

Executive Function

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Readings

- Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science*, 318(5855), 1387-
- Make sure you check out the supplemental materials to actually see how the study worked
-
- Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, 333(6045), 959-964.
 - Read with caution: this describes preliminary findings that some now doubt the conclusions
-
- Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in cognitive sciences*, 13(2), 65-73.

Outline

- Introduction to Executive Function
- Response Inhibition
- Task Switching
- Working Memory
- SES & Executive Function Interventions

Introduction to Executive Function



• Watch later for quick revision •

Introduction to Executive Function

- Critical for:
- devising a plan and keeping that plan
- monitoring what you are doing or learning
- metacognitive evaluation
- emotion regulation
- social appropriateness
- The executive of the mind/brain, controls your thoughts, feelings, behaviors.

Development of Executive Function

- Drastic improvements from 3 – 5 years across EF's but keeps on changing/improving through your 20's!
 - Which is why car rentals are much more expensive until you are 25.
- Prefrontal cortex
- Integrates, amplifies, down-regulates information from the rest of the brain
- Major frontal growth in first few years of life
 - Largest time of growth is actually 7-11
- Strengths of connections/myelination continue through adolescence, and recent work documenting the brain changes in prefrontal connectivity through the 20's
 - One important example of prefrontal connectivity: people at risk for depression have less white matter connecting prefrontal cortex and amygdala
 - (work by Chris Beavers, David Schnyer, & Jenni Pacheco)

Response Inhibition

- Most studied EF from developmental perspective
- Inhibit the most immediately alluring or habitual response
- Immediate vs. long term goals
 - It's 5 pm, keep on writing that paper or go have a drink?
- Marshmallow test predictive of lifelong outcomes
 - Worse performance in school, worse liked among peers
 - Likelihood of being a drug addict, not completing high school.
 - Disorders of impulsivity
- More precise measures of behaviours used...

red blue orange purple

orange blue green red

blue purple green red

orange blue red green

purple orange red blue

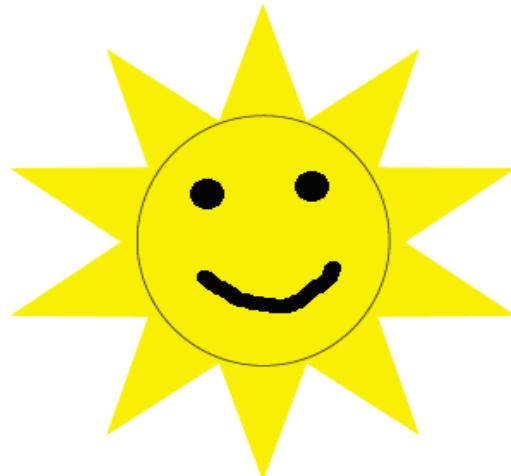
green red blue purple

orange blue red green

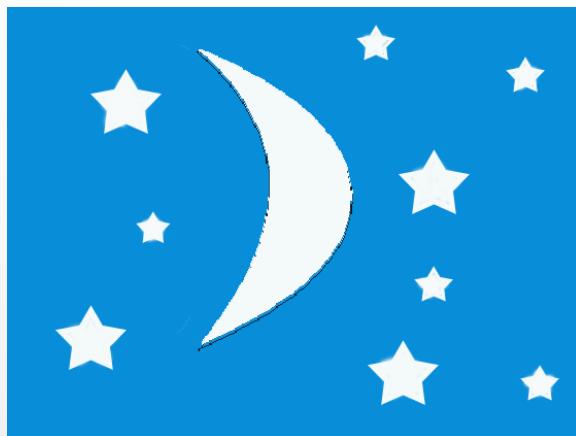
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Day - night ‘Stroop-like’ task

When you see:



SAY “NIGHT”



SAY “DAY”

Response Inhibition: Theoretical Implications

- Often claims have been made that children do not possess knowledge of a certain kind, but really they cannot show it because there is a more alluring option
 - Competence V Performance
- Social-cognition
- Analogical reasoning/relational learning
 - Remember the lure of visual features over matching relations?
Some say a lot of that is about a lack of response inhibition
 - E.g., Richland, Morrison, & Holyoak (2006)
- Munakata's work argues however that response-inhibition comes from representing goals, and that what changes is the ability for the PFC to represent goals robustly/abstractly enough that immediate stimuli don't drive behaviour

Task Switching/Cognitive Flexibility

- Dimensional Change Card Sort Task: 3 year-old children possess knowledge of either way to sort categories, but cannot switch from one strategy to the next

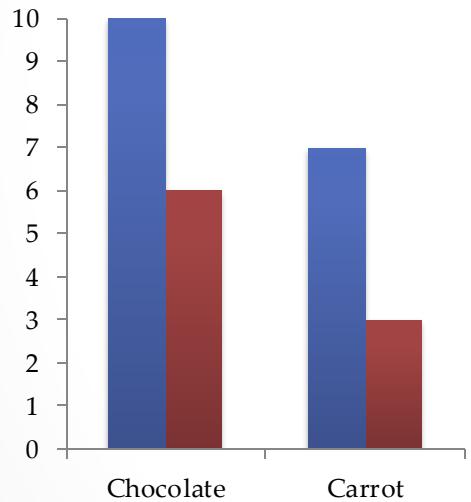


Working Memory

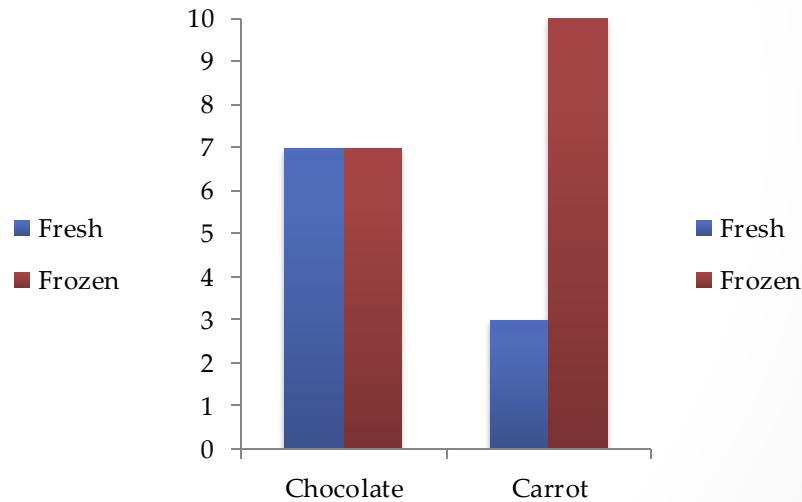
- The amount of stuff you can juggle in your mind at once
- Critical for complex problem solving and learning complex concepts
- Halford's: Relational Complexity Theory → It's not the number of items, but items in relation to one another
 - PFC supports analogical reasoning. Finding commonalities in the relations requires WM, in addition to inhibiting more superficial matches
- If just # of items, they can be processed serially, but the relations among them force one to process them at once.

Working Memory

- Relational complexity
- Think about 2 main effects vs. an interaction vs. a 3 way interaction.



Fred's Bakery



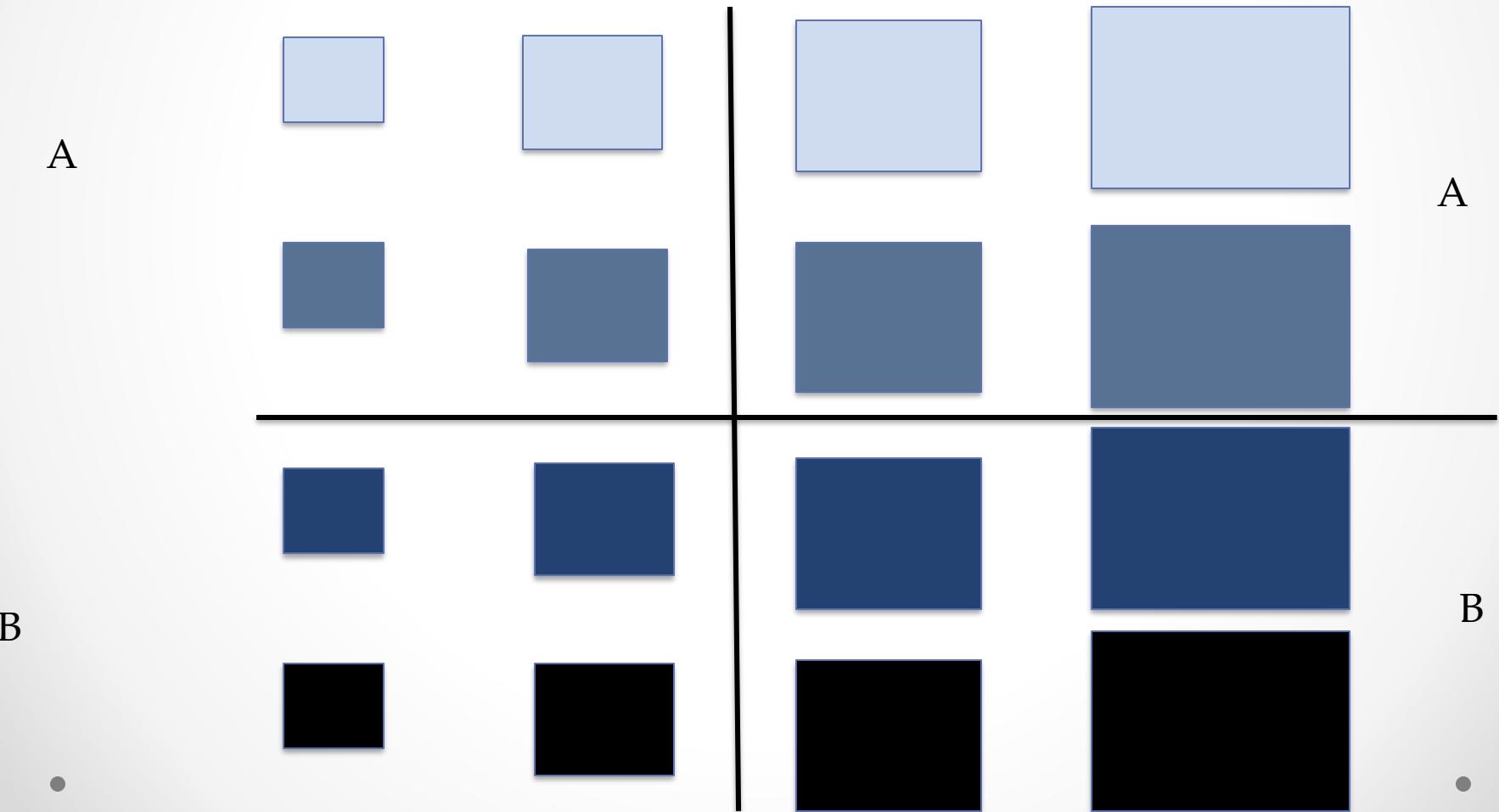
Bob's Bakery

Development of WM

- Andrews & Halford (2002): Children < 5 pretty bad at considering relations between multiple variables at once
 - Across language comprehension, learning, reasoning

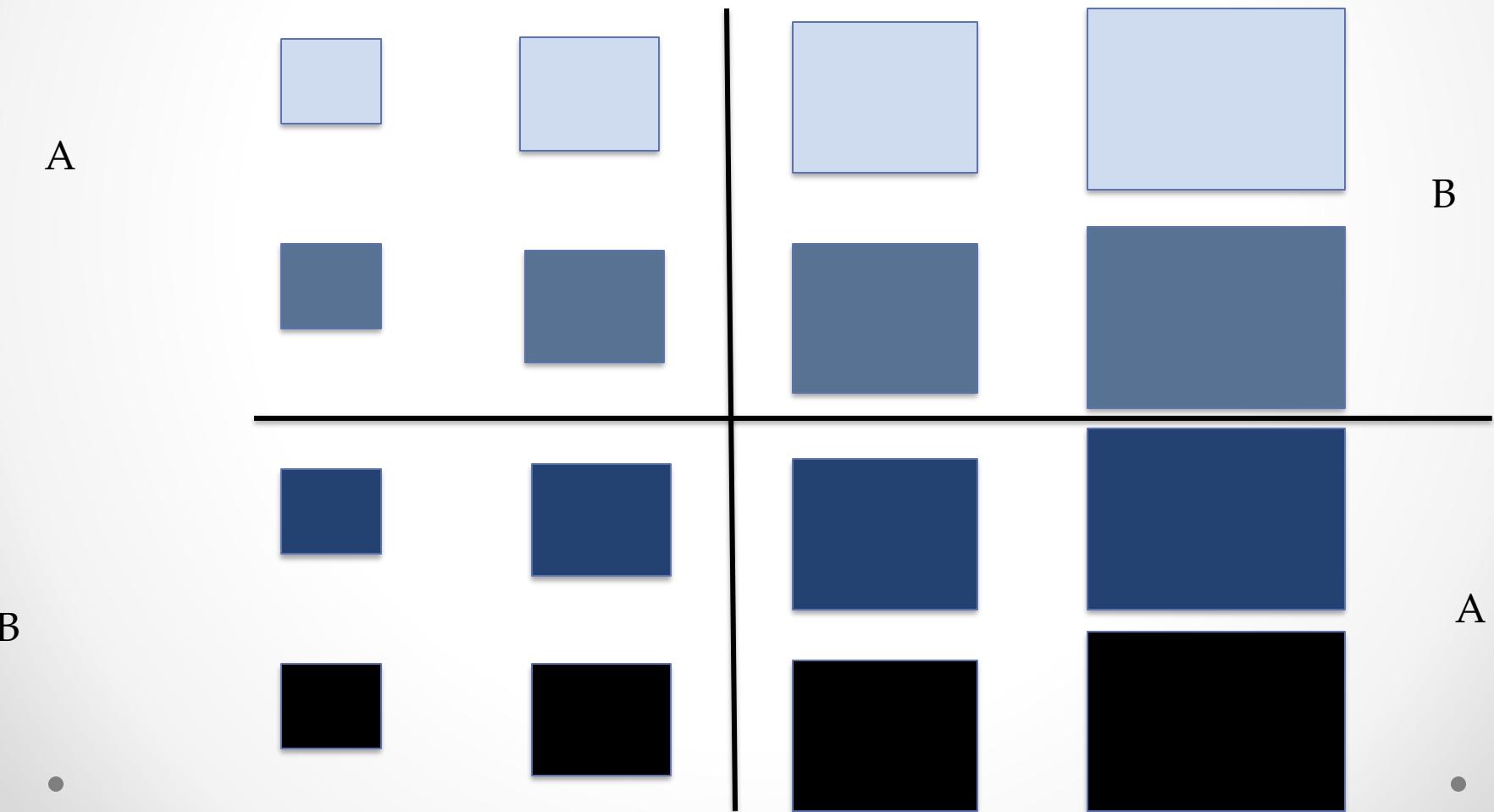
Development of WM

- Example: Categorization
- When adjacent quadrants map to categories -> easy



Development of WM

- Example: Categorization
- When diagonal quadrants map to categories -> hard for pre-schoolers



Interaction of Knowledge & WM

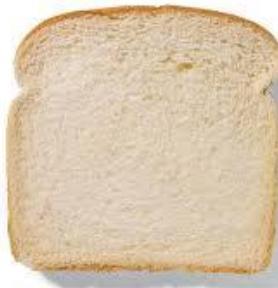
- WM is critical for learning complex concepts
- But high-quality knowledge reduces WM load in problem solving
 - With higher quality stuff in mind, less stuff has to be juggled at once
 - e.g., chess experts
- Why old people can think better than one might predict given decline in PFC function
 - Myelination lessens in old age, reverse of child development
- Also suggests why EF is so critical in childhood: need to acquire the high-quality knowledge in the first place

Interaction of Knowledge & WM

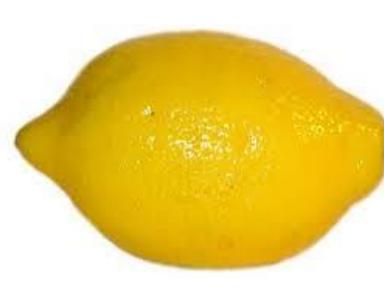
- A:B::C:D analogies: in Piaget's studies Pre-operational children couldn't solve them
- Goswami & Brown (1990): 3 year olds can solve with relations they know



Is to



As



Is to



Interaction of Knowledge & EF

- What is the driver of cognitive development?
- The contemporary update to Piaget focusses on the combination of how increases in knowledge improve how you think and increases in the three EF faculties of “cognitive capacity” improve how you think.
- So, these two factors together, not stage transitions, account for cognitive improvements over development.

Outline

- SES & Executive Function Interventions

SES & Executive Function

- Lower SES children have lower EF's across the board, and this is predictive of educational/longitudinal outcomes
- Stress specifically effects PFC and EF's
- Lack of stimulation & stress hinder PFC growth
- EF and language primary issues that connect SES and achievement
 - Classic language brain areas (Broca's area) is frontal region very involved in verbal working memory
- Hackman & Farah for review

Executive Function Intervention

- Traditional martial arts training, with a focus on discipline and self-control
 - Not just teaching kids how to fight
 - Lakes & Hoyt (2004)
 - This was a single low sample size study.
- “Brain training:” Early computer training games of various kinds showed promise, but have not stood up to scrutiny
- Abcedarian- was not called an EF study, did not directly measure EF, but you can be confident that it improved EF
 - EF and Fluid IQ are very highly correlated.

“Tools of the Mind” curriculum in pre-K

Diamond et al. (2007)

- Goal to create a curriculum that any pre-k teacher could implement: no special training or equipment
 - (such as with martials arts training or computer games)
- A Vygotskian, structured play-based curriculum
- Low-income urban public school system agreed to test this curriculum for EF against one it designed to improve early literacy.
- But after some time, all schools starting using Tools because all the kids and teachers were so much happier!
- No behaviour problems in Tools classrooms, so no stressed kids and teachers.
- Evidence that Tools kids go on to have improved literacy and maths skills.

“Tools of the Mind” curriculum in pre-K

- Curriculum/Activities
- Concrete External Aids: for example
- “During the Tools of Mind activity of “Buddy Reading,” all children get a picture book, and are told to take turns telling a story that goes with their book to one another in pairs, turning the book’s pages and pointing at the pictures as the story progresses. Initially all want to tell their story; none want to listen. The teacher gives one child per pair a drawing of lips and the other a drawing of an ear, explaining that “ears don’t talk; ears listen.” With the concrete graphic symbol to refer to, preschoolers with the ear inhibit talking, wait their turn, and listen. Children then trade drawings and roles, thus learning to enact the social norms of turn-taking and waiting one’s turn. The visual aids remind children who is doing what. After only a few months, the pictures are no longer needed.”

“Tools of the Mind” curriculum in pre-K

- Regulate others
- “For example, during a math activity, again done in pairs, one child has a “hand” and counts out objects while the other child checks whether the counting has been correct (the second child serving as a regulator of the first child’s performance). The child who is the “checker” waits until the first child finishes counting out the number of objects and then, using a checking sheet, makes sure the answers are correct. This supports self-reflection as well as inhibition. The child who checks inhibits the desire to act until it is his or her turn. The “counter” engages in self-reflection while watching the checking, reflecting on his/her previous answer, thinking about whether it’s correct or not. “Reliving” one’s actions by watching someone check is practice in self-reflection on action, a metacognitive aspect of EFs.”

“Tools of the Mind” curriculum in pre-K

- Private speech to regulate oneself & encourage cognitive flexibility
- Teachers model speaking to oneself during lots of learning activities to be aware of one's thinking
- Pattern Movement Game
- “Children are shown a pattern, such as ABABBA represented by shapes: Triangle, Square, Triangle, Square, Square, Triangle. The teacher assigns specific movements to each shape and the children then enact the pattern as the teacher points to the pattern. Then the shapes are assigned a different set of motor movements and the children have to place a new set of behaviors in working memory and enact them. They have to inhibit the previous set of actions and change to the new actions. Children use private speech to help them remember the changed sets of actions and hold each new set in working memory.”

“Tools of the Mind Curriculum” in pre-K

- Dramatic Role Play
- “Children are taught to think about their play scenario ahead of time. Children are taught to plan the play scenario together. They might say, “Let’s pretend you’re the mommy and I’m the baby. I’ll get sick; you’ll need to take me to the doctor. She’ll be the doctor and give me medicine.” The child who’ll be Mom might add, “I’ll have to drive you there. I’ll need a car.” After the children agree, they act out the scenario. Then they plan another scenario and play it. ”

“Tools of the Mind” curriculum in pre-K

- Dependent measure: Executive function computer-based task no child had any familiarity
 - Attentional control

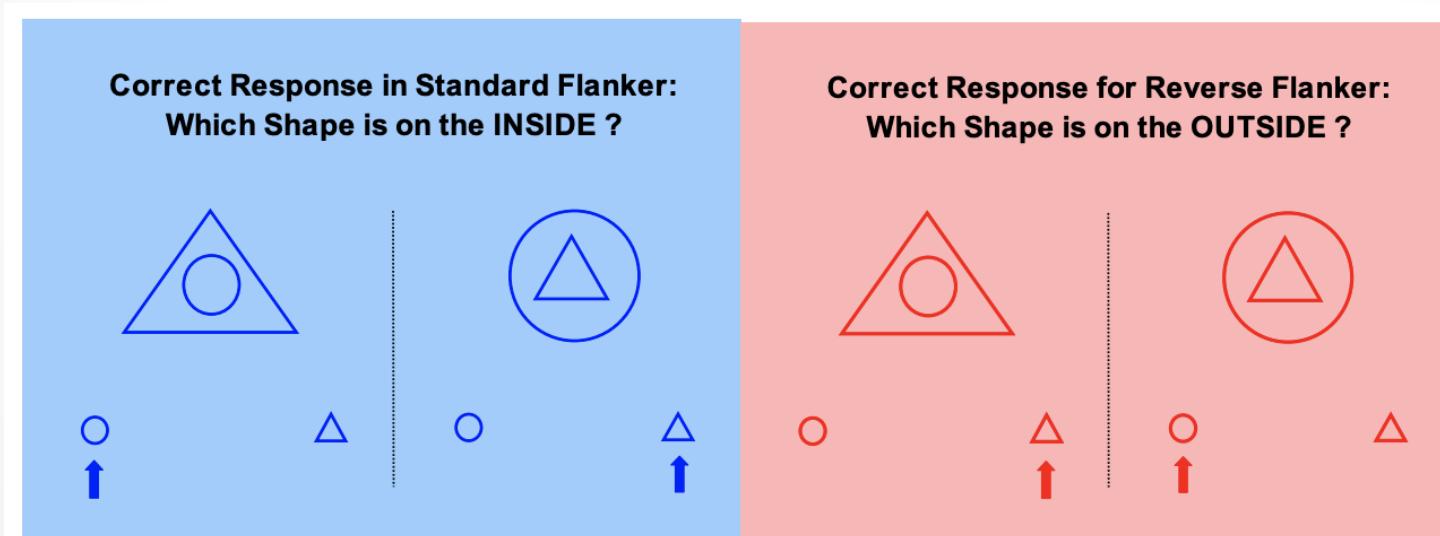


Figure S7. Two trials of the standard flanker and reverse flanker conditions are shown.

“Tools of the Mind” curriculum in pre-K

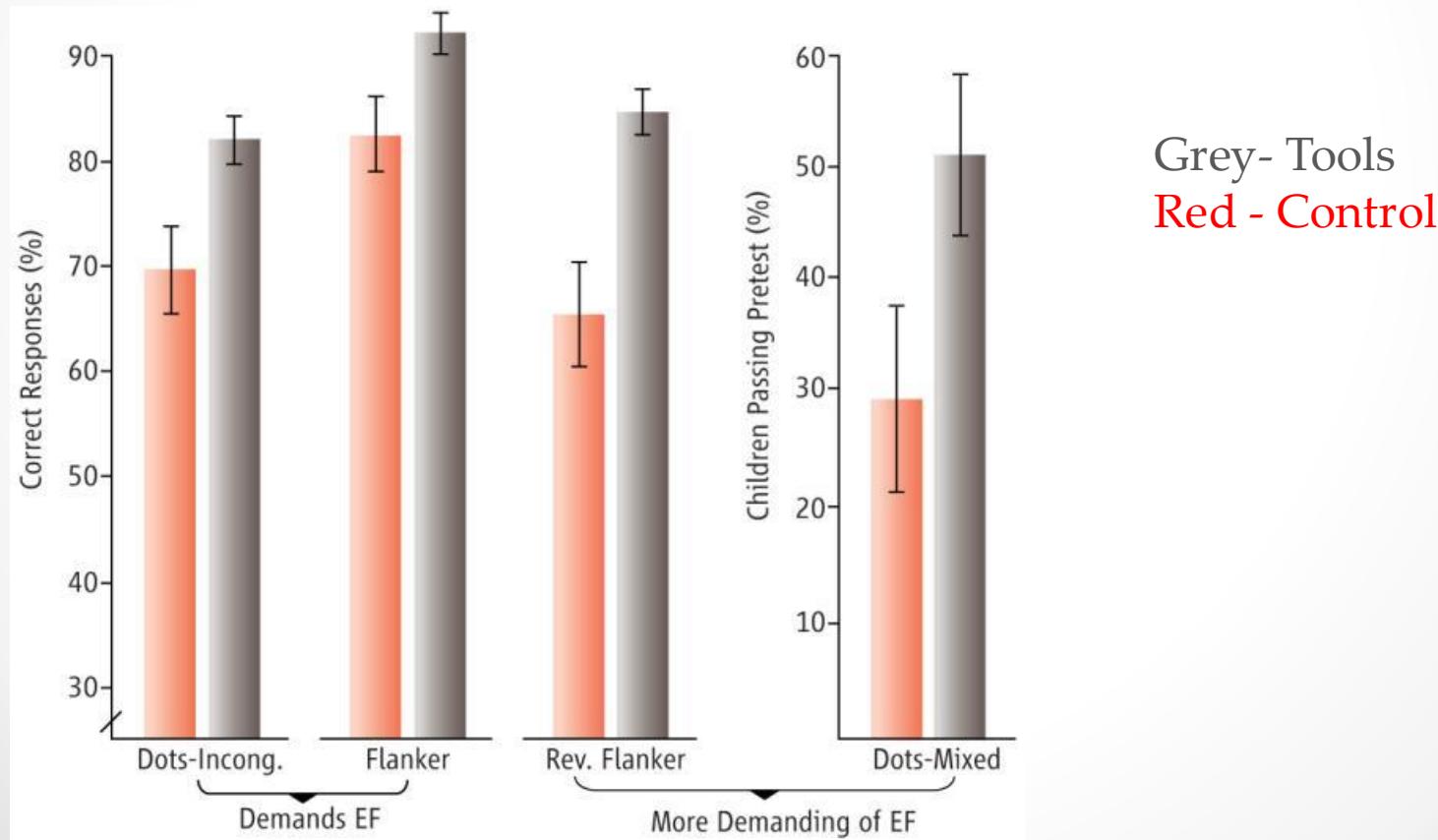
- Dependent measure: Executive function computer-based task no child had any familiarity
 - Requires maintaining multiple rules in mind, inhibit responses

Dots Task (using Hearts and Flowers)

| Congruent | Incongruent |
|---|--|
|  Push Left |  Push Right |
|  Push Right |  Push Left |

“Tools of the Mind” curriculum in pre-K

- Tools > Control especially when EF demands were higher (trials were intermixed on dots, and reverse flanker)



“Tools of the Mind” since Diamond et al. (2007)

- Both Pre-K and Kindergarten versions
- Early promising results that started to fizzle a bit
- 2017 systematic review showed that there was some evidence for increased school performance, cognitive, and social benefits, but weak
- Blair et al. (2018): RCT of Kindergarten program- improved socio-emotional outcomes related to aggressive behaviour between children, better teacher-student relationships
- Diamond et al. (2019): RCT of Kindergarten program shows benefits for literacy, and EF-in class gains
 - Sustained task-focus without supervision

Principles of EF Interventions

- Biggest benefits for children with the biggest deficits
 - You can't create super EF children, but you can potentially level the playing field
- Time intensive and adaptive training is critical
 - Limits need to be pushed frequently, and setting higher and higher standards as improvements are seen

Executive Function: Summary

- From 3 – 5 years old there are drastic changes in prefrontal function, but continues into early 20's.
- Inhibitory control, task switching, and working memory
- Critical for emotion regulation, social appropriateness, learning complex concepts
- EF's during early childhood predict longitudinal outcomes in many domains of achievement in life
- Low SES children at risk from stressful environment to have EF deficit
- Interventions show promise to improve at-risk children's EF