Conclusions About Interventions, Programs, And Approaches for Improving Executive Functions That Appear Justified And Those That, Despite Much Hype, Do Not

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The Executive Functions (EFs) of inhibitory control, working memory, and cognitive flexibility enable us to think before we act, resist temptations or impulsive reactions, remain focused, reason, problem-solve, flexibly adjust to changed demands or priorities, and see things from new and different perspectives. Further, it is now clear that they can be improved at any age through training and practice. We predict that in addition to training EFs directly, the most successful approaches for improving EFs will also address emotional, social, and physical needs.

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The Executive Functions (EFs) of inhibitory control, working memory, and cognitive flexibility enable us to think before we act, resist temptations or impulsive reactions, remain focused, reason, problem-solve, flexibly adjust to changed demands or priorities, and see things from new and different perspectives. Moreover, it is now clear that they can be improved at any age through training and practice. However, despite claims to the contrary, wide transfer does not seem to occur and 'mindless' aerobic exercise does little to improve Efs. Since stress, sadness, loneliness, or poor health impair Efs (and the reverse enhances EFs), we predict in addition to training EFs directly, the most successful approaches for improving EFs will also address emotional, social, and physical needs.

- There has been great interest in improving EFs, accelerating their development, stopping or slowing their decline, and/or remediating deficits.
- Many different methods have been tried to improve EFs, including diverse types of computerised cognitive training, diverse physical activities as well as other things such as certain school curricula.
- EFs are predictive of achievement, health, wealth, and quality of life throughout life, often more so than IQ or socioeconomic status.

What are Executive functions (EFs)?

- Three, interrelated core skills: inhibitory control, working memory, and cognitive flexibility. From these, higher-order EFs are built such as reasoning, problem-solving, and planning.
- Inhibitory control involves acting more wisely instead of responding with an initial impulse or 'strong pull'

to do a certain thing.

- Inhibitory control makes it possible for us to choose how we react and to change how we behave rather than being ‘unthinking’ creatures of habit or impulse.
- Working memory (WM) involves holding information in the mind while performing one or more mental operations.
- WM is critical for reasoning and problem-solving, because they require the storage of copious amounts of information, exploring their interrelations, and then perhaps dis-assembling those combinations and re-combining the elements in new ways.
- Cognitive flexibility is the ability to adjust to changed demands or priorities—look at the same thing in different ways or from different perspectives.

Interventions, programmes, and approaches for improving EFs

- 84 studies met the inclusion criteria.
- Many different activities have at least one peer-reviewed published report on their efficacy in improving executive functions. These include computerised training, games, aerobics, resistance training, martial arts, yoga, mindfulness, theatre, and certain school curricula.

Conclusions that emerge from the various studies on different

methods of improving EFs

1. While EF training appears to transfer, it appears to be narrow.

- For example, computerised WM training improves WM but not self-control, creativity, or flexibility.
- Wide transfer to untrained cognitive skills has not been demonstrated in either cognitive or physical activity training.
- To see widespread benefits, diverse skills must be practiced. Accordingly, real-world activities such as martial arts and certain school curricula have demonstrated more widespread cognitive benefits than targeted computerised training.

2. Whether EF improvements are achieved depends on the amount of time spent practicing.

- Ericsson's (2006, 2009, 2010) conclusion about the critical importance of practice (with difficulty progressively increasing) for becoming really good at anything also appears to apply to improving EF skills, just as with every other skill Ericsson investigated.
- Longer duration of training (such as computerised cognitive training, mindfulness retreats, or physical activity) produced improved EF results.
- With regard to the duration of training, studies have indicated that the dose (length of each session) and frequency (how often the sessions occur) are significant and more time spent practicing is beneficial.

3. Whether EF improvements are achieved depends on the way an activity is presented and conducted.

- The personal characteristics of programme leaders can have a major effect on programme efficacy.

4. EFs should be continually challenged (not just used) to

produce improvements.

- To become an expert requires copious amounts of practice—not simply practicing what is easy, but continually pushing to go beyond one's comfort zone or current level of competence.
- Challenging one's comfort zone is consistent with what Vygotsky (1986) referred to as the 'zone of proximal development'. This is the zone just beyond what one accomplishes on one's own, but where success can be achieved with a little help from someone else.

5. Those with the poorest EFs consistently gain the most from any programme that improves EFs.

- Since those who start further behind on EFs tend to progress more from any EF intervention, EF training might reduce societal disparities.
- With extreme groups, such as children with very low IQs or adults with severe cognitive decline, cognitive training has not been shown to help.

6. Once practice ends, benefits diminish.

- While studies have demonstrated that EF benefits can last for months (or even years), they invariably reduce with time after training.

7. Often, differences between treatment and control groups only appear when participants' EF skills are pushed near to their limit.

- The largest differences between groups are consistently found on the most demanding EF tasks and task conditions.

8. Aerobic exercise (resistance training) without a cognitive component produces little or no EF benefits.

- Two meta-analyses of randomised control trials in mostly

older adults found little or no EF benefits from aerobic activity.
- Studies involving children have not found any EF benefits from aerobic activities.
- It has been consistently found that people who are more physically active and have better aerobic fitness have better EFs compared to those who are more sedentary.
- Exercise that includes cognitive challenges (such as Tae-Kwon-Do martial arts, soccer, or yoga) have exhibited greater improvement in EFs.
- Several school programmes integrate physical activity with the teaching of academic subjects, and studies indicate improved academic outcomes from these programmes compared to when academic subjects are taught traditionally (sitting still).

9. The reason why improvements are found is not always obvious and sometimes it can be counter-intuitive.

A different perspective based on the neurobiology of EFs and prefrontal cortex

- EFs depend on the prefrontal cortex and other neural regions with which it is interconnected.
- The prefrontal cortex is the newest and most vulnerable area of the brain.
- Since stress, sadness, loneliness, and poor health impair EFs. Accordingly, we predict the most successful approaches for improving EFs will directly train and challenge EFs while indirectly supporting EFs by working to reduce things that impair them and enhance things that support them.
- The main reason stress impairs EFs is because even mild stress overwhelms the prefrontal cortex with excess dopamine.
- The adrenal cortex releases cortisol in response to

stress, which can disrupt functional connectivity between the prefrontal cortex and other brain regions.

- People exhibit improved cognitive flexibility and creativity when they are happy.
- Our EFs suffer when we are lonely, whereas we exhibit improved EFs when we feel socially supported. Accordingly, feeling excluded or not belonging impairs prefrontal cortex functioning, selective attention, and reasoning.
- Lack of sleep impairs EFs.
- When people are infected, their prefrontal cortex does not function as well and executive functioning is of poorer quality.
- Feeling confident in your ability to succeed, believing that through effort you can improve, treating errors and failed attempts as learning opportunities (or what happens when you push past your comfort zone), and venturing beyond what you already know are important attributes for succeeding at many things. It is predicted this may also apply for improving EFs.