

Cognitive Control and Self-Regulation in Young Children: Ways to Improve them and Why



Adele Diamond PhD, FRSC
Canada Research Chair Tier 1 Professor of
Developmental Cognitive Neuroscience
University of British Columbia (UBC)

adele.diamond@ubc.ca

OUTLINE

- Executive functions are cognitive skills critical for success in school and in life.
- Most young children today, regardless of their background, are behind on these crucial skills compared to past generations.
- But these skills CAN be improved in young children without specialists or fancy equipment.
- Look at what has been part of children's experience for 10's of 1,000's of years across all cultures -- play, storytelling, music, and dance.
- Improving key EF skills early gets children started on a trajectory for success. Conversely, letting children start school behind on these skills is letting them get started on a negative trajectory that can be hard and extremely expensive to reverse.

**“Executive Functions” (EFs),
which depend on prefrontal cortex,
are comprised of 3 core abilities:**

(a) Inhibitory control (self-control)

the ability to resist a strong

inclination to do one thing

and

instead do what is most

appropriate or needed

Makes it possible for us to resist acting on our first impulse so we do not do something we'd regret.

**Being able to... (1) stay on task
despite boredom, initial failure,
interesting digressions, or
tempting distractions**

**requires the ability to inhibit
strong inclinations to give up or to
do something more fun.**

DISCIPLINE

**Evidence shows that
discipline accounts for over
twice as much variance in final
grades as does IQ, even in
college.**

(Duckworth & Seligman, 2005)

Being able to... (2) inhibit acting impulsively & instead make a more considered response enables you to:

- resist grabbing another child's toy
- resist saying something socially inappropriate (or hurtful)
- resist hurting or hitting someone else to get back at that person for hurting or hitting you (the cycle of tit for tat)
- resist a luscious dessert when you want to lose weight

Being able to...

(3) pay attention despite distraction

e.g., suppressing attention to what others are saying

such as screening out all but one voice at a cocktail party

so that you stay focused on what's important

SELECTIVE or FOCUSED ATTENTION

Inhibition allows us a measure of control over our attention and our actions, rather than simply being controlled by external stimuli, our emotions, or old habits of mind or behavior.

Therefore it helps make change possible.

(b) Working Memory:

**Holding information in mind
while mentally working with
or updating it**

Working memory is critical for making sense of anything that unfolds over time, for that always requires holding in mind what happened earlier & relating that to what is happening now.

but...

WM is ephemeral, like writing on fogged-up glass.

such as

-  relating one idea to another
-  relating what you read (or learned / heard) earlier to what you are reading (learning / hearing) now
-  doing mental arithmetic (e.g., adding or subtracting)
-  prioritizing the things you need to do
-  following a conversation while keeping in mind what you want to say

Why is WORKING MEMORY important?

Working Memory makes it possible to

-  consider things from different perspectives
-  understand what you are reading (relating beginning, middle, & end)
-  remember our good intentions, the big picture, & *why* we are doing what we're doing (or why we shouldn't do something)
-  translate instructions into action plans.

WORKING MEMORY is critical to our ability to see connections between seemingly unconnected things, and hence to **CREATIVITY**, for the essence of creativity is to be able to disassemble and recombine elements in new ways.

What some people call
“**working memory**” could also
be termed:

Keeping your **ATTENTION**
focused on specific mental
contents while mentally
working with them

The distinction between attention and working memory may be arbitrary.

They appear to be similar in many ways, including neural basis.

(c) COGNITIVE FLEXIBILITY

**being able to easily & quickly switch perspectives or the focus of attention,
flexibly adjusting to changed demands or priorities,
being able to think outside the box.**

COGNITIVE FLEXIBILITY is critical to creative problem-solving.

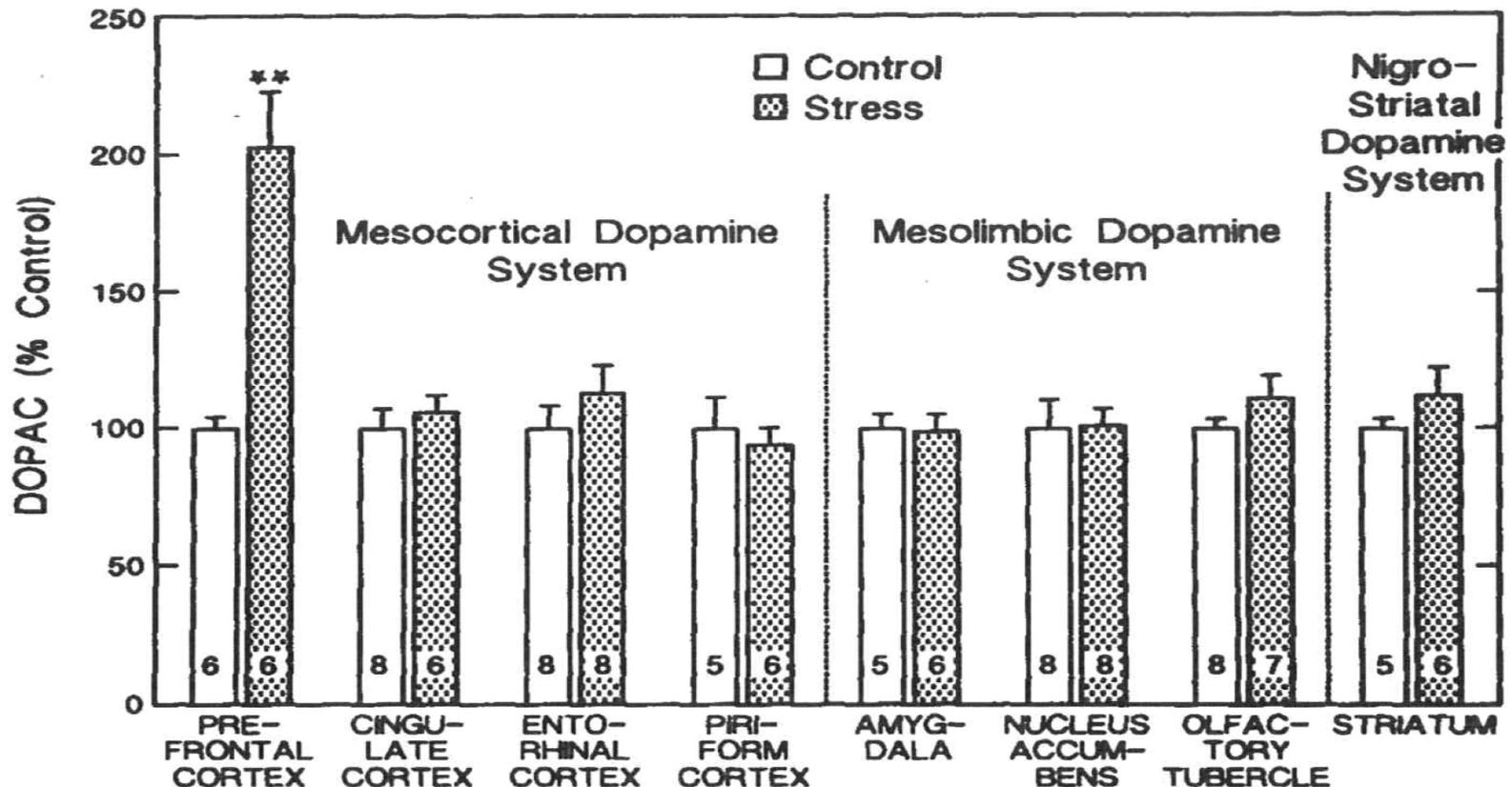
- **What are other ways I can react when something happens?**
- **What are other ways I can conceptualize a problem (e.g., perhaps it is an opportunity)?**
- **What are other ways I can try to overcome a problem?**

Stress impairs Executive
Function and can cause
someone to look as if he or
she has ADHD.



Stress and Prefrontal Cortex

Even mild stress increases DA release in PFC but not elsewhere in the brain

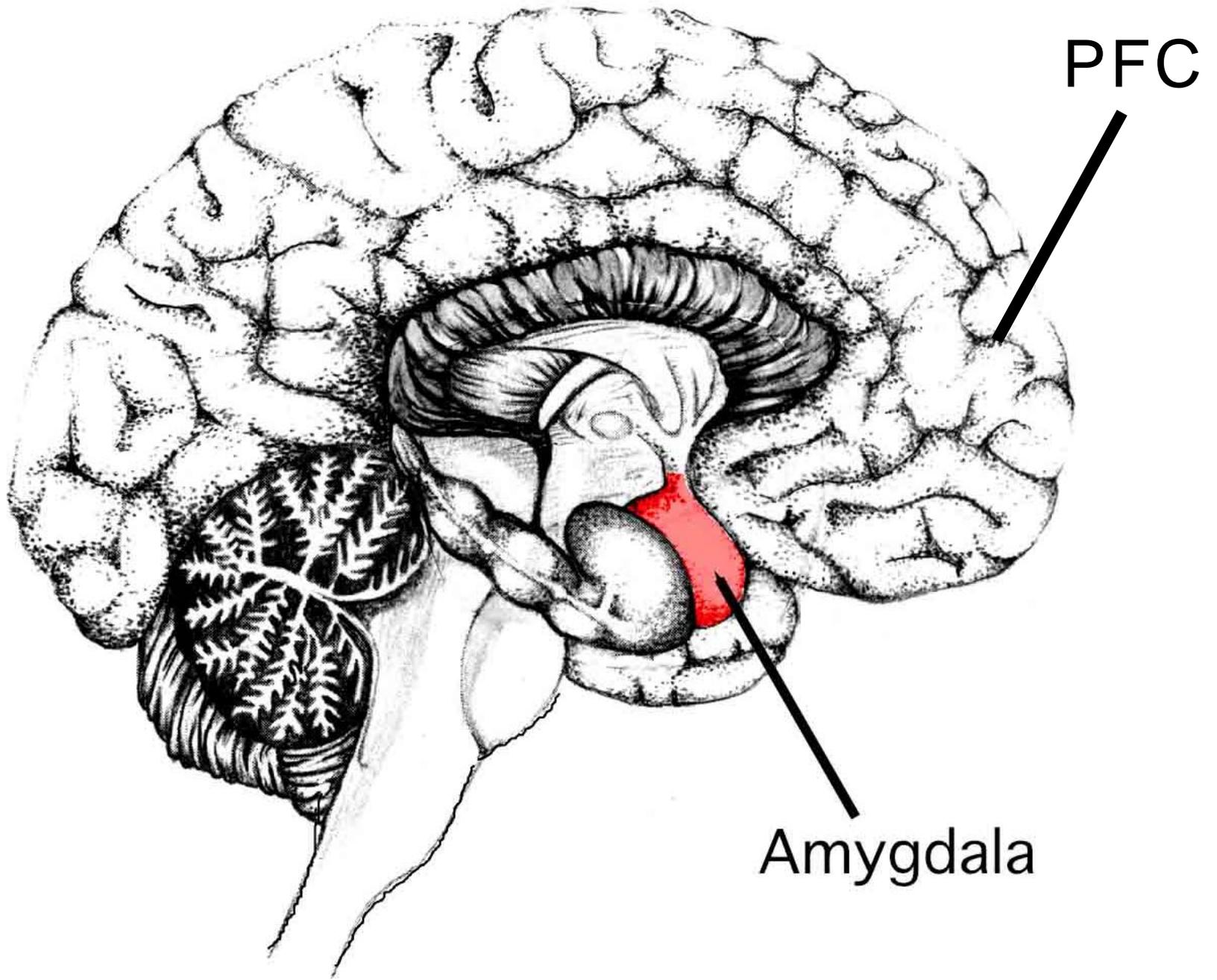


(Roth et al., 1988)

PFC



Stress



Putting Feelings Into Words Produces Therapeutic Effects on the Brain

When you put feelings into words, you increase activation in prefrontal cortex and that produces a reduced response in the amygdala.



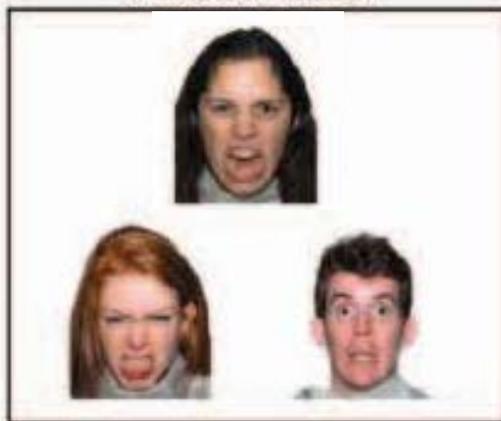
a

Affect Label



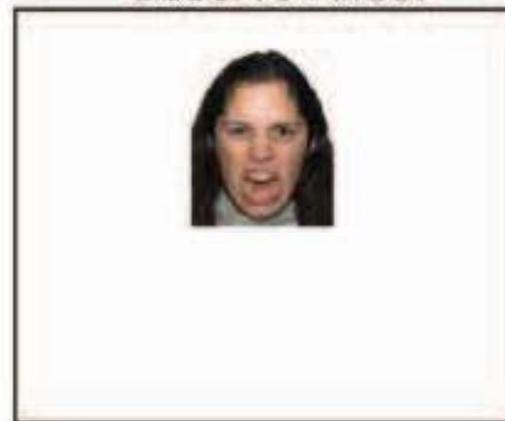
b

Affect Match



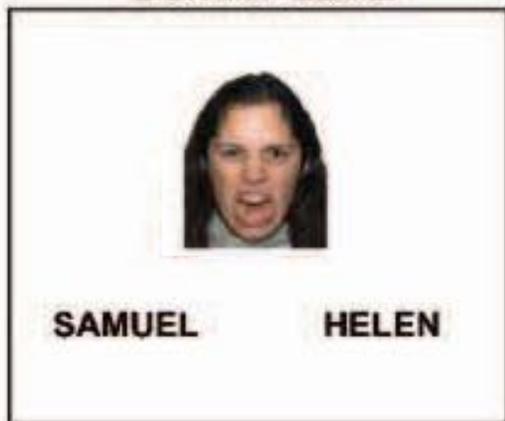
c

Observe Affect



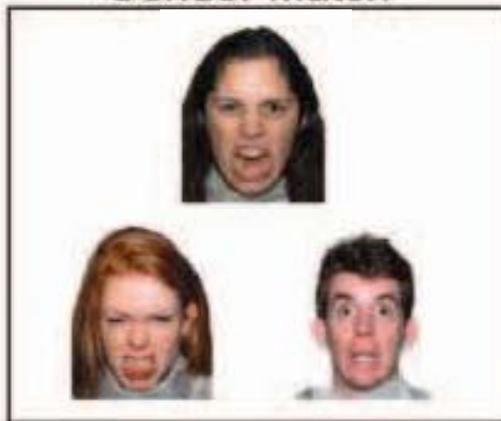
d

Gender Label



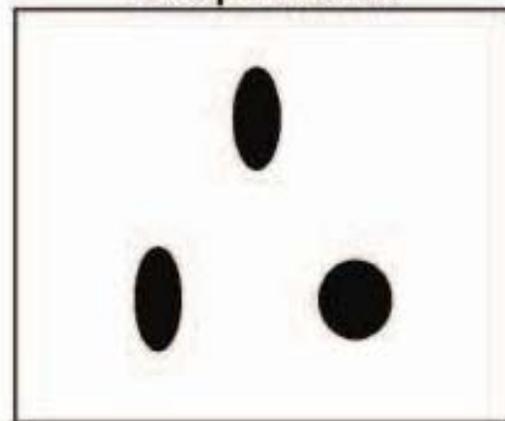
e

Gender Match



f

Shape Match



Amygdala activation went up in ALL conditions when an angry or fearful face was shown, but **ONLY** in the one Condition A, where subjects had to assign a verbal label to the emotion, did amygdala activation **GO DOWN**.

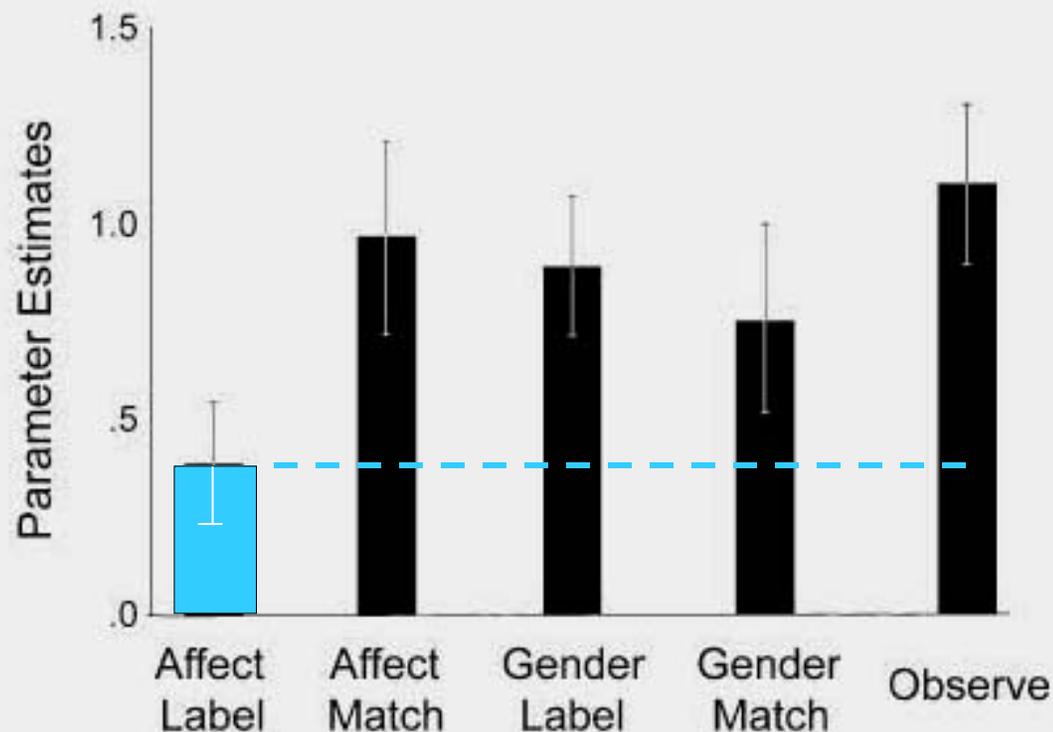
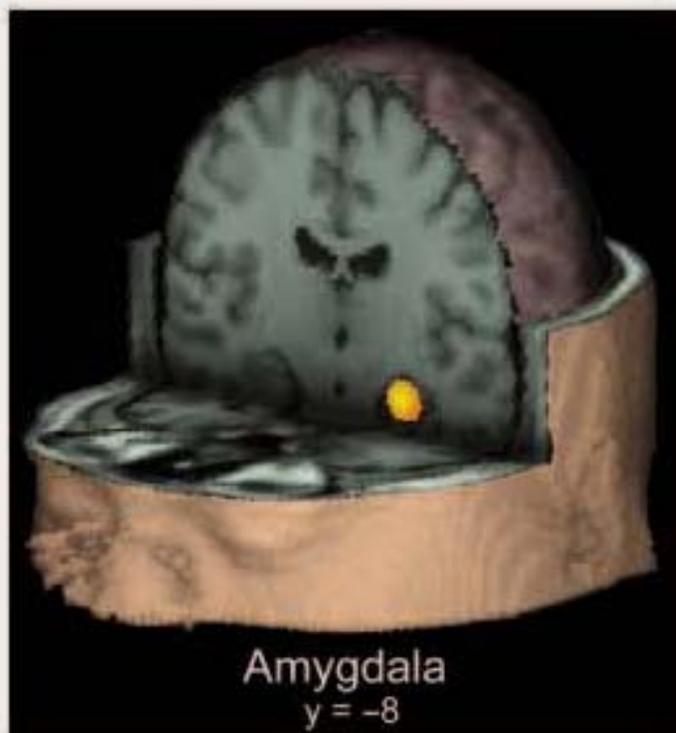
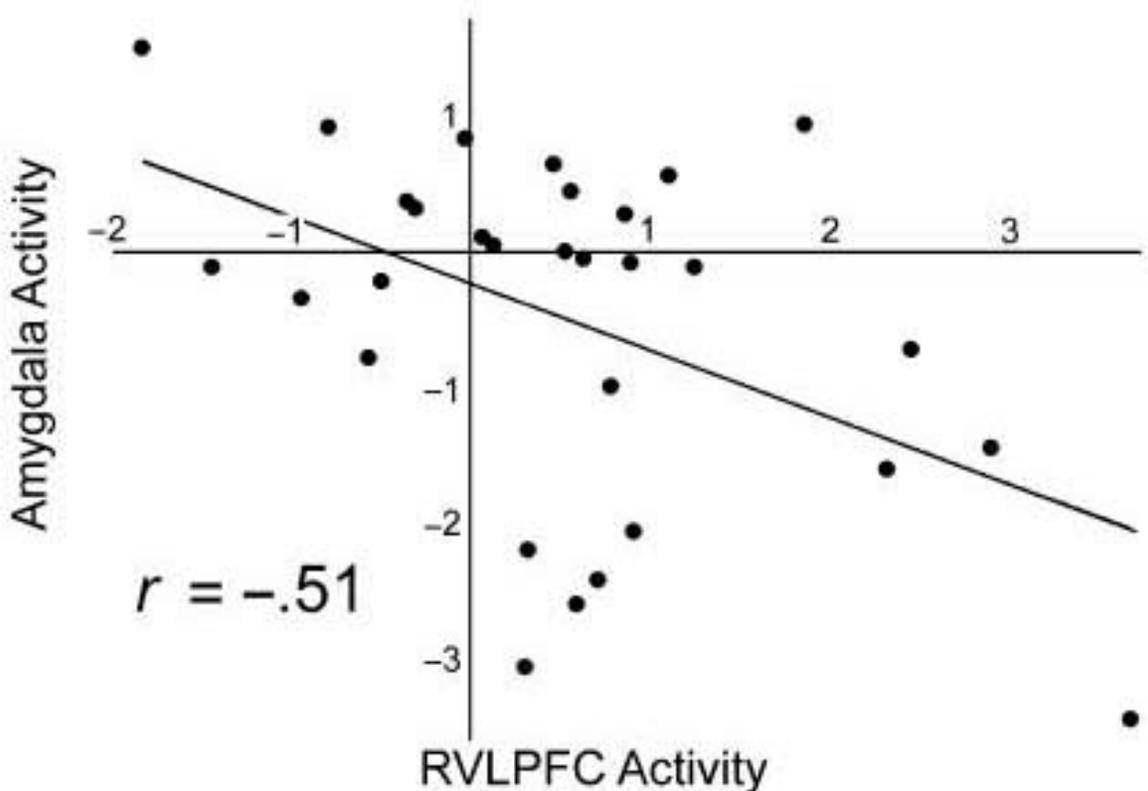
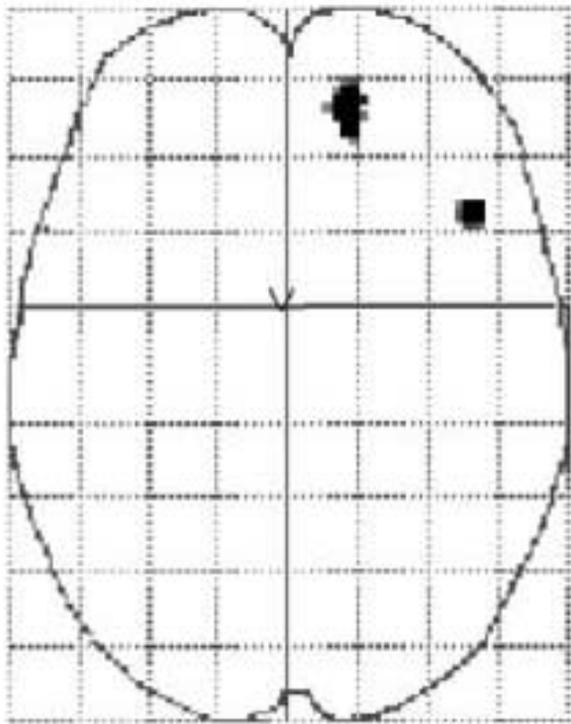


Fig. 2. Parameter estimates of activity during five conditions (relative to activity in the shape-match control condition) in an amygdala region of interest (ROI). The ROI was identified by comparing activity in the observe condition and activity in the shape-match condition. The illustration on the left shows an axial slice indicating the extent of the ROI.

Inverse Relation between Activation in PFC and the Amygdala in the Lieberman et al. study

(When activation in PFC goes up, activation in the amygdala goes down.)



If you can get people to talk or write about their problems, their psychological and physical health improves.

--- James Pennebaker,
*Opening Up: The Healing Power
of Expressing Emotions*



Translating an emotional experience into language, talking or writing about, alters the way it is represented and understood in our mind and our brain (gets prefrontal cortex more involved).



EF skills are important for school readiness.

They are more strongly associated with school readiness than IQ or entry-level reading or math.

(e.g., Blair, 2002; 2003; Blair & Razza, 2007; Normandeau & Guay, 1998)

**Many children begin
school lacking needed
executive function skills.**

Research shows that 5-year-olds today are behind in EFs compared with 5-year-olds of a couple of generations ago.

(Smirnova, 1998; Smirnova & Gudareva, 2004)

Although Executive Functions are *the* skills *most* predictive of school readiness,

sadly, Kindergarten teachers report...

- that over half their children lack effective EF skills, and

- that that poor EF is their single most difficult challenge in teaching (Rimm-Kaufman *et al.*, 2000).

**Kindergarten children at risk
because of economic disadvantage
are disproportionately behind in EF**

**relative to other cognitive skills
and**

**relative to children from middle-
income homes.**

Executive Functions are also important for school success.

Working memory and inhibitory control each independently predict both math and reading competence throughout the school years.

	WORKING MEMORY	INHIBITION
VERY EARLY GRADES		
Language Skills	Adams & Gathercole, 1995; Blair & Razza, 2007	Blair & Razza, 2007; McClelland et al., 2007
Math Skills	Blair & Razza, 2007; Espy et al., 2004; Passolunghi et al., 2007	Blair & Razza, 2007; Espy et al., 2004; McClelland et al., 2007
LATER GRADES		
Language Skills	De Beni et al., 1998; Gathercole et al., 2004, 2005; Savage et al., 2006	De Beni et al., 1998; Fiebach et al., 2007; Savage et al., 2006
Math Skills	Barrouillet et al., 2005; Bull & Scerif, 2001; Gathercole et al., 2004; Swanson & Kim, 2007	Bull & Scerif, 2001; Shallice et al., 2002; Passolunghi & Siegel, 2001

I predict that improving young children's Executive Function skills will:

- **improve their longterm acquisition of academic skills,**
- **their school success & graduation rates,**
&
- **can reduce the disparity in achievement between rich and poor.**

I also predict that focusing on early stages in the development of Executive Functions rather than trying to remediate deficits later, might reduce the incidence or severity of mental health disorders of Executive Function, such as ADHD, addictions, or conduct disorder.

How can young children be helped to develop these critical EF abilities?



Vygotsky: Engaging in social pretend play is critical for developing executive function skills in very young children. It is emphasized in *Tools of the Mind*.



- During social pretend play, children must hold their own role and those of others in mind (working memory)
 - inhibit acting out of character (employ inhibitory control), and
 - flexibly adjust to twists and turns in the evolving plot (cognitive flexibility)
- all three of the core executive functions thus get exercise.



Second Edition

Tools *of* the Mind

The Vygotskian Approach to Early Childhood Education



The Tools of the Mind program is based on theories of Vygotsky and Luria



● Elena Bodrova & Deborah Leong

Foreword by Michael Cole

Deb and Elena tried EF activities as a module, added onto a curriculum.

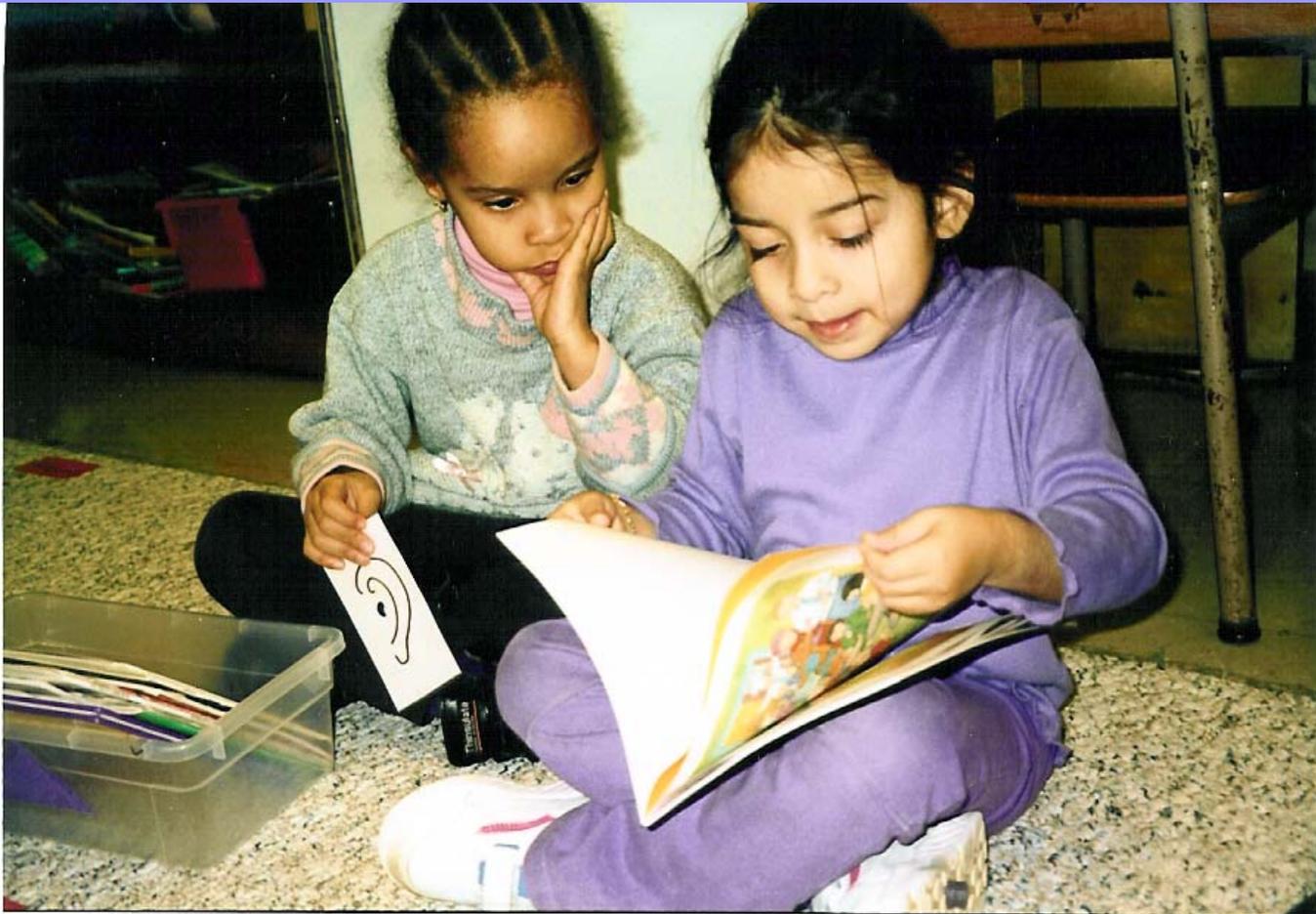
They found that children improved on what they practiced in the module, but the benefits did not transfer to other contexts or other EF skills.



They found that for benefits to generalize to other contexts and other EF skills, supports for, training in, and challenges to EF needed to be embedded in all aspects of the school day.



Buddy Reading



vs. what teachers usually do:

- avoid problem situations**
- provide external control**
- scold for lack of control**

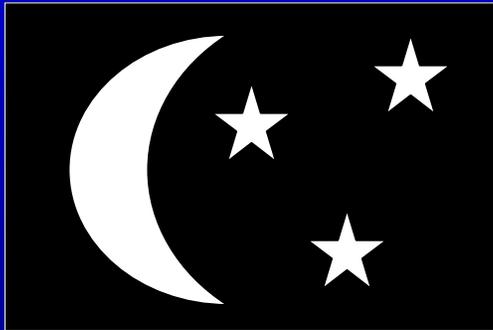


6

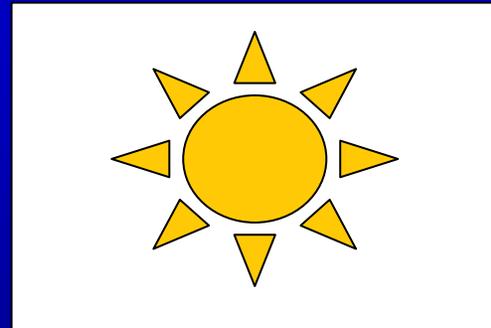
THE DAY-NIGHT TASK

(Gerstadt , Hong, & Diamond, 1994)

Semantically conflicting labels



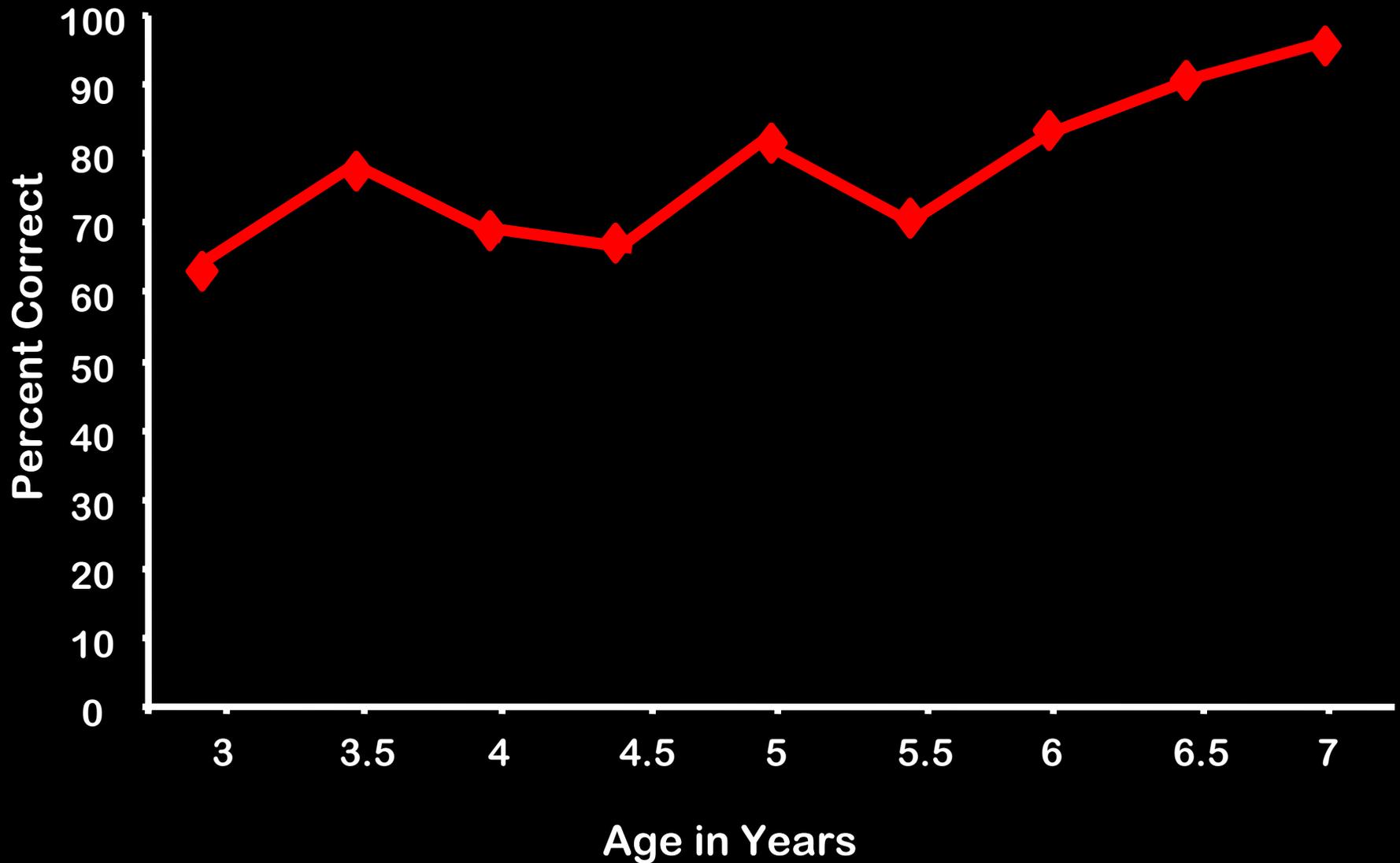
“Day”



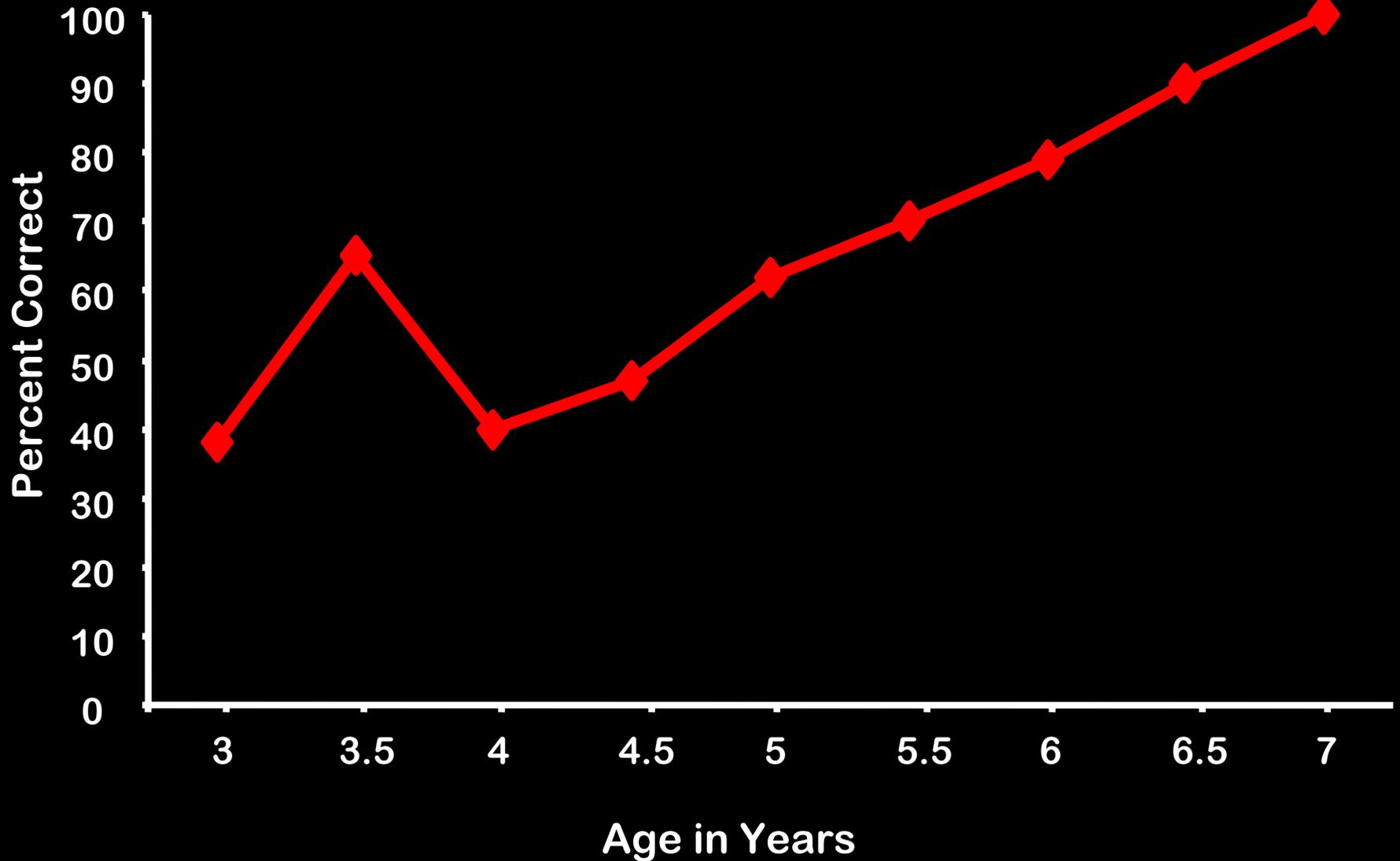
“Night”

Requires holding 2 rules in mind, and inhibiting saying what the images really represent, saying the opposite instead.

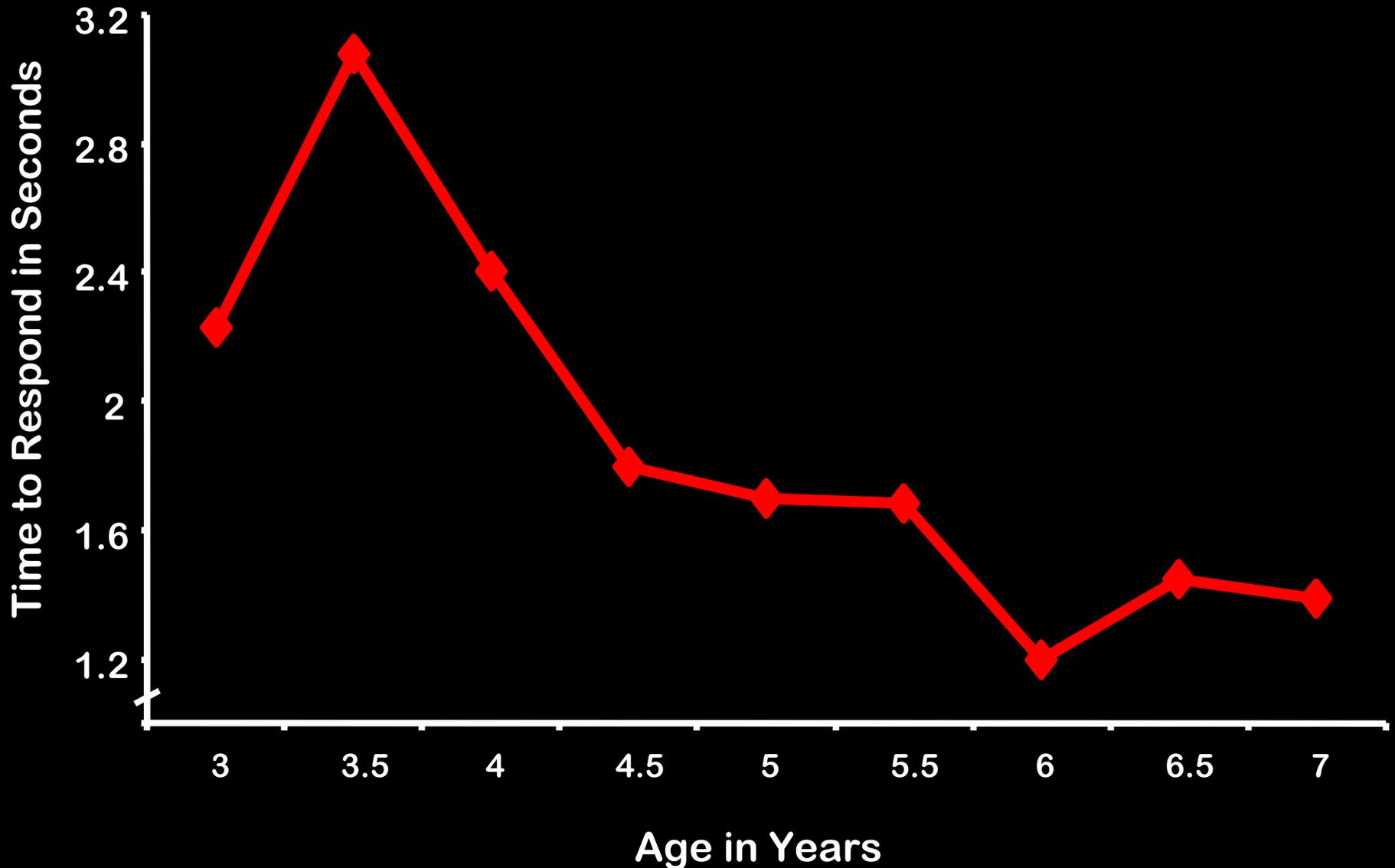
Percent Correct on the First 4 Trials (out of 16) on the Day-Night Test



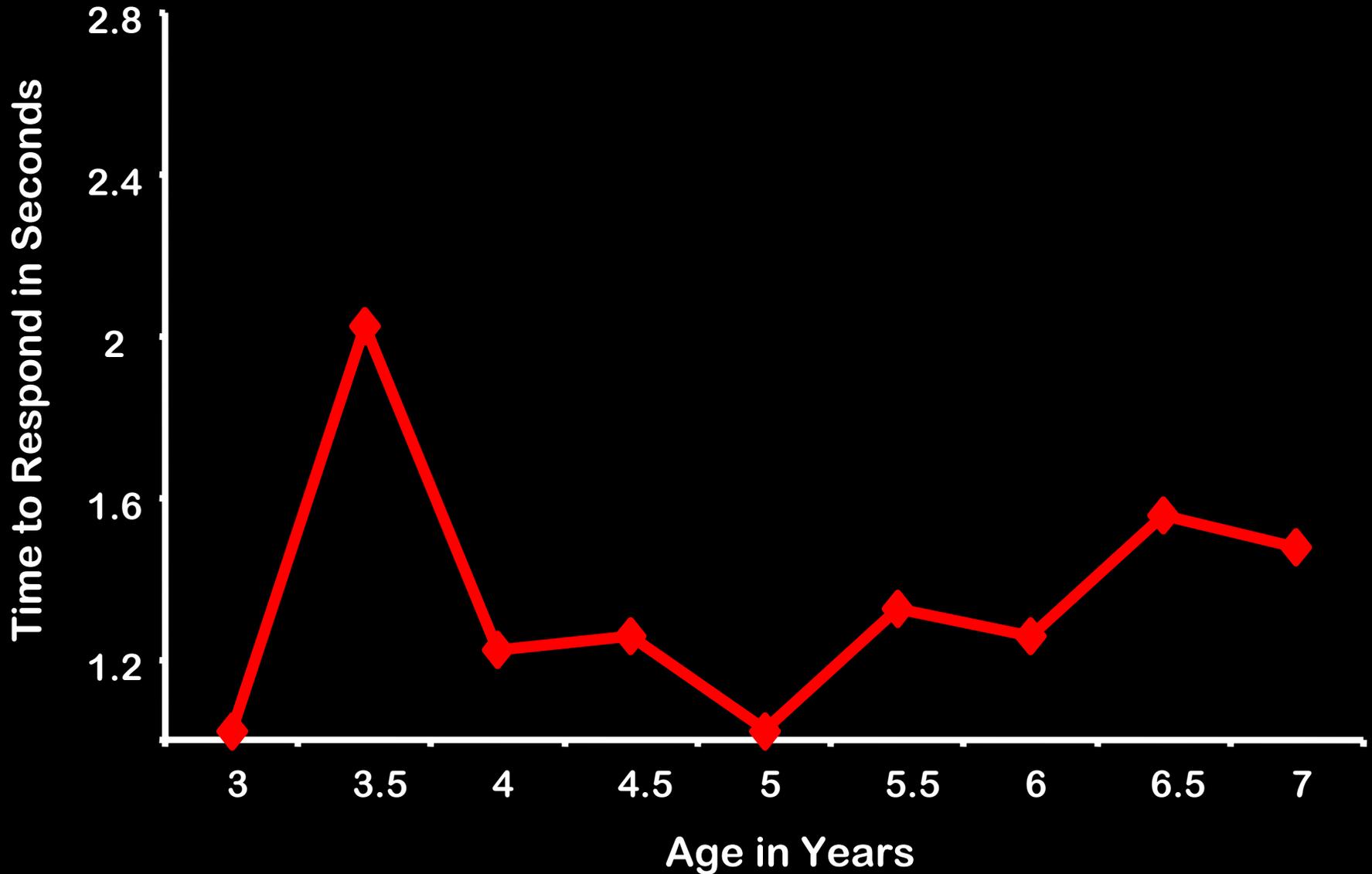
Percent Correct on the Last 4 Trials (out of 16) on the Day-Night Test



Response Latency on First 4 Trials (out of 16) on the Day-Night Test



Response Latency on the Last 4 Trials (out of 16) on the Day-Night Test



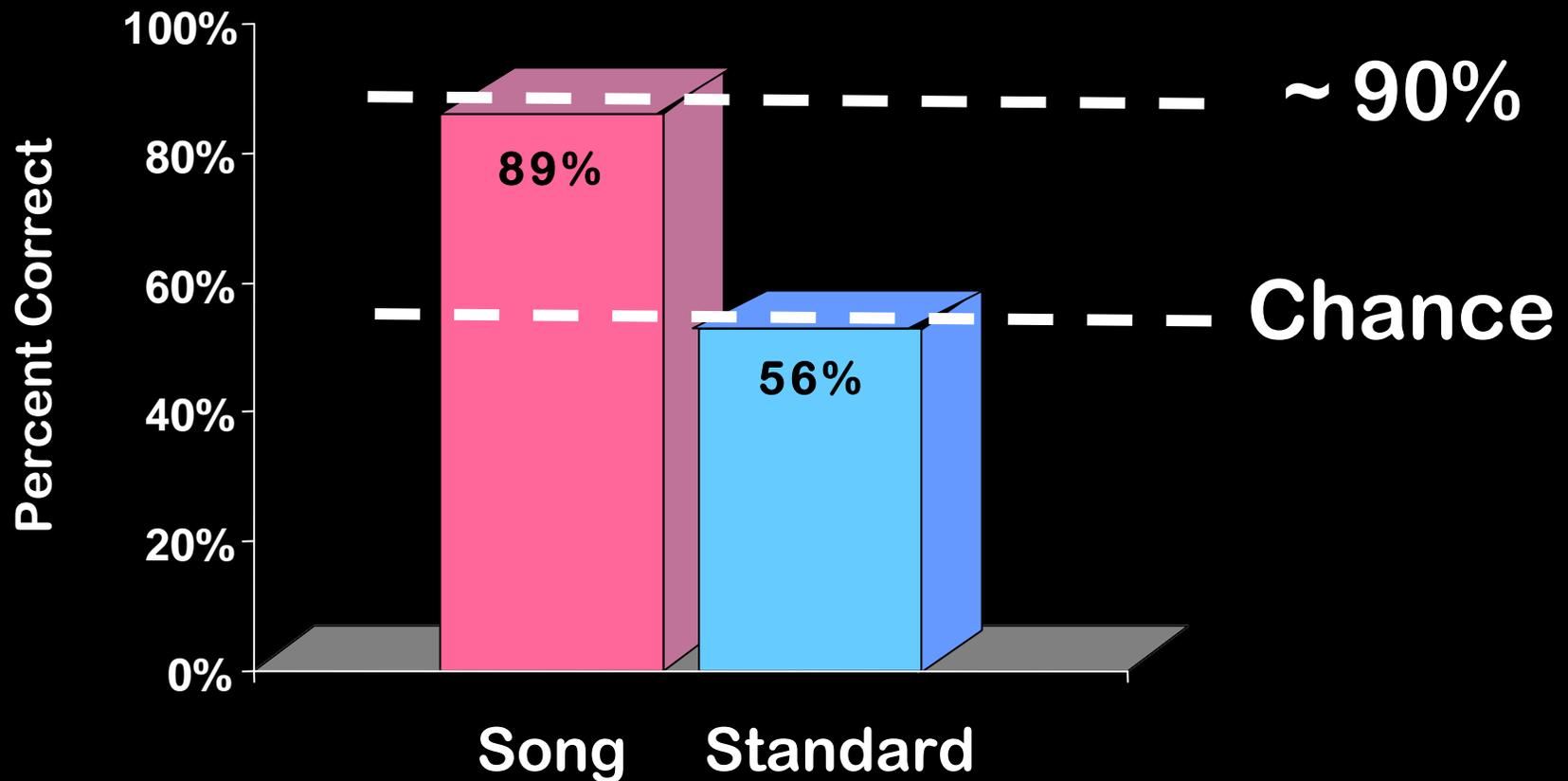
DITTY

Experimenter sings a little ditty

♪ think about the answer, don't tell me ♪
before the child responds.

Imposes time between presentation of stimulus
and response to make children take the time
they need to 'compute' the answer

Percentage of Correct Responses by 4-Year-Old Children on the Song and Standard Conditions of the Day-Night Task



VIDEO

<http://www.devcogneuro.com/videos/DayNight2.wmv>

၈

In evaluating *Tools* we specifically chose EF measures completely different from anything any of the children had ever done before.

To see a difference by condition, the children would have to TRANSFER their training in EF to utterly new situations.

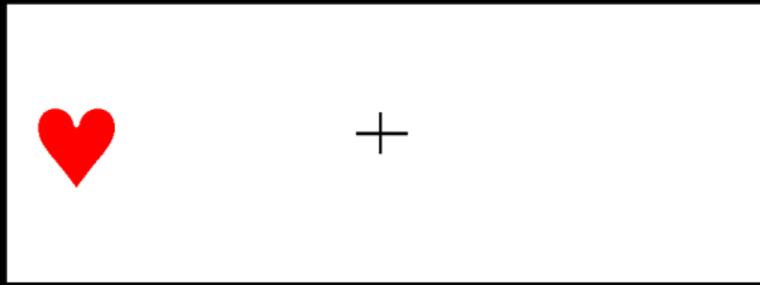


All children came from the same neighborhood and were randomly assigned to Tools or district-curriculum classrooms.

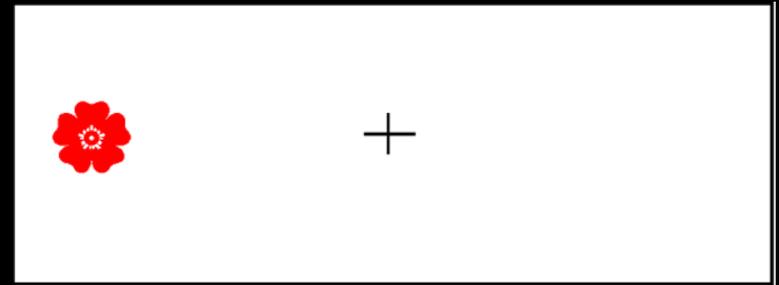
HEARTS & FLOWERS

Congruent

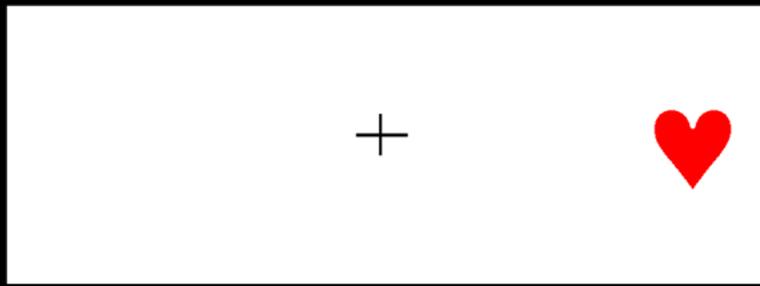
Incongruent



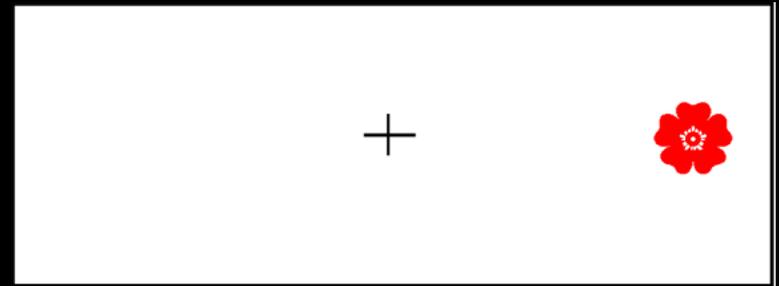
Push Left



Push Right

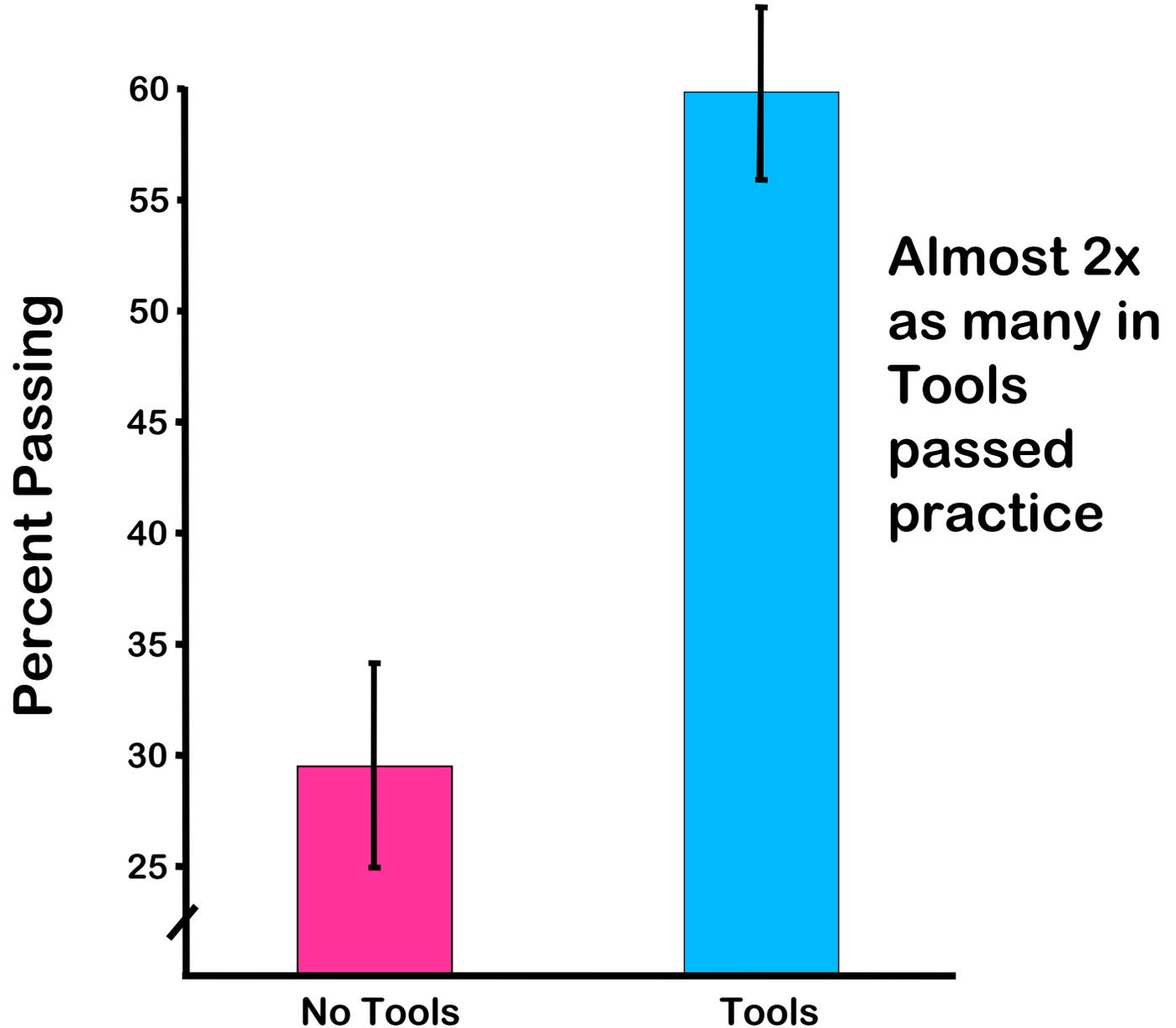


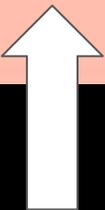
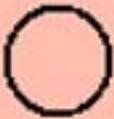
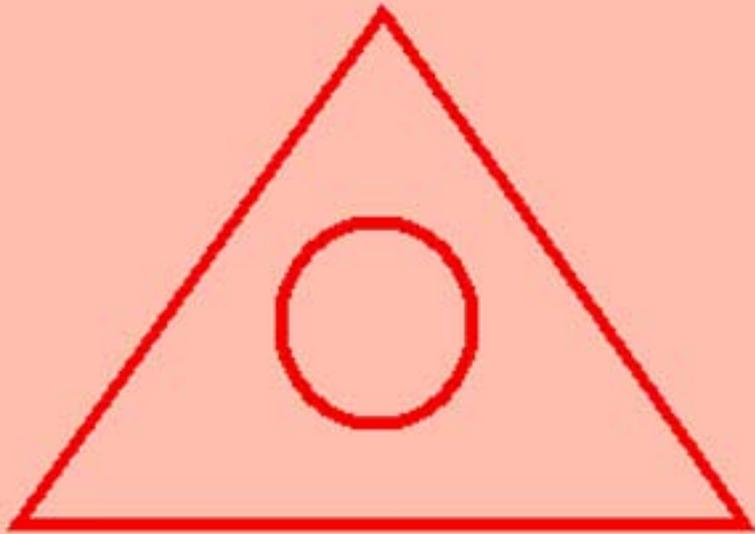
Push Right



Push Left

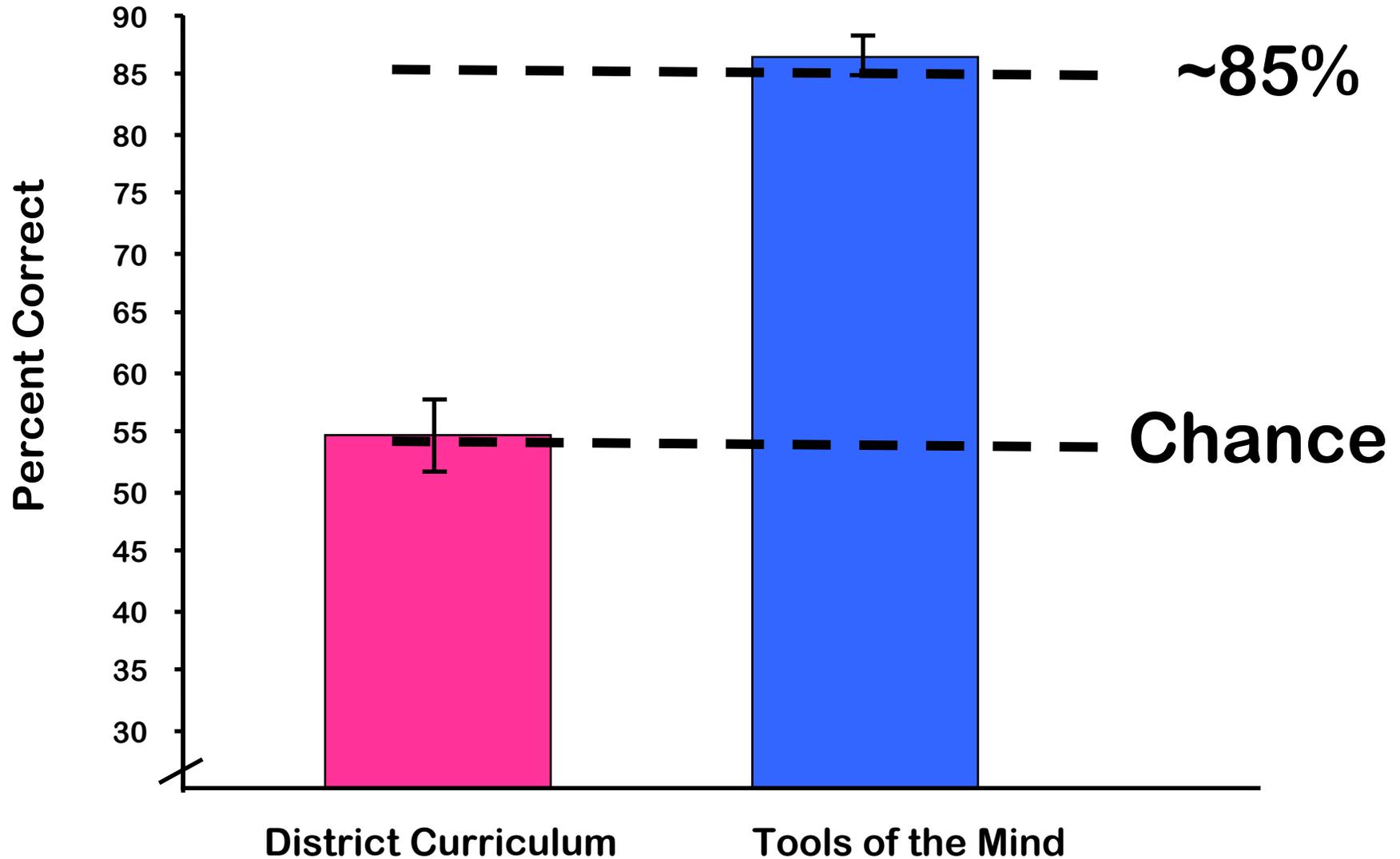
Mixed Block (Hearts & Flower Trials Intermixed) Percent of Children who Passed Criterion for Testing







Percentage of Correct Responses on Reverse Flanker Trials



**Whether children were in
Tools of the Mind or not
accounted for more variance
in EF than did age or gender.**



The more EF-demanding the task, the more highly the task correlated with academic performance.





November 30, 2007

THE EARLY YEARS

Preschool Program Improves Cognitive Control

Adele Diamond,^{1*} W. Steven Barnett,² Jessica Thomas,² Sarah Munro¹

Superior academic performance in children who have been through Tools has been replicated in other Tools of the Mind programs with other children and other teachers, in other schools and states, and with different comparison conditions.



Take-home Message #1:

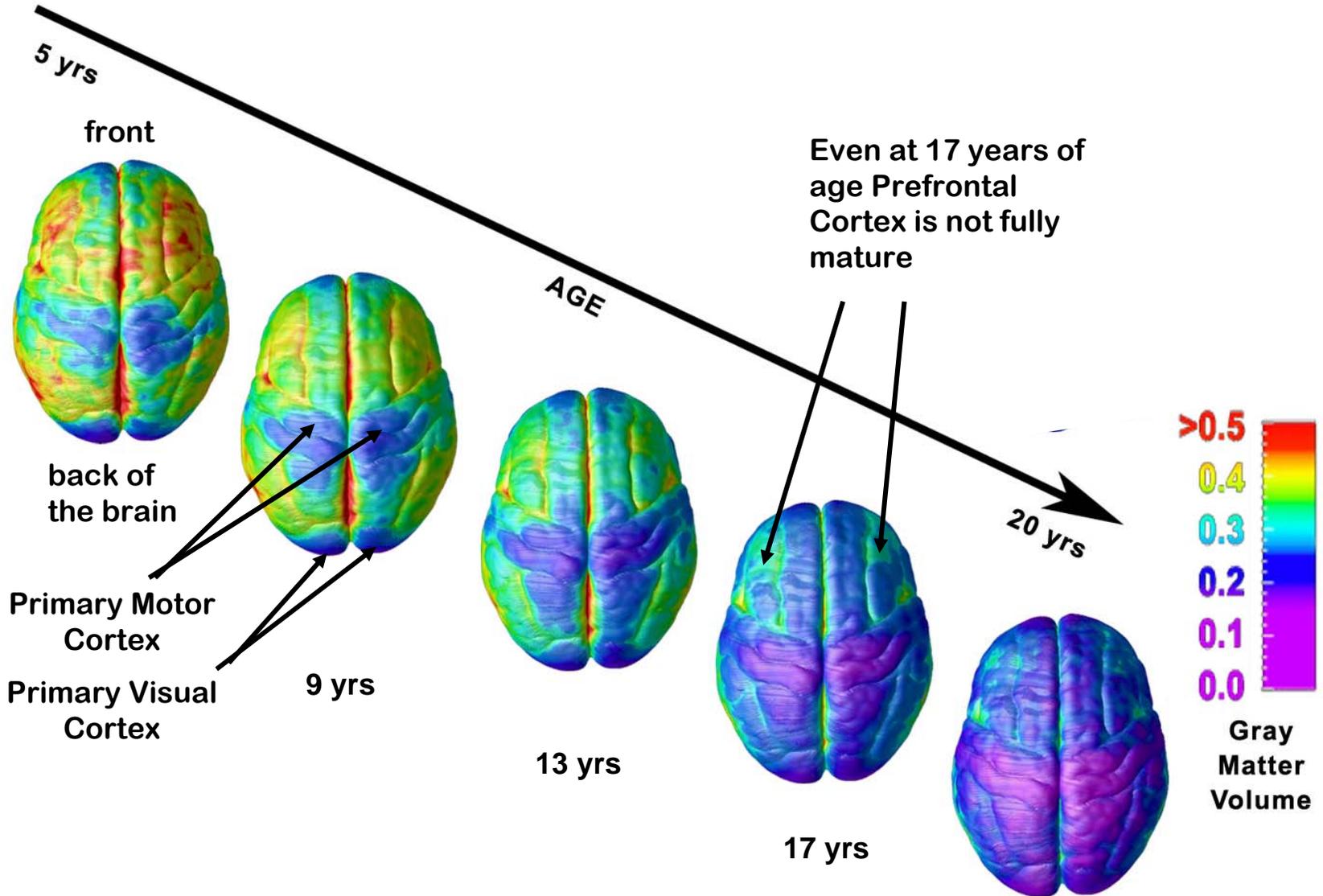
EF skills can be improved
even in children as young as 4-5 years

without expensive, highly
technical equipment

by regular teachers
in regular classrooms



Human Brain Development



Even those who believed that EF can be improved, have doubted whether that could be done as early as preschool since EF depends on PFC, and PFC isn't fully mature until young adulthood.

(Analogy with leg length at 2 years and walking and even running at age 2.)

Just because PFC isn't fully functional, doesn't mean that it isn't functional at all.



Kovács AM, Mehler J. (2009)

**Cognitive gains in 7-month-old
bilingual infants.**

*Proceedings of the National
Academy of Sciences.*

vol 106, p. 6556-6560

Very little is fixed or unchangeable.

90% of our genes are switched off. To a large extent, our experiences, and our reactions to them, determine which genes get turned on, and which stay on.

Experience sculpts the brain, and the brain changes throughout life.

Take-home Message #2:

**Importance of
Action (Doing) for
Learning**



a Chinese proverb:

I hear, and I forget.

I see, and I remember.

I do, and I understand.



If information is not relevant for action, we don't pay attention in the same way (hence the difference in route memory for the driver, versus the passenger, of a car).



A key aspect of Tools of the Mind is the minimal time devoted to large group activities and the emphasis on children actively engaging with one another and with the material.

Take-home Message #3:

Schools are under pressure to cut back on time allowed for play to provide more time for academic instruction.

BUT, the children in Tools, who have more time to play, perform **BETTER** on academic outcome measures than the children who had more time in direct academic instruction.



“Young children’s cognitive performance at 7 years of age was better for those children who had spent less time in whole-group activities and more time working or playing individually or in small groups.”

International Association for the Evaluation of Educational Achievement (IEA) (2007)

BUT not all Play is Equal.

It is NOT that “anything goes” or so structured by adults that the children get no opportunity for creative input.

Take-home Message #4:

Feedback Loops



Children at-risk fall progressively farther behind other children in academic achievement over the school years.

That widening achievement gap may result from a negative feedback loop beginning with poor initial EFs.

I hypothesize that helping at-risk children improve their EF skills early might be critical to closing the achievement gap and reducing societal inequalities.

Consider:

Poor EF leads to problems paying attention in class, completing assignments, and inhibiting impulsive behaviors.

School is less fun...

the teacher is always getting annoyed with you
& compliance w/ school demands is very hard

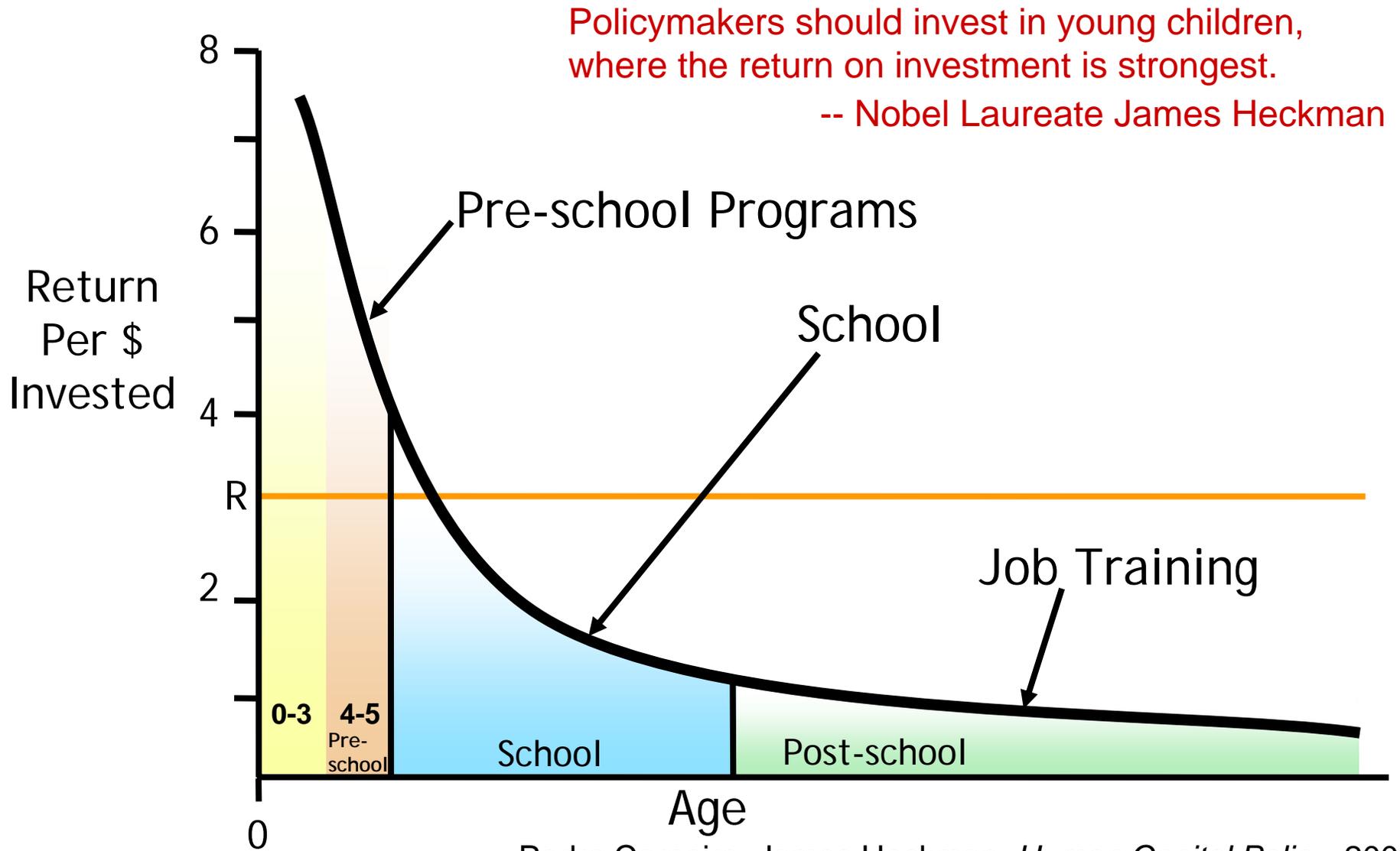
Teachers come to expect poor self-regulation and poor work, and the children come see themselves as poor students.

On the other hand, children who have better EFs are likely to be praised for good behavior, enjoy school more and want to spend more time at their lessons. Their teachers enjoy them and a self-reinforcing positive feedback loop is created.

I hypothesize therefore that the benefit from early EF training may INCREASE over time, and

that helping at-risk children improve their EF skills early might be critical.

Rates of Return to Human Capital Investment at Different Ages: Return to an Extra Dollar at Various Ages



The recent explosion in the diagnoses of ADHD might be due, in part, to some children never learning how to exercise self-regulation.



I predict (and we are now testing) that early education programs that improve EFs will not only lead to better school outcomes but to better mental health outcomes (e.g., fewer children diagnosed with ADHD, because the program will have taught them how to exercise self-control and emotion regulation).



**Many issues are not simply
Education issues or Health
issues. They are both.**



Take-home Message #5:

Tools of the Mind does not
address **ONLY** EFs or **ONLY**
cognitive development



**Tools' approach is multi-dimensional
& I think that is key to its success.**

It targets EFs, but it also...

- a) emphasizes Active Learning vs.
Passive Listening, as I've already
mentioned**

**We are not just intellects,
we have bodies
we have emotions
& we have social needs**

b) *Tools* intentionally helps children develop socially as well as academically.

Vygotsky: cognitive development occurs in the context of social development; growth in each depends, in part, on growth in the other.

Children in *Tools* do a lot of activities with one or a small number of other children, & within each week, every week, every child is paired with every other in the class at least once.

“Social isolation can be more harmful to your health than smoking, obesity, high blood pressure or a sedentary lifestyle....

People who are isolated have higher rates of disease and death.”

-House, Landis, & Umberson (1988, *Science*)

“Social isolation grinds the body through a physical wear-and-tear essentially akin to premature aging.”

-- John Cacioppo & William Patrick

2008 book, *Loneliness: Human Nature and the Need for Social Connection*

Roy Baumeister et al. (2002, *Journal of Personality and Social Psychology*)

- One group of subjects were told beforehand they'd have close relationships throughout their lives;
- another group was told the opposite;
- a third group was told unrelated bad news.

On simple memorization questions, the groups were comparable.

On sections involving logical reasoning (EF), subjects primed for loneliness performed much worse.

A later study by a separate research group found that brain scans conducted during math tests showed less activity in the brain's executive function regions (in Prefrontal Cortex) among participants who felt isolated.

c) Reduced stress in the classroom.

Because children in *Tools* exercise better EFs, teachers need to discipline them less & “time-outs” are not needed.

By helping children inhibit their impulsive behaviors & act appropriately, *Tools* reduces the stress experienced by both teachers & students.

Also, *Tools* teachers are taught procedures for implementing paired activities by the children that create a positive atmosphere of cooperation & friendship.

**We know that stress impairs
Executive Functions & can
make you look as if you have
an EF impairment.**

(Arnsten, 1998)



Storytelling requires and invites a child's rapt attention for extended periods (sustained, focused attention), and, working memory to hold in mind all that has happened thus far, different characters' identities, and to relate that to the new information being revealed.



**An activity from
Montessori schools, that
is essentially a type of
walking meditation.**

**Everyone (even the
grown-ups) gets a bell
and walks in a line or
circle. The goal is
for no one's bell to
make a sound.**





Studies have demonstrated that young people involved in orchestras show better academic performance and school success.







Applied Developmental Psychology, 2004, vol 25, p 283-302

Promoting self-regulation through school-based martial arts training

Kimberley D. Lakes*, William T. Hoyt

Found that Tae Kwon Do training improved children's executive functions (inhibition: discipline, emotion regulation; working memory: performance on a mental math task), and respectful treatment of peers.



The Effects of a Creative Dance and Movement Program on the Social Competence of Head Start Preschoolers

Yovanka B. Lobo and Adam Winsler, *George Mason University*

Social Development, 2006, 15: 501-519

Abstract

2 times a week

The effects of an eight-week instructional program in creative dance/movement on the social competence of low-income preschool children were assessed in this study utilizing a scientifically rigorous design. Forty preschool children from a large Head Start program were randomly assigned to participate in either an experimental dance program or an attention control group. Teachers and parents, blind to the children's group membership, rated children's social competence both before and after the program, using English and Spanish versions of the Social Competence Behavior Evaluation: Preschool Edition. The results revealed significantly greater positive gains over time in the children's social competence and both internalizing and externalizing behavior problems for the experimental group compared with the control group. Small-group creative dance instruction for at-risk preschoolers appears to be an excellent mechanism for enhancing social competence and improving behavior. The implications for early childhood education and intervention are discussed.

These are not just beneficial for cognitive fitness, they are also beneficial for physical fitness.

Our brains work better when our bodies are physically fit.



Nature Reviews Neuroscience (January 2008)

"Be Smart, Exercise Your Heart:
Exercise Effects on Brain and Cognition"
Charles Hillman, Kirk Erickson & Art Kramer

"There is little doubt that leading a sedentary life is bad for our cognitive health."

The evidence shows that physical activity (especially aerobic exercise) robustly improves cognition and brain function. In particular, the frontal lobe and the executive functions that depend on it show the largest benefit from improved fitness.

The positive effects of aerobic physical activity on cognition and brain function are evident at the molecular, cellular, systems, and behavioral level.

The brain does not recognize the same sharp division between cognitive and motor function that we impose in our thinking.

Substantially overlapping brain systems subserve BOTH cognitive and motor function.



**Close Interrelation of
Motor Development and Cognitive
Development
and of the Cerebellum and Prefrontal
Cortex**

Diamond, A.

(2009)

Child Development, vol 71, 44-56



Venezuela's national system of Youth and Children's Orchestras, also known as El Sistema, the brainchild of Venezuelan economist, conductor, and composer, José Antonio Abreu, who in 1975 envisioned classical music training as a social intervention that could transform the lives of lower-income, at-risk, and special needs children.



The National Dance Institute (NDI) was founded in 1976 by the remarkable Jacques d'Amboise, a former principal dancer for the American Ballet Theater for whom Ballanchine choreographed dances, recipient of the National Medal of Honor - to help troubled youth.

Jacques came from a poor family, dropped out of school, and was headed for trouble. His life was transformed by dance.

NDI has met with great success with some of the poorest, neediest children in New York City slums, Native American reservations, and abroad, including Senegal, West Africa.



El Sistema

Nacional de las Orquestas Juveniles e Infantiles de Venezuela

since 1975, has reached
almost 400,000 children, often
in the poorest communities

serves ALL children - incl.
deaf, blind, or otherwise dis-
abled, & some as young as 2

free music classes & free
instruments regardless of
their ability to pay.

National Dance Institute

NDI

since 1976, has reached
over 1 million children, often
in the poorest communities

serves ALL children - incl.
those in wheelchairs -
beginning in primary grades

free - offered to all children
in a grade without regard to
ability

BOTH

HARD WORK, PERSISTENCE, DISCIPLINE

practice, practice, practice

HIGH STANDARDS – challenge the children

COGNITIVELY DEMANDING – challenges concentration, sustained attention, working memory (remember complicated sequences)

COGNITIVE

PHYSICAL ACTIVITY, INTENSIVE MOVEMENT & VISUOMOTOR TRAINING

PHYSICAL

SELF-CONFIDENCE, PRIDE

JOY – engages & motivates the children

EMOTION

SOCIAL SUPPORT, SOCIAL BELONGING – part of a group (an ensemble of dancers or musicians) – children help one another, listen to one other, & respect one another. Each is an important part of the whole.

SOCIAL



VIDEO

[http://www.devcogneuro.com/videos/El sistema v2.wmv](http://www.devcogneuro.com/videos/El_sistema_v2.wmv)