Interrelations between Creativity and Executive Functions: Lessons from Psychology and Neuroscience for Cultivating Giftedness in Young People

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in Evergreen School & University of Washington Speaker Series
SMA & Premotor Cortex

Dorsolateral Prefrontal Cortex

Rostral Prefrontal Cortex (the Frontal Pole)

Inferior (ventrolateral) Prefrontal Cortex

Central Sulcus

Motor Cortex

Ventromedial (orbital) Prefrontal Cortex
“Executive Functions” (EFs), which depend on prefrontal cortex, are comprised of 3 core abilities:
(a) 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, playing with ideas in your mind (reasoning, problem-solving)
- relating what you read (or learned / or heard) earlier to what you are reading (learning / hearing) now
- doing mental arithmetic (e.g., adding or subtracting)
- 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 or listening to (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 re-combine 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 in the system of brain regions that is used for each.
(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
Being able to... (2) inhibit acting impulsively & instead make a more considered response enables you to:

- 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.
Also, since inhibition makes it possible to resist the most salient thought, perception, or response, it can help students resist the lure of examples.

When we give students examples, those become salient, and can lessen how much creativity students show unless they can inhibit the salience of those examples in their mind.
Finally, inhibition is critical in helping students resist the temptation to answer quickly, instead taking the time they need.
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

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**Percent Correct**

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

**Age in Years**

- 3
- 3.5
- 4
- 4.5
- 5
- 5.5
- 6
- 6.5
- 7

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The line graph shows the percent correct on the last 4 trials out of 16 for different age groups on the Day-Night Test. The percent correct increases with age, with a noticeable dip around the age of 4 years.
Response Latency on First 4 Trials (out of 16) on the Day-Night Test

Time to Respond in Seconds

Age in Years

<table>
<thead>
<tr>
<th>Age in Years</th>
<th>Time to Respond in Seconds</th>
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<tbody>
<tr>
<td>3</td>
<td>2.8</td>
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<tr>
<td>3.5</td>
<td>3.2</td>
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<td>4</td>
<td>2.4</td>
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<td>4.5</td>
<td>1.6</td>
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<td>5</td>
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<tr>
<td>7</td>
<td>1.2</td>
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Response Latency on the Last 4 Trials (out of 16) on the Day-Night Test

Time to Respond in Seconds

Age in Years
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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percent Correct</th>
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</thead>
<tbody>
<tr>
<td>Song</td>
<td>89%</td>
</tr>
<tr>
<td>Standard</td>
<td>56%</td>
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</tbody>
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Chance ~ 90%
(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.

In other words, CREATIVITY.
For example, try to think of as many uses for a TABLE as you can.

What are all the things you might use a table for?
For example, think about the uses of a table:

A table might be used to write on or to eat food on.

It might be turned on its side and used to keep a door closed or used as a shield against bullets or snowballs.

You could get under it to hide or to keep dry.
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?
Executive Functions are important for school success.

Working memory and inhibitory control each independently predict both math and reading competence throughout the school years.
<table>
<thead>
<tr>
<th></th>
<th>WORKING MEMORY</th>
<th>INHIBITION</th>
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<tbody>
<tr>
<td><strong>VERY EARLY GRADES</strong></td>
<td></td>
<td></td>
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<tr>
<td>Language Skills</td>
<td>Adams &amp; Gathercole, 1995; Blair &amp; Razza, 2007</td>
<td>Blair &amp; Razza, 2007; McClelland et al., 2007</td>
</tr>
<tr>
<td>Math Skills</td>
<td>Blair &amp; Razza, 2007; Espy et al., 2004; Passolunghi et al., 2007</td>
<td>Blair &amp; Razza, 2007; Espy et al., 2004; Passolunghi et al., 2007</td>
</tr>
<tr>
<td><strong>LATER GRADES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Language Skills</td>
<td>De Beni et al., 1998; Gathercole et al., 2004, 2005; Savage et al., 2006</td>
<td>De Beni et al., 1998; Fiebach et al., 2007; Savage et al., 2006</td>
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<td>Math Skills</td>
<td>Barrouillet et al., 2005; Bull &amp; Scerif, 2001; Gathercole et al., 2004; Swanson &amp; Kim, 2007</td>
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Evidence shows that discipline accounts for over twice as much variance in final grades as does IQ, even in college.

(Duckworth & Seligman, 2005)
Want to be able to use PFC whenever you...
.. are presented with the unexpected,
.. need to think outside the box,
.. need to concentrate particularly hard,
.. need to adapt to change...

BUT
Want most tasks to be so familiar and well learned that PFC is NOT needed. Instead, those tasks are handed off to subcortical regions that have had 100,000s of more years of evolutionary time to perfect their functioning and can subserve task performance ever so much more efficiently than can PFC.

(re: *Zen and the Art of Archery*)
The DLPFC Slice for 8 Individuals (A/P=+45)
Note also that because we are able to selectively attend, we can miss important things because we were selectively attending to other things.
“Our notions of what should happen block us from seeing what actually does happen.”

-- Bernie Glassman,
Bearing Witness
One of my patients, a woman with ovarian cancer, told me this: “Before I got sick, I was very certain of everything. I knew what I wanted and when I wanted it. Most of the time I knew what I had to do to get it too. I walked around with my hand outstretched saying, ‘I want an apple.’ Many times life would give me a pomegranate instead. I was always so disappointed that I never looked at it to see what it was. Actually, I don’t think I could have seen what it was. I had the world divided up into just two categories: ‘apple’ and ‘not-apple.’ If it wasn’t an apple, it was only a not-apple. I had ‘apple eyes.’ ”

from the story, “I never promised you a Rose Garden”
Rachel Naomi Remen
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.
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.
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).
Lack of sleep also will produce deficits in Exec Func skills, and cause someone to look as if he or she has impaired Executive Functions.
About 25% of children diagnosed with ADHD have sleep apnea or other problems sleeping.
Attention-Deficit/Hyperactivity Disorder with Obstructive Sleep Apnea: A treatment outcome study.

Huang YS, Guilleminault C, Li HY, Yang CM, Wu YY, Chen NH. Sleep Medicine 2007 vol 8: 18-30

Studied 66 school-age children with ADHD and 20 healthy controls.

Conclude: Recognition and treatment of underlying mild sleep-disordered breathing (SDB) in children with ADHD may prevent unnecessary long-term MPH use and the potential side effects associated with drug intake.
ATTITUDE
by Charles Swindoll

The longer I live, the more I realize the impact of attitude on life. Attitude, to me, is more important than facts. It is more important than the past, than education, than money, than circumstances, than failures, than successes, than what other people think or say or do. It is more important than appearances, giftedness or skill. It will make or break a company...a church...a home. The remarkable thing is, you have a choice every day regarding the attitude you will embrace for that day. We cannot change our past...we cannot change the fact that people will act in a certain way. We cannot change the inevitable. The only thing we can do is play on the one string we have, and that is our attitude....I am convinced that life is 10% what happens to me and 90% how I react to it.
Powerful Role of Expectations and Attitude

Pygmalion in the Classroom -- powerful role of expectations  
Robert Rosenthal

Stereotype threat - female performance on math exams  
Claude Steele
Importance of not being afraid to take risks, try something new, to fall on your face, or to be wrong.

"Anyone who has never made a mistake has never tried anything new."  

Albert Einstein
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.
"You've never failed until you've tried for the last time, and you've never lost until you quit."

-- Samuel Proctor Massie

Few people have attained the respect, admiration, and degree of excellence achieved by Samuel Massie.

Born in Little Rock, Arkansas in 1919, Samuel Massie was the grandson of slaves. In 1966 he became the first African-American professor at the U.S. Naval Academy. He was named one of the six best college chemistry professors in the United States and one of the 75 premier chemists of the 20th century, along with Marie Curie, James Watson, and Francis Crick. In 1995 Dr. Massie’s portrait was hung in the National Academy of Science gallery and in 2002 the US Dept. of Energy chose to name its Chairs of Excellence in the environmental sciences in his honour.
The Tools of the Mind program is based on theories of Vygotsky and Luria

Elena Bodrova & Deborah Leong

Foreword by Michael Cole
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 at 17 years of age Prefrontal Cortex is not fully mature.
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.

*Proceedings of the National Academy of Sciences.* vol 106, p. 6556-6560
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.
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.”


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


- 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)
Studies have demonstrated that young people involved in orchestras show better academic performance and school success.
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.
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
Thank you for your attention!

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