Executive Functions in Children and Youth: How and why Dance, Music, Sports, and Storytelling might well Support the Development of these Critical Skills

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What will it likely take to be successful in the 21st century?

1) Creativity

- Coming up with new ideas, hypotheses and Inventions.
- If one way of solving a problem isn’t working, how else might we succeed here? Can we think outside the box to come up with a way of attacking this no one else has considered before?
2) Flexibility

- Seeing opportunities and seizing them: I was planning to do X, but an amazing opportunity has arisen to do Y, do I have the flexibility to take advantage of serendipity?
- My opinion was X, but now that I see this new information, I’m able to change my opinion.
- Being able & willing to change course when it seems you were wrong
An example of poor cog. flexibility:

When one door closes, another door opens; but we often look so long and so regretfully upon the closed door, that we do not see the ones which open for us.

- Alexander Graham Bell
3) Discipline

Having the discipline to stay on task...

- seeing it through to completion despite some aspects being tedious or difficult

- being able to stay focused despite distractions

- continuing to work at something though the reward may be a long time in coming
Evidence shows that discipline accounts for over twice as much variance in final grades as does IQ, even in college. (Duckworth & Seligman, 2005)
4) Self-control

Having the self-control to...

- think before you speak or act
- resist temptations (e.g., a luscious dessert)
- give a considered response instead of an impulsive one
- resist saying something socially inappropriate (or hurtful)
- resist ‘tit for tat’ (hurting someone because that person hurt you)
- resist jumping to an interpretation of what something meant or why it was done
ALL of the above are “Executive Functions” or rely on them
The 3 core Executive Functions are:

- **Cognitive Flexibility**
  (including being able to switch perspectives & see things in a new light)

- **Inhibitory Control**
  (which includes self-control & discipline)

- **Working Memory**

Higher-order Executive Functions are:

- Problem-solving
- Reasoning
- Planning
Inhibitory control includes being able to 

(1) stay focused despite distraction SELECTIVE or FOCUSED ATTENTION 

(2) stay on task (& complete task) though tempted not to - DISCIPLINE 

(3) inhibit acting impulsively & instead make a more considered response (not putting your foot in your mouth, not hitting, not drinking too much, dieting) SELF-CONTROL
Children with less inhibitory control (i.e., children who were less persistent, more impulsive, and had poorer attention regulation) as adults 30 years later have...

- worse health
- earn less
- and commit more crimes

than those with more self-control as young children,
controlling for IQ, gender, social class, & home lives & family circumstances growing up across diverse measures of self-control.
That’s based on a study of 1,000 children born in the same city in the same year followed for 32 years with a 96% retention rate.


Since “self-control’s effects follow a linear gradient, interventions that achieve even small improvements in self-control for individuals could shift the entire distribution of outcomes in a beneficial direction and yield large improvements in health, wealth, and crime rate for a nation.”
(b) Working Memory:
Holding information in mind while mentally working with 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.
• relating one idea to another
• relating what you read (or learned / heard) earlier to what you are reading (learning / hearing) now
• mental math calculations
• understanding cause and effect
• remembering multi-step instructions & executing them in the correct order
(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.
“Executive Functions” depend on Prefrontal Cortex and the other neural regions which are interconnected with prefrontal cortex.
Why are Executive Functions important?
Executive Functions are important for school success from the early elementary years straight through high school.

Working memory and inhibitory control each independently predict both math and reading competence throughout the school years.
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<th>WORKING MEMORY</th>
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Executive Functions are also critical for job success. Poor EFs lead to poor productivity and difficulty finding and keeping a job (Prince et al. 2007).
Executive Functions are also important for marital harmony. People with poor EFs are more difficult to get along with, less dependable, and more likely to act on impulse (Eakin et al. 2004).
Poor EFs can lead to social problems such as aggression, emotional outbursts, & crime (Bailey 2007; Broidy et al. 2003; Moffitt et al. 2011; Prince et al. 2007; Saarni 1999).

Early EF gains can reduce the later incidence of aggression & anti-social behavior (Nagin & Tremblay 1999).
EFs are impaired in many mental health disorders
e.g., addictions, ADHD, OCD, depression, conduct disorder, & schizophrenia (Verdejo-García et al. 2006; Penadés et al. 2007; Diamond 2005; Lui and Tannock 2007; Taylor-Tavares et al. 2007; Barch 2005).

Such disorders are increasing at alarming rates (Moffitt et al. 2010; Robinson et al. 1999) & account for more lost years of life & productivity than any other illness including cancer (Prince et al. 2007).
In short, EFs are core skills

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- success in school and in life,
In short, EFs are core skills

- critical for cognitive, social, and psychological development,
- success in school and in life, &
- for mental & physical health.
Many issues are not simply Education issues or Health issues. They are both. EFs are important for academic achievement and for mental health.
Nowhere is the importance of **social, emotional, and physical health** for cognitive health more evident than with PFC & EFs.

EFs are the first to suffer, and suffer disproportionately, if we are lonely, sad, sleep-deprived, or not physically fit.
To show the EFs they are capable of, to achieve the academic outcomes of which they are capable,

- children need to feel joyful
- children need to feel they are in a supportive community they can count on, and
- their bodies need to be fit and healthy.
A school curriculum that ignores children’s emotional, social, or physical needs will find that those unmet needs will work against achievement of the academic goals.
Our brains work better when we are not in a stressed emotional state.

Amy Arnsten, 1998

The biology of being frazzled

Science

This is particularly true for PFC & EFs.
Stress and Prefrontal Cortex

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

(Roth et al., 1988)
Stress impairs Executive Functions and can cause someone to look as if he or she has an EF impairment (like ADHD).
In college students, one month of stress in preparation for a major exam disrupts prefrontal cortex functional connectivity. Stress decreases coupling between left DL-PFC and right DL-PFC, and between DL-PFC and premotor cortex, the ACC, the insula, posterior parietal cortex (PPC), and the cerebellum.
Stress impairs their attention shifting (shifting between attending to color or motion).

Liston et al. (2009) *PNAS*
When we are sad we’re worse at filtering out irrelevant information (i.e., worse at selective attention).

Desseilles et al., 2009
von Hecker & Meiser, 2005

When we are happy we are better at selective attention.

Gable & Harmon-Jones, 2008
People show more creativity when they are happy

THE most heavily researched predictor of creativity in social psychology is mood. The most robust finding is that a happy mood leads to greater creativity (Ashby et al. 1999). It enables people to work more flexibly (Murray et al. 1990) & to see potential relatedness among unusual & atypical members of categories (Isen et al. 1985, 1987).

Hirt et al. 2008: 214
It’s important that parents & teachers are not so stressed that they are unable to provide caring role models for our children.
Stress is not only detrimental to the teacher’s ability to be a good teacher, the children will pick on their teacher’s stress. It will cause them to feel stressed. And if they are stressed, their executive functions will suffer and thus their performance in school and at work will suffer.
It is extremely important that you relax, and SLOW DOWN, so that you can take the time to give your child your undivided attention. The importance of that cannot be over-emphasized.
The most basic and powerful way to communicate to our children that we care about them is to listen to them. Truly listen.

Give them our time and our attention.

The quality of our listening, rather than the wisdom of our words, is often what has the most impact.
“Children who are truly loved...know themselves to be valued. This knowledge is worth more than any gold.

“The principal form that love takes is giving of your time, and truly listening. When something is of value to us we spend time with it. When we love our children, we give them our time.... True listening, total concentration on the other, is always a manifestation of love.
“Your willingness to listen is the best possible concrete evidence of your esteem that you can give your child. There is no better and ultimately no other way to teach your children that they are valuable people than by valuing them.

When children know that they are valued… they feel valuable….This feeling of being valuable is the cornerstone of discipline because when one considers oneself valuable one will take care of oneself in all ways that are necessary. Self-discipline is self-caring.”

-- Scott Peck, *The Road Less Traveled*
“Perhaps the most important thing we ever give each other is our attention. And especially if it's given from the heart…”

“Listening is the oldest and perhaps the most powerful tool of healing.”

-- Dr. Rachel Naomi Remen
When a child is speaking, just listen. When we interrupt to try to show we understand, we move the focus of attention to ourselves.

Because we care, we are tempted to want to do ‘more’ than ‘just’ listen. But what a child needs most is not for us to go into problem-solving mode, but just for us to listen - truly listen and care.
Our brains work better when we are not feeling lonely or socially isolated.

*Loneliness: Human Nature and the Need for Social Connection*
2008
a book by John Cacioppo & William Patrick

This is particularly true for PFC & EFs.

- 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 told they’d be lonely performed much worse.

Campbell et al. (2006) found that during math tests there was Prefrontal Cortex worked less efficiently among participants who felt isolated.
Children need activities where they can...

Help one another
Learn that each is an important part of the whole

Learn to collaborate
(as team members or partners)
Come to see the value of collaborating & cooperating.
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.”

This is *particularly* true for PFC & EFs.
The brain doesn’t recognize the same sharp division between cognitive and motor function that we impose in our thinking.

The SAME or substantially overlapping brain systems subserve BOTH cognitive and motor function.
For example, the pre-Supplementary Motor Area (SMA) is important for sequential tasks, whether they are sequential motor tasks or sequential numerical, verbal, or spatial cognitive tasks.

Hanakawa et al., 2002
Motor development and cognitive development appear to be fundamentally intertwined.


Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex.

*Child Development, 71, 44-56*
When cognitive development is perturbed, as in a neurodevelopmental disorder, motor development is often adversely affected as well.
For example……

At least half of all children with ADHD have poor motor coordination & fit the diagnosis for developmental coordination disorder.

At least half of all children with developmental coordination disorder have ADHD.

Similarly for dyslexia, autism, and other disorders.
Though many studies have found that aerobic exercise improves prefrontal function and EFs, all but 3 of those studies have either been with adults and/or examined effects of a single bout of aerobic exercise, where benefits may be transient. In general, the studies with children have not found strong effects.
Exercise alone appears not to be as efficacious in improving EFs as exercise-plus-character-development (traditional martial arts) or exercise-plus-mindfulness (yoga).
Lakes & Hoyt (2004) randomly assigned children in grades K thru 5 (roughly 5-11 years-old) by homeroom class to Tae-Kwon-Do martial arts ($N = 105$) or standard physical education ($N = 102$).
Children who had been assigned to Tae-Kwon-Do training showed greater gains than children in standard phys. ed. on all dimensions of EFs studied (e.g., cognitive [distractible — focused] and affective [quitting — persevering] - subtests of the Response to Challenge Scale). This generalized to multiple contexts and was found on multiple measures. They also improved more on mental math (which requires working memory).
Traditional martial arts emphasize self-control, discipline (inhibitory control), and character development.
In a study with adolescent juvenile delinquents (Trulson, 1986), one group was assigned to traditional Tae-Kwon-Do (emphasizing qualities such as respect, humility, responsibility, perseverance, honor as well as physical conditioning). Another group was assigned to modern martial arts (martial arts as a competitive sport).
Those in traditional Tae-Kwon-Do showed less aggression and anxiety and improved in social ability and self-esteem.

Those in modern martial arts showed *more* juvenile delinquency and aggressiveness, and decreased self-esteem and social ability.
The Tools of the Mind early childhood program, based on theories of Vygotsky and Luria

Elena Bodrova & Deborah Leong

Foreword by Michael Cole
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*.

Children must **plan** who they want to be in a pretend scenario, and the teacher holds them accountable for following through.
• 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.
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.
Teachers & teaching assistants were randomly assigned to condition, stratified by level of education & amount of time teaching.
All children came from the same neighborhood; the children in Tools and the district-curriculum were very closely matched.
Percentage of Correct Responses on Reverse Flanker

- No Tools
- 1 Year Tools
- 2 Year Tools

Chance ≈ 85%
Preschool Program Improves Cognitive Control

Adele Diamond,¹* W. Steven Barnett,² Jessica Thomas,² Sarah Munro¹
One school was so impressed by how much better *Tools* children were doing, that it withdrew from the study and switched all classes to *Tools*. 
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.
Schools are under pressure to cut back on time allowed for play to provide more time for academic instruction.

BUT, children in *Tools of the Mind*, who have more time to play, perform BETTER on academic outcome measures than their peers who have more time in direct academic instruction.
PLAY doesn’t take away time from improving academic outcomes; play helps improve academic outcomes.

But not just any play!
Great News!
The BC Ministry of Health and BC Mental Health Foundation are funding the very FIRST trial of Tools in Canada.

It’s a small trial; but it’s a beginning.

As of next Fall, Tools will be introduced into 6 Kindergartens in Vancouver and 6 in Surrey.
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.
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
JOY
Science asked me to write a review of all interventions shown to improve EFs in young children

Diamond, A. & Lee, K.
(2011)
Interventions shown to Aid Executive Function Development in Children 4-12 Years Old

Science, vol. 333
accompanying online tables
Diverse activities including computer training, aerobics, martial arts, yoga, mindfulness, playing a musical instrument, & school curricula have all been shown to improve children’s executive functions.
Regardless of the program, a few principles hold:
1. Those with initially poorest EFs gain the most.

e.g., lower-income, lower WM span, or ADHD children generally show the most EF improvement from any program.
Since those with initially poorest EFs gain the most, early EF training is an excellent candidate for leveling the playing field and reducing the gaps in achievement and in health between more- and less-advantaged children.
2. EFs need to be continually challenged to see improvements.
Groups assigned to the same program, but without difficulty increasing, do not show EF gains. Setting aside a time to work on EFs is less effective than working on EFs as part & parcel of everything you do.
The most important element is probably that children love what they’re doing, so they spend a lot of time at it, practicing and pushing themselves to do better.

It is the discipline, the practice, that produces the benefits. Even the best activity for improving EFs if done rarely will produce little benefit.
Might as well have children do something they can put their heart and soul into.
Royston Maldoom is a choreographer known internationally for his work in the field of 'community dance.' He’s worked with: children & young people (in, & excluded from, mainstream education), street kids, the displaced, people with disabilities, men & women in prison, communities in conflict or marginalized or divided by cultural, religious, social or economic circumstances. His passion is to give all of them the opportunity to transform, thru the medium of dance, their view of: themselves, their abilities and their potential -- & to change how others view & judge them. He’s convinced that dance & performance can transform the lives of individuals & communities; supporting & encouraging comprehension, cohesion, sympathy & dialogue.
• Dance, approached as balanced social, physical, emotional and spiritual activity touches every part of us.

• In seeking creative solutions to artistic challenges we acquire understandings and skills that spill over into our daily lives.

-- Royston Maldoom
Jacques d'Amboise founded the National Dance Institute (NDI) to help troubled youth through dance, in the belief that the arts have a unique power to engage children and motivate them toward excellence, enabling young people to come to believe in themselves through seeing that they can conquer challenges and achieve what at first looked impossible. The program combines fun with serious discipline & high demands. It has met with great success with some of the poorest, neediest children in New York City slums, Native American reservations, & West Africa.
Dancing Makes You Smarter

Vergheese et al. (2003) examined the relation between leisure-time cognitive activity or physical activity on the incidence of dementia. At the study’s outset all participants were at least 75 years and dementia-free. Five years later…..
- Reading or doing crossword puzzles was associated with 35% reduced risk of dementia.
- Almost none of the physical activities offered protection against dementia except dance.
- Dance conferred the greatest risk reduction of any activity studied, cognitive or physical – a whopping 76% reduced risk of dementia.
José Antonio Abreu founded Venezuela’s National System of Youth and Children's Orchestras (*El Sistema*) in 1975 as a social intervention to transform the lives of at-risk children. *El Sistema* incorporates intensive training on a musical instrument with extensive orchestral experience. Such music training challenges executive functions by requiring focused attention over sustained periods and the self-control required to put in the hours of practice.

*El Sistema* is intended as a social program with music at its core. Rather than aiming to produce great musicians, it aims to create community. There are *El Sistema* programs now in 25 countries across 3 continents. Independent studies from Venezuela & Scotland report *El Sistema* transforming the lives of at-risk children, enhancing their effort and achievement in school.
For 10's of 1,000's of years, across all cultures, storytelling, dance, art, & play have been part of the human condition. People in all cultures made music, sang, danced, did sports, and played games. There are good reasons why those activities have lasted so long and been found so ubiquitously.
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 info being revealed.
I predict that while storytelling is wonderful, storytelling should tax EFs more, and so improve them more.
Music-making, singing, dancing, and playing address our physical, cognitive, emotional, and social needs.

These activities

- challenge our executive functions,
- make us happy & proud,
- address our social needs,
- & help our bodies develop
DANCE

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**Brings JOY**

**Increases feelings of Social Belonging & that we’ll all help one another.**

**Improves physical fitness.**

**Builds EFs**
- requires concentration,
- focus,
- discipline,
- holding complex sequences in mind, quickly adapting to changed circumstances

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**Indirect routes**

- Increases Pride, Confidence, & Sense of Self-efficacy

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**Direct path**
HARD WORK, PERSISTENCE, DISCIPLINE
  practice, practice, practice

HIGH STANDARDS – challenge the children

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

PHYSICAL ACTIVITY, INTENSIVE MOVEMENT & VISUOMOTOR TRAINING

SELF-CONFIDENCE, PRIDE

JOY, PASSION – engage & motivate

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.
School curricula empirically shown to improve EFs share several features in common.
These curricular programs:

- challenge EFs,
- reduce stress in the classroom,
- cultivate joy, pride, and self-confidence, and
- foster social bonding.
MANY activities not yet studied might well improve EFs.
caring for an animal....
SERVICE ACTIVITIES

activities where the children are working to help their community or people elsewhere

a goal larger than oneself --
helping children in Haiti, helping a local family whose home burned down, lobbying to get a new playground for the neighborhood
These are acts of caring and generosity,
They require forethought, planning, and perseverance even in the face of setbacks, creativity and flexibility when unexpected obstacles or opportunities arise, and putting into use what they’ve learned in school.

Each is a member of a group working toward an important shared goal.
Circus Arts
Circus challenges one’s executive functions

Have to concentrate & stay focused.
Have to quickly think on their feet & adapt.
Circus builds community, learn to cooperate & to trust others not to let you get hurt
Circus develops physical skills (fitness, balance, coordination, strength, flexibility)
Doing circus arts brings kids JOY and builds their confidence, & sense of self-efficacy. They learn that with effort they can succeed. (fail, then succeed, iteratively)
Brings JOY

Increases feelings of Social Belonging & that we’ll all help one another.

Improves physical fitness.

Builds EFs - requires concentration, focus, discipline, holding complex sequences in mind, quickly adapting to changed circumstances.

Increases Pride, Confidence, & Sense of Self-efficacy

Indirect routes

Direct route

Brings JOY

CIRCUS
Almost any activity can be the way in, can be the means for disciplining the mind and enhancing resilience. It all depends on the way the activity is done and the amount of time that is spent doing it, practicing and pushing oneself to do better.
Repeated Practice is Key
Prefrontal cortex (what I specialize in) is over-rated.

To learn something new, we need prefrontal cortex.

But after something is no longer new, persons who perform best recruit prefrontal cortex least.
The DLPFC Slice for 8 Individuals
To learn something, you need PFC

When something is new, those who recruit PFC most, often perform best.

But when you are really good at it, you are usually NOT using PFC so much.

AFTER something is no longer new, those who perform best usually recruit PFC least.
Older brain regions have had far longer to perfect their functioning; they can subserve task performance ever so much more efficiently than can prefrontal cortex (PFC).

A child may know intellectually (at the level of PFC) that he should not hit another, but in the heat of the moment if that knowledge has not become automatic (passed on from PFC to subcortical regions) the child will hit another (though if asked, he knows he shouldn’t do that).
knowing what one should do vs. 2nd nature (automatic) (i.e., NOT dependent on PFC)
The only way something becomes automatic (becomes passed off from PFC) is through action, repeated action. Nothing else will do.
“We are what we repeatedly do. Excellence, then, is not an act, but a habit.

We don’t act rightly because we have virtue or excellence, but we rather have these because we have acted rightly; these virtues are formed in a person by doing the actions; we are what we repeatedly do.”

Aristotle, *Ethica Nicomachea*, 4th century BC
To recap...

We’re not just intellects, we also have emotions, social needs, & bodies.
Our brains work better, and we have better EFs, when

- we’re not stressed or sad
- we’re not feeling lonely or isolated
- we’re physically fit
The different parts of the human being are fundamentally interrelated.

- Each part (cognitive, spiritual, social, emotional, & physical) develops best when no part is neglected.
- What nourishes the human spirit may also be best for Executive Functions. Perhaps we can learn something from the traditional practices of people across many cultures & 1,000’s of years.
- The arts, play, and physical activity may be critical for achieving the outcomes we all want for our children.
Programs that address the WHOLE PERSON (our cognitive, emotional, social, spiritual, and physical needs) will probably be the most successful at improving any aspect.
Even if your goal is *only* to improve academic achievement, the best way to achieve that is *not* to focus narrowly on academics alone, but to address children’s emotional and social development (as do all curricular-based programs that improve EFs) and children’s physical development (as do aerobics, martial arts, & yoga).

     Counterintuitively, the most efficient and effective strategy for advancing academic achievement is not to focus only on academics but to nurture all aspects of the child.
While it may seem logical that if you want to improve academic outcomes you should concentrate on academic outcomes alone, not everything that seems logical is correct.
Thank you for your attention

And my thanks to NIMH, NICHD, NIDA, the Spencer Foundation, CFI, & IES for funding our research.