, path analysis, secondary data analysis

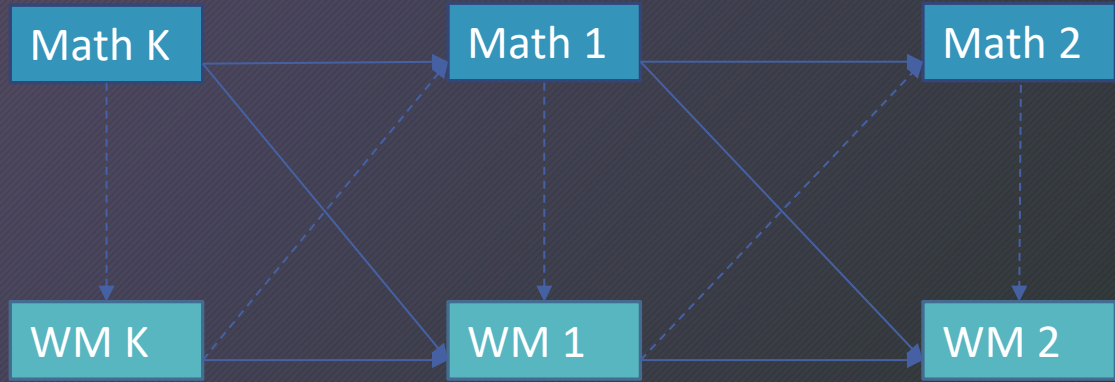
Cognitive Filter



Positive Manifold



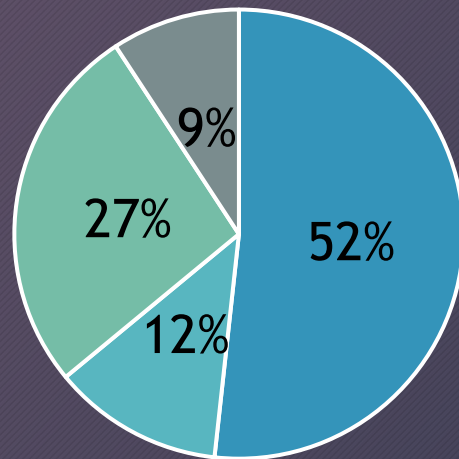
Transactional



Testing Theories of EF and Math

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- National Sample
- Used statistical analyses to test these three theories



White Black Latinx Asian

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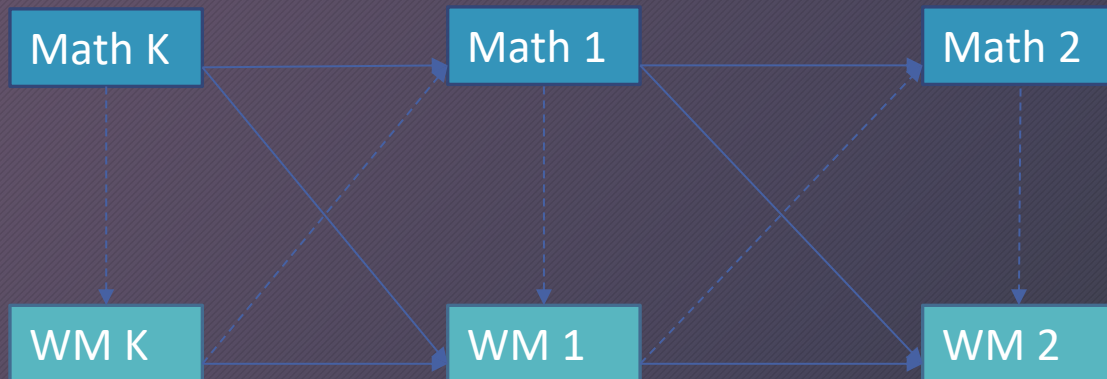
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Testing Theories of EF and Math

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- Findings
 - Analyses suggested a reciprocal relationship
 - Relations decreases with age



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What now?

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- Suggests that working memory helps pull information from memory
- This might suggest that building working memory would improve one's ability to pull information from memory

What now?

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- EF training has demonstrated limited results.
- Less focus on training, more on other things.

Supporting Executive Functions

For each set, first examine the problem on the left. Then complete the similar problem on the right.

SET 1 Solve each equation.



Denise solved this problem correctly.
Here is her work:

$$3(4x + 7) = 15$$

$$\begin{aligned} 3(4x+7) &= 15 && \div 3 && \div 3 \\ 4x+7 &= 5 && -7 && -7 \\ 4x &= -2 && \div 4 && \div 4 \\ x &= -\frac{1}{2} \end{aligned}$$



Your Turn:

$$4(3x + 9) = 12$$

Supporting Executive Functions

- Fading Worked Examples

Example 1	Example 2	Example 3	Example 4	Example 5
$\begin{array}{r} 534 \\ \times 56 \\ \hline 3\ 204 \\ + 26\ 700 \\ \hline 29\ 904 \end{array}$	$\begin{array}{r} 385 \\ \times 24 \\ \hline 1\ 540 \\ + 7\ 700 \\ \hline \end{array}$	$\begin{array}{r} 621 \\ \times 48 \\ \hline 4\ 968 \\ + \quad 0 \\ \hline \end{array}$	$\begin{array}{r} 917 \\ \times 54 \\ \hline 3\ 668 \\ \hline \end{array}$	$\begin{array}{r} 639 \\ \times 28 \\ \hline \end{array}$

Change Math Problem Presentation

28

- Does presenting too much of a problem at once overwhelm students?
- Worked Examples

EDUCATIONAL PSYCHOLOGY
<https://doi.org/10.1080/01443410.2019.1646411>

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Testing the ecological validity of faded worked examples in algebra

Dana Miller-Cotto^a  and Abbey E. Auxter^b

^aLearning, Research, and Development Center, University of Pittsburgh, Pittsburgh, PA, USA;
^bDepartment of Foundational Mathematics, Community College of Philadelphia, Philadelphia, PA, USA

ABSTRACT
Faded worked examples have been used to promote problem solving performance, such as mathematics performance in many laboratory studies and short-term classroom studies. However, few studies have examined the ways educators may use fading in their own classroom on more accessible platforms that do not require programming experience. Further, few classroom studies have administered fading more than once, limiting the treatment effect. The current study examined whether faded worked examples would promote learning in a classroom. Undergraduates ($N = 135$) completed four homework assignments over the course of one unit in a college semester over the course of two waves of data collection. Using Canvas, homework assignments were deployed once a week for four weeks in the form of (a) faded worked examples, (b) faded worked examples with self-explanations, (c) self-explanations, and (d) business as usual. Results indicated that students in the problem-solving group outperformed those exposed to fading with self-explanation prompts but showed no difference between the fading alone or self-explanation alone condition. Findings are discussed in terms of future research.

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KEYWORDS
Faded worked examples;
self-explanation; algebra;
higher education

Change Math Problem Presentation

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- Does presenting too much of a problem at once overwhelm students?
- Altered the way mathematics problems were presented
 - Faded worked examples
 - Faded worked examples with self-explanations
 - Self-Explanations
 - Business as usual
- Students with lower prior knowledge benefitted from the altered presentation.
- How does working memory and inhibitory control fit in?

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Change Math Problem Presentation



Children were given faded worked examples, faded worked examples with self-explanation prompts, worked examples, as business as usual



Assessed their inhibitory control and working memory

Children's adaptation of the Stroop Task
Numbers Reverse Task



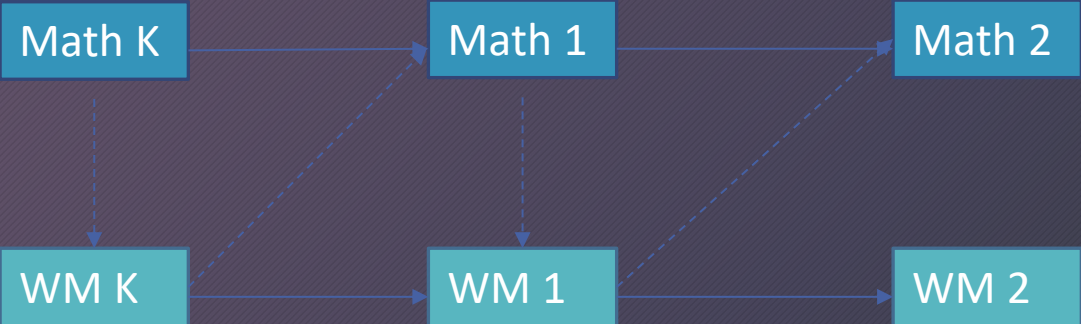
Children who demonstrated weak working memory but average prior knowledge benefitted most from faded worked examples.

Educational Implications

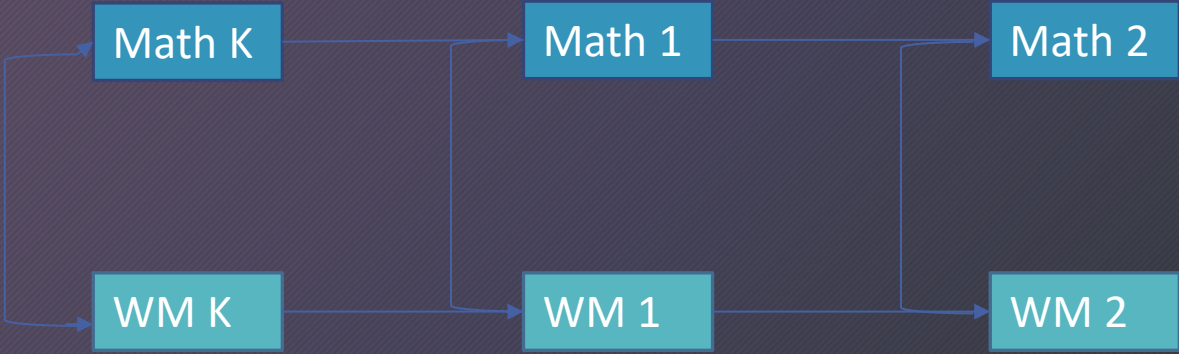
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- Executive functions appear to affect how much students benefit from problem presentation.
- Some people argue it may be fruitful to *train* executive functions.
- Unfortunately, there is little evidence that training executive function skills transfers to academic outcomes.

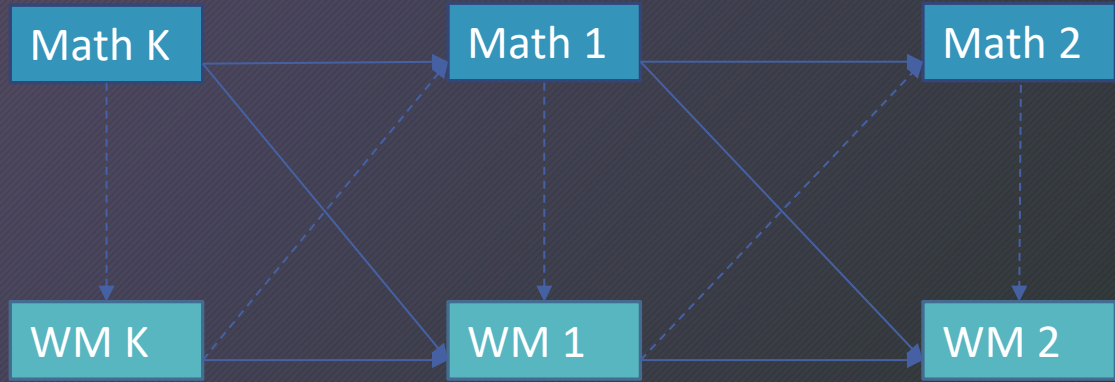
Cognitive Filter



Positive Manifold



Transactional



Alternative Perspective

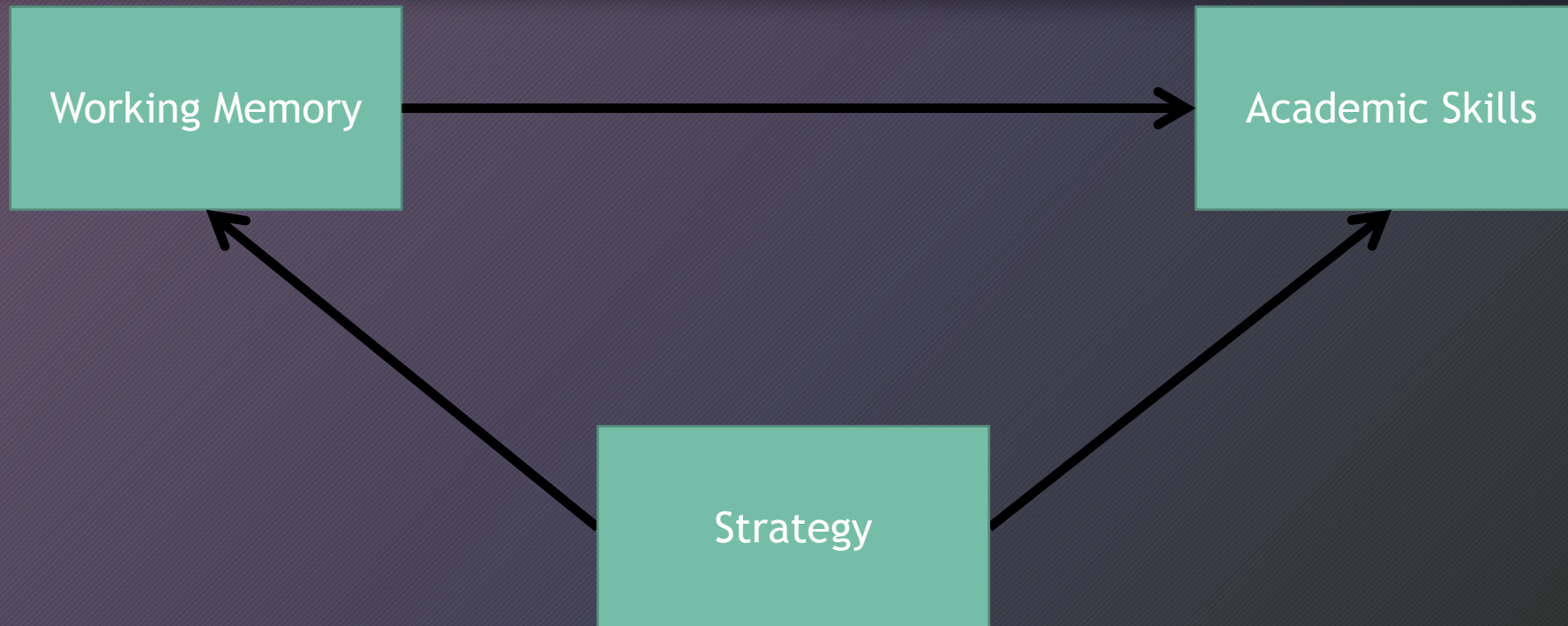
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- What if there is something about children who do well on EF tasks that also do well on academic tasks?
 - Prior work has already ruled out intelligence as the underlying factor

Strategies?

Strategy Mediation Hypothesis

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What can
we do to
advocate
for our
children?

Takeaways

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- Things to remember:
 - There is more research around success in supporting EFs than building.
 - Altering presentation
 - Giving directions in fewer steps
 - Going slower

Takeaways

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Things to remember:

- Executive Functions practices for one topic won't necessarily transfer to another topic
 - Practicing executive functions in reading won't transfer to mathematics

Thank you!

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