A Critical Review of Research on Executive Functions in Sport and Exercise

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Philip Furley[*a], Lisa-Marie Schütz[b], & Greg Wood[c]

[a]*German Sport University, Cologne, Germany*

[b]*University of Heidelberg, Germany*

[c]*Manchester Metropolitan University, UK*

* Corresponiding author: :

Philip Furley, German Sport University, Cologne. Institute of Training and Computer Science in Sports, Am Sportpark Müngersdorf 6, 50933 Köln, Germany or email (p.furley@dshs-koeln.de)

Abstract

The investigation of Executive Functions (EF) has become a trending topic of investigation in sport science. This critical review provides a comprehensive synthesis of the underlying theory and the typical methodology (and problems with the methodology) in the interdisciplinary study of EFs as it relates to the two most researched questions within the sports literature: 1) if the engagement in sports and exercise can enhance EFs; and 2) if and how EFs contribute to superior performance/expertise in sports. A critical evaluation on theoretical and methodological work on EF shows numerous problems on how to conceptualize and measure the EF construct. These problems within the basic research on EF seem to be widely overlooked in the sport literature and have contributed to ambiguous empirical evidence on the question if sport and physical exercise can be used to train EF. Similarly, the second question 'if EF contribute to superior performance in (some) sports' has also received inconclusive empirical support. We conclude by pointing out avenues for future theoretical and empirical work regarding the important topic of EF in sport and exercise.

Keywords: Cognition, Working Memory, Inhibition, Expertise, Cognitive Training, Brain Training

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The investigation of Executive Functions (EF) has become a trending topic in sport science, probably because EFs have been proposed to be important for successful performance in almost every domain of human life and sport and physical exercise have been argued to be promising activities to improve EFs (Diamond, 2013 for a review). Despite the increasing research interest on EF in sport and exercise, this field of research has provided highly ambiguous findings and the answers to fundamental questions on EFs in sport and exercise remain highly controversial.

Arguably, the most researched questions within the sports literature have been 1) if the engagement in sports and exercise can enhance EFs; and 2) if and how EFs contribute to superior performance/expertise in sports. Before we critically review the evidence base for these two broad questions, we will first argue that theoretical controversies and methodological issues have led to many misunderstandings and ambiguous findings on these two broad questions. Therefore, the central aim of this critical review is to provide a comprehensive review of the underlying theory, the typical methodology (and problems with the methodology) in the study of EFs as this literature is important to shed light on some of the controversies surrounding the research on EFs in sport and exercise and will likely help advance future research in this field. Given this overarching goal and diversity of studies covered in the present review, we adopted critical review methodology following the guidelines of Baumeister and Leary (1997; see also Furley & Goldschmied, 2021; Grant & Booth, 2009) instead of a systematic or meta-analytic form of literature review (Greenhalgh et al., 2018; Ioannidis, 2016). In contrast to previous literature summaries (e.g., Ludyga et al., 2020; 2022), the present critical approach attempted to zoom in on the theoretical background and overlooked methodological issues regarding the malleability of EF through sports and exercise (i.e., long term changes instead of cognitive effects of single bouts of sport or exercise) in a novel attempt to scrutinize some widely held beliefs in the literature that have resulted in overly optimistic media reports and applied interventions.

What are Executive Functions?

The term EF first appeared in the neuropsychological literature in the eighties (Lezak, 1982), after researchers had started to use the term ‘executive’ when describing both frontal lobe functioning (Pribram, 1973) and mental control over lower-level cognitive abilities (Baddeley & Hitch, 1974). EFs are assumed to play a central role in human thought and behavior. They are typically described as a family of cognitive processes that enable humans to pay attention in a goal-directed manner, focus attention on the task at hand, reason and solve problems, choose between alternatives, exercise self-control and discipline, avoid being impulsive, see things from a different perspective, take alternatives into consideration, relate different ideas to one another, reflect on past occurrences, consider an imagined future, and update and adjust oneself flexibly to new information (Jacques & Marcovitch, 2010; Diamond, 2013).

EFs are assumed to engage when behavior must be adjusted to novel, unanticipated circumstances and humans cannot rely on their automatic, instinctive or intuitive response tendencies. That is why EFs are often described as effortful. The interest in EFs arises from the fact that they are necessary for complex, intelligent behavior and humans have a limited capacity in their EFs, which is why individual differences in EFs have been shown to be highly correlated with academic achievement and life outcomes (Katz et al., 2018). In the literature, often three core EFs are distinguished from one another: Working memory (WM), inhibitory control, and cognitive flexibility (Diamond, 2013).

WM can be defined as the cognitive mechanisms capable of retaining a small amount of information in an active state for use in ongoing tasks (Baddeley, 2007; Baddeley & Hitch, 1974;

Conway et al., 2007; Cowan, 1995; Miyake & Shah, 1999). Hence, WM is of central importance to understanding cognition as it occurs in everyday life and scholars have attributed an important evolutionary advantage to species possessing the capacities of WM (Carruthers, 2013; Engle, 2010). The most important advance of the WM model was the proposal of a system not only responsible for the storage of information but also for mechanisms of cognitive control and attention (Baddeley & Hitch, 1974; Baddeley, 2003) which made the model applicable to complex behavior.

Inhibitory control involves self-regulation by controlling one's attention, thoughts, and emotions. Typically, this involves overriding impulses resulting from internal or external stimulation and instead adjusting behavior in an intentional, goal-directed manner (Simpson et al., 2012; Diamond, 2013; Watson & Bell, 2013). Sometimes inhibitory control is further subdivided into response inhibition, which is sometimes also referred to as self-control and interference control (Diamond, 2020). Self-control or response inhibition is about suppressing a dominant response tendency where it is not appropriate and executing a more appropriate behavior. Interference control is more about controlling one's thoughts and attention in a goal-directed manner. Without the capacity of inhibitory control, humans would be 'at the mercy' of external and internal stimulation, like old habits or instincts (Diamond, 2020).

The third core EF is cognitive flexibility and refers to the ability to flexibly switch between different mind sets or tasks and taking a different perspective on matters. Another aspect of cognitive flexibility is to quickly and flexibly adjust to new information and changing circumstances. It is assumed that cognitive flexibility builds on working memory and inhibitory control and therefore develops later (Diamond, 2013). In addition, it is believed to show much overlap with creativity and prevents human behavior from being rigid.

Figure 1. Executive Functions Model based on Diamond (2013)

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The core executive functions—WM, inhibitory control, and cognitive flexibility—are theoretically assumed to underpin higher-order EFs such as reasoning, problem solving, and planning (Collins & Koechlin, 2012) which together comprise fluid intelligence. It seems intuitive that almost every aspect of human life would benefit from the capacity to adjust one's behavior flexibly and appropriately to the demands of the situation instead of behaving impulsively in a rigid manner. For this reason, EFs have been called the 'cognitive toolkit for success' (Hendry et al., 2016) in various domains. Hence it is not surprising that there is substantial interest in improving and measuring EFs with a variety of methods.

Controversy on the Conceptualization of the EF Construct

Whereas pioneering EF scholar Adele Diamond (2013, p. 136) suggests that "there is general agreement that there are three cores EFs" (WM, inhibition, and cognitive flexibility) that constitute the core building blocks of higher-order EFs such as reasoning, problem solving, and planning, other scholars disagree with this component or modular view of EFs (e.g., Barkley, 2012; Baggetta & Alexander, 2016; Karr et al., 2018). About 20 years ago, over 33 definitions for executive functions had already been suggested (Eslinger, 1996). A recent literature review (Packwood et al., 2011) identified vast amounts of disagreement in commonly used tests and labels with about 68 subcomponents of executive function (that could arguably be reduced to 18 sub-components after accounting for semantic and psychometric overlap between terms). According to a recent systematic review (Karr et al., 2018), the terms most frequently encountered in the literature to label EF include planning, WM, fluency, inhibition, and set-shifting (see also Packwood et al., 2011). However, this just means that these terms occur frequently in connection with EFs in the literature and not that there is general consensus. Hence, even after years of research the exact number of constructs rightfully labeled EFs remains largely unknown (Karr et al., 2018).

As going into the details of this debate is beyond the scope of the present review, we will only briefly refer interested readers to literature supporting competing views on how to conceptualize EFs. Although, this debate has gone on for decades, there is still no consensus. Nevertheless, most definitions and conceptualizations describe EFs as a multidimensional construct (Barkley, 2012; Baggetta & Alexander, 2016; Jurado & Rosselli, 2007). A large body of literature has been summarized as the unity-but-diversity view and suggests that EF consists of related but separable components (e.g., Anderson et al., 2001; Asato et al., 2006; Bull & Scerif, 2001; Hughes, 1998; Huizinga et al., 2006; Lehto et al., 2003; Miyake et al., 2000; St. Claire-Thompson & Gathercole, 2006). Other research raises concerns regarding the modularity conceptualization of EFs (Bernstein & Waber, 2007; Wiebe et al., 2008) as latent variable analysis revealed that different subcomponents of EFs are very highly correlated and loaded onto one distinct latent variable.

A recent comprehensive analysis (e.g. Karr et al., 2018) summarized the primary literature as providing some evidence for greater unidimensionality of EFs among child/adolescent samples and both unity and diversity among adult samples. The authors raise caution as they found low rates of model acceptance/selection which likely suggests bias towards the publication of well-fitting, but potentially non-replicable models with underpowered samples.

Neurobiological Correlates and the Plasticity of Executive Functions

Early neuropsychological studies, (e.g., Luria, 1966; Stuss & Benson, 1984) have suggested that the prefrontal cortex (PFC) plays a critical role in EFs. Without going into detail, EFs have been shown to depend primarily on the prefrontal cortex and interconnected brain regions like the anterior cingulate cortex and parietal cortex (Braver & Barch, 2002; Petrides, 2005; Aron, 2007; McTeague et al., 2017). Pertinent to the present review, the prefrontal cortex is not only the brain region that has evolved most recently, but also the brain region that takes the longest to fully mature, until the early to mid 20s (Fuster, 1997; Luna et al., 2004; Waxer, & Morton, 2011). Of further importance, the prefrontal cortex has been described as the most plastic brain area. This is supported by evidence showing that the prefrontal cortex, and the EFs that depend on it, are substantially affected by environmental factors like stress or social isolation (Baumeister et al., 2002; Cerqueira et al., 2007; Cacioppo & Patrick, 2008; Arnsten et al., 2015; Hackman et al., 2015; Harms et al., 2018). In addition, a growing body of research claims that it is possible to improve EFs throughout the lifespan via different pathways, for example via physical exercise or sports (Kramer et al., 1999; Diamond et al., 2007; Kovács & Mehler, 2009; Diamond & Lee, 2011; Wass et al., 2011; Röthlisberger et al., 2012; Tennstedt & Unverzagt, 2013; Stepankova et al., 2014; Gothe & McAuley, 2015; Schonert-Reichl et al., 2015; Lind et al., 2018; Diamond & Ling, 2020). Before going into more detail of this literature, it seems necessary to describe the typical development of EFs.

Development of Executive Functions

As noted earlier, EF development seems strongly correlated to PFC development and has generally been described to involve both progressive changes like neuron proliferation, synaptogenesis, myelination, and regressive changes like cell death and synaptic pruning changes (Casey et al., 2006; O'Hare & Sowell, 2008). During normal EF development both progressive and regressive changes have been shown to occur concurrently, driven by both genetic and experiential factors to create an efficient neural network supporting EF (O'Hare & Sowell, 2008).

Although the prefrontal cortex takes about twenty years to fully develop, this does not mean that EFs are absent or hardly developing during early developmental stages. To the contrary, evidence shows that the prefrontal cortex develops rapidly during early infancy (Hodel, 2018) and that initial levels of prefrontal function are important for good cognitive functions across the life span (Lövdén et al., 2020). In the first two years of development the prefrontal cortex begins to organize and direct further cortical developments and connections throughout the brain (Hodel, 2018 for a review). Starting with the early work of Piaget about 80 years ago (Piaget, 1954) a growing body of research (Diamond, 2020 for a recent review) shows how goal-directed behavior (i.e. executive or intentionally controlled) starts to develop in early infancy. Of further importance, correlational studies point to experiential effects on EFs during early infancy: e.g., benefits of bilingual exposure (Kovács & Mehler, 2009) or debilitative effects of early life stress (Hostinar et al., 2012). Two-to-three-year-old children are typically described as cognitively rigid and inflexible which has been linked to their stage of brain maturation. Substantial improvements can be seen in the transition from about three to five years (Diamond, 2020). EFs have been shown to substantially improve during the early school years (Krikorian et al., 1994; Anderson et al., 1996) and continue to improve gradually through adolescence (Best & Miller, 2010; Best et al., 2009; Welsh et al., 1991; Krikorian et al., 1994).

Beside evidence showing a protracted development and late maturation, EFs have further been shown to be highly vulnerable to age-related decline (Dempster, 1992; Jurado & Rosselli, 2007). Research has suggested that around the age of 60 years, old adults show impairments on a variety of tasks that require EFs like measures of attentional control, response inhibition, planning, WM, set shifting, and verbal fluency (Bäckman et al., 2006; Jurado & Rosselli, 2007; Rhodes, 2004). Regarding the neural correlate of EF deterioration research suggests that this is most likely due to selective cell loss, dendritic deterioration, and chemical dysregulation in the PFC and hippocampus that is characteristic of normal aging (Burke & Barnes, 2006). Interestingly, non-executive cognitive measures like procedural memory, vocabulary, and numeric abilities are hardly affected by aging (Basak et al., 2008; Jurado & Rosselli, 2007).

The Measurement of Executive Functions

One of the many hotly debated aspects of EFs is how to measure these and which component(s) of EFs a task requires (e.g., see, for example, MacLeod et al. [2003] on the Stroop task and Roberts & Pennington [1996] on the antisaccade task). EF tests have a reputation for task impurity—this means that many other factors besides EFs explain performances on tests purported to measure EF (Burgess, 1997; Miyake & Friedman, 2012; Phillips, 1997).

> It is always important to remember that any test or assessment is an imperfect indicator of the underlying ability it is intended to assess. […] Low scores on any assessment measure can be obtained for any number of reasons other than a problem with the ability one intended to assess. […] Almost no EF measure requires only one EF. A child might fail a WM task because of problems with inhibitory control (not WM), fail an inhibitory control task because of WM problems, or fail a cognitive flexibility, planning, or reasoning task because of problems with inhibitory control or WM. (Diamond, 2020, p. 221).

Most objective measures of EFs use laboratory-based measures or computer-based methods that are relatively remote from everyday life. Another commonly used method amongst children are parent and teacher rating scales that are typically more subjective and potentially biased (see online appendix for a list of measures for children and adolescents). However, these have the advantage to be more related of everyday life. Other behavioral measures like Mischel's delay of gratification task have also been used as a pointer to children's' EFs, but recent research has shown that performance on these behavioral tasks are affected by various other factors besides EFs (Callan et al., 2009; Michaelson et al., 2013; Michaelson & Munakata, 2016). Hence, it seems to be a fair assessment that the measurement of EFs, also in relation to the developmental stage the study participants are in, remains a huge issue.

Frequently Used Measures of EF.

This list is not intended to be a comprehensive list to the numerous EF measures that have been used but is limited to frequently used behavioral measures of core EFs amongst adults that have been used in the sports literature (see online appendix for a list of measures for children and adolescents).

Inhibitory Control. Psychological measures of inhibitory control include the Stroop task (e.g., MacLeod et al., 2003), Simon task (Hommel, 2011), Flanker task (Eriksen & Eriksen 1974, Mullane et al., 2009), antisaccade tasks (Munoz & Everling, 2004), delay-of gratification tasks (Kochanska et al., 2001, Sethi et al., 2000), go/no-go tasks (Cragg & Nation, 2008), and stop-signal tasks (Verbruggen & Logan, 2008).

Working memory. Complex span tasks (e.g., counting span or operation span (Conway et al. 2005) have often been used to assess WM. However, a problem with these tasks is that the typically require more subcomponents of EFs and have therefore been described as EF measures rather than WM measures (Diamond, 2013). Another common measure of WM are N-back tasks, although they also have the problem of requiring other EF subcomponents. Digit-span tasks that require reordering of items compared to the presented order are also common WM measures. A widely used measure of visual-spatial WM is the Corsi Block test (Lezak, 1983). Plenty of computerized versions of WM tasks (including the Corsi and various digit span tasks) exist, e.g. the Automated WM Assessment (AWMA; Alloway 2007, Alloway et al. 2009), the CANTAB battery battery (Luciana & Nelson 2002).

Cognitive Flexibility. Tasks measuring cognitive flexibility includes design fluency (also called the unusual uses task), verbal fluency, and category (or semantic) fluency (Baldo et al. 2001; Baldo & Shimamura 1997; Chi et al. 2012). Another family of tasks used to measure cognitive flexibility are task switching and set-shifting tasks like the Wisconsin Card Sorting Task (Milner, 1964, Stuss et al., 2000). Today many alternative task-switching paradigms have been developed and have been used to assess cognitive flexibility (e.g., Monsell, 2003; Wylie & Allport, 2000; Zelazo et al., 2013).

Factors affecting Performance on EF Measures

As indicated earlier, performance on EF measures can be affected by many more variables than an individual's actual EF ability. Research has shown that performance on EF measures declines when an individual is stressed (Arnsten, 1998, Liston et al., 2009, Oaten & Cheng, 2005), sad (Hirt et al., 2008, von Hecker & Meiser, 2005), lonely (Baumeister et al., 2002, Cacioppo & Patrick, 2008, Campbell et al., 2006, Tun et al., 2012), sleep deprived or tired (Barnes et al., 2012, Huang et al., 2007), or not physically fit (Best, 2010, Chaddock et al., 2011, Hillman et al., 2008). In addition, it has been argued that performance on EF tests is affected by placebo (Foroughi et al., 2016) and experimenter/Rosenthal effects (Jussim, 2017). That is, certain expectations by either the test taker or the person administering the test have the potential to affect the test score. Further variables like the motivation or task commitment of the test taker or a person's self-efficacy have also been argued to be variables that are likely to affect a person's test score (Furley et al., 2016). Hence, there is plenty of evidence and logical reasons to believe that a person's EF scores will be influenced by many variables besides their EFs.

The use of EF measures in sports.

We do not seek to be comprehensive with regard to the EF tests that have been employed in contemporary research in sports but focus on some of the most commonly used ones to illustrate apparent issues with the use of these tasks in the context of sports. The goal is not to criticize the use of these tasks per se, but rather to highlight the limits on their utility of using these tasks as dependent measures in sports.

Within the current debate on the crisis of confidence in psychology, which mainly refers to the fact that many findings within psychology do not replicate (Camerer et al., 2018; Open Science Collaboration, 2015), it has further been stated that psychology but also kinesiology suffer from an implausibly high positive result rate. Studies have shown that high-ranking journals in the respective disciplines exceed a positive result rate of 80%. In other words, 80% of the studies that were published were able to confirm their hypotheses (Twomey et al., 2021; Scheel et al., 2021). Compared to other publication formats such as registered reports, which show a positive result rate of 46%, the positive result rate of traditional articles is unusually high (Scheel et al., 2021). It would therefore be desirable to find registered reports on the topic of EF in sport and exercise in addition to traditional articles. Moreover, psychology suffers from a validation crisis (Schimmack, 2010, Schimmack, 2021). In this respect, Schimmack (2021) has noted that everybody would probably agree that good science requires valid measures. However, a critical assessment of the psychological literature indicates that many highly popular and frequently used measures in psychology have not been validated adequately (Schimmack, 2021).

In our opinion this critique applies well to the domain of EF. For example, a recent highly powered study (overall $N = 2{,}641$) comparing various measures that have all been used as proxies for an individual's core EF of inhibition (the Self-Control Scale, the Stroop, and Flanker task; (Saunders et al.,2018) suggested little-to-no relationship between self-reported measures and performance on the Stroop and Flanker tasks, which have been argued to measure the same psychological constructs.

Cremen and Carson (2017) have highlighted additional concerns regarding the use of behavioral response inhibition (e.g., Stroop or Flanker) tasks in the field of sport and exercise due to the motor component of these tasks. They, convincingly argue and report evidence showing that alleged improvements in people's cognitive capacity of inhibition due to sport/exercise participation is likely due to a shared motor component of the cognitive task and the physical activity intervention and not due to improvements of an individual's core EF (that per definition is divorced from motor influence). "Thus, when drawing inferences on the basis of the flanker task, and indeed response inhibition tests more generally, it is necessary to recognize that motor function is central to their interpretation" (Cremen & Carson, 2017, p. 3). Hence, it seems necessary to control for reaction times and movement times when using these tasks as measures for EF improvements.

Without going into more detail here, the authors make similar arguments of other frequently used core EF measures that have only been validated to distinguish between pathological and healthy conditions and are therefore not valid to measure enhancements of EFs through sport and exercise interventions. For example, the Delis-Kaplan test batterie (D-KEFS; Delis et al., 2001) has frequently been used in the context of sport and exercise (Vestberg et al., 2012, 2017, 2020), which has only been validated as diagnostic of clinical disorders and has been criticized based on its psychometric properties (Baron, 2004; Schmidt, 2003). A recent review study (Nyongesa et al., 2019) on the psychometric robustness of commonly used EF measures (with a focus on their use in adolescents) also raised questions regarding the validity and reliability of the measures used. Of the 705 studies included in the systematic review only 48 studies even reported on aspects of reliability or validity, and over half of these studies that reported on psychometric properties utilized self-report scales. The authors conclude from their review “that there is just not enough validity and reliability data to support the use of measures of EF” (Nyongesa et al., 2019, p.149). While a similar argument has been made regarding the use of EF tests in the field of sport and exercise, we are not aware of much research that has explicitly targeted validity and reliability of EF tests in the context of sport. One recent exception (Finkenzeller et al., 2021) with the title “The design fluency test: a reliable and valid instrument for the assessment of game intelligence?” has zoomed in on this question by investigating psychometric properties of a commonly used test in the sport literature. In general, the psychometric properties were disappointing and based on test-retest reliabilities (ranging from (-0.08 to 0.72) the authors concluded that “… the findings on test–retest reliability indicate that the design fluency test cannot be recommended for application in sports” (Finkenzeller et al., 2021, p. 146).

The Effects of Experience, Training, and Practice on EF

A common belief is that ‘practice supposedly makes perfect’. However, it is less clear if practice also leads to tangible improvements in skills or even abilities that are not directly trained? Given findings that suggest that EFs are critically correlated with success in desired outcomes in life, like academic achievement, mental health, social functioning, and well-being it is not surprising that there have been substantial efforts in trying to improve and train EFs via a variety of methods in various domains. However, findings on the effectiveness of these endeavors remain equivocal (Diamond & Ling, 2020; Redick, 2019; Titz & Karbach, 2014). While some scholars appear very optimistic and have no doubt that EFs can be improved via training (Diamond, 2013; Diamond & Lee 2011; Klingberg 2010) others are more skeptical (Katz et al., 2018; Moreau, 2022; Simons et al., 2016). Beside the theoretical and methodological problems regarding the construct of EF, one of the main reasons for this controversy is that it is difficult to judge whether interventions are effective above and beyond the influence of confounding factors (Diamond & Ling, 2020). Recent methodological advances have suggested that controlling for several confounding factors to detect "true moderate effect sizes" requires impractically large sample sizes (Westfall & Yarkoni, 2016). A related problem is that typical studies in this field of research test participants on a large number of EF tests but are usually very far from the sample sizes needed to conduct multiple comparison corrections. In addition, the controversy in this field of research is surely also affected by what has been termed "motivated reasoning" (Lord et al., 1979) which scientist are also affected by: "If they have strong beliefs or motivations inconsistent with the results of the study, they are easily able to find flaws. But when they wish to believe a finding, the flaws are less visible" (Katz et al., 2018, p. 9902).

Brain Training

The "brain-training industry" has grown to a multibillion Dollar market that capitalizes on the human tendency of trying to self-improve and is estimated to have a net worth of more than $8 billion by 2021 (Ahuja, 2019; Harris et al., 2018). Especially in sports, "brain training programs" are promoted to enhance performance. Bailey et al. (2018) revealed that non-evidence-based-ideas regarding the brain and "neuromyths" have a high prevalence among sport coaches, which could influence coaching philosophy or practice. Despite this growing popularity, the evidence base of this field remains poor (Katz et al., 2018; Smid et al., 2020; Harris er al., 2018). "A cursory study of news articles seems to reveal a new "brain-training works" or "brain-training doesn't work" headline every single week (Katz et al., 2018, p. 9897). Comercial cognitive training programs suggest scientific proofen benefits for basic cognitive tasks. However, scientific approaches to the subject show that "[…] there is a gulf between scientific findings and marketing claims" (Harris et al., 2018, p. 14), and companies like Lumosity had to pay millions in settlement fees for misleading advertising after research had shown (Kable et al., 2017) that the advertised brain training did not result in the promised effect (Ronson, 2017).

Recent literature reviews conclude that there is general consensus that training activities can impact closely related domains (near transfer), but it remains very unclear if these training activities can lead to improvements in loosely related domains (far transfer; Diamond & Ling, 2020; Harris et al., 2018). In three large-scale analyses, Sala and Gobet (2017, 2019; Gobet & Sala, 2022) dispute the existence of transfer effects after cognitive training like WM training. More specifically they suggest that the evidence shows that cognitive training does not enhance general cognition. In addition, they reveal substantial flaws and methodological shortcomings in the literature and show that effect sizes in favor of transfer effects are inversely correlated with the quality of the study. On the other hand, another meta-analysis that adopted a broader inclusion approach regarding the cognitive-training interventions (e.g., EF training, classroom-based and game-based activities) did report evidence for far transfer across several domains (literacy, numeracy, language skills, IQ, and psychosocial outcomes; Smithers et al., 2018).

Several review papers, that all agree upon the methodological limitations of the primary research in this field (Harris et al., 2018; Katz et al., 2018; Moreau, 2022; Simons et al., 2016) come to the conclusions that there is some evidence for near transfer, but that far transfer may not be possible or at least that there is no evidence for this: “Specifically, I suggest that the purported cognitive improvements elicited by many interventions are not reliable, and that their ecological validity remains limited.” (Moreau, 2022, p. 1). Katz et al. (2018) also caution about the interpretation of finding improvements in EF measures due to some kind of intervention as these could have little to do with the actual intervention and—as discussed in the methodology section of the paper—could reflect other variables like positive mood, motivation, or a placebo effect.

The Effects of Sport and Exercise on EFs

In a much-cited review article, Diamond and Lee (2011) concluded optimistically that sport and exercise improved prefrontal cortex function and EFs. However, in 2019, Diamond and Ling (2019) seem far less optimistic about the effects of sport and physical exercise which becomes evident in the title of their paper “aerobic-exercise and resistance-training interventions have been among the least effective ways to improve executive functions of any method tried thus far”. This also shows in the title of a similar commentary article of Diamond (2014) “Whether coordinative (soccer) exercise improves executive functioning in kindergarten children has yet to be demonstrated”. However, Diamond and Ling (2019) emphasize that these provocative titles are not saying that physical activity does not benefit EFs, since they do think there is reason to hypothesize this, but they are saying that interventions used to try to prove that have generally produced disappointing results. As in the previous sections there again seems to be plenty of controversy and ambiguous results regarding the effects of sports and exercise on EFs. Opposing positions in the dispute are nicely summarized in Hillman et al. (2018) and Diamond and Ling (2019).

In the next sections, we will review the existing primary evidence on the effects of different forms of sport and exercise across various age groups. A large body of research has targeted child and adolescent populations as neuroscientific research has suggested that this developmental window poses a great opportunity for experience-dependent brain plasticity (Giedd et al., 1999) and it has been argued that the structural and functional organization of the brain can be positively influenced through sport and physical activity (Kobilo et al., 2011). This line of reasoning has led researchers to propose that sport and physical activity in early childhood and adolescence will enhance EFs, and, in turn, positively influence school and academic achievement (e.g., Singh et al., 2019). This claim has also been used as a 'sales pitch' to promote physical education classes in schools (Dalziell et al., 2015; Kubesch, 2008; Kubesch, & Walk, 2009; Kubesch et al., 2009; Van der Niet et al., 2014), physical activity breaks (Egger et al., 2019; Van den Berg et al., 2019) and classroom-based physical activity (Have et al., 2018; Vazou & Smiley-Oyen, 2014) and is therefore found in the curricula of various educational institutions around the world (Singh et al., 2019 for a review). Unfortunately, the evidence base for this claim is less clear than it is often portrayed both in the scientific literature and the media.

Various studies and reviews have been published on this topic in the past two decades (e.g., Alvarez-Bueno et al., 2017; Castelli et al., 2014; Donnelly et al., 2016; Hillman et al., 2008; Sibley & Etnier, 2003; Singh et al., 2012; Vazou et al., 2019) and have widely concluded that sport and physical activity is positively associated with cognition, brain health, and academic performance. However, these summarizing reports were not very critical about the quality of the primary evidence that apparently backed up this conclusion. This was agreed upon by an expert panel (Singh et al., 2019) who revisited the primary evidence (including 58 studies) in an attempt to critically evaluate the methods used in this field of research in an attempt to come up with an expert panel statement. The short version of the statement reads: “there is currently inconclusive evidence for beneficial effects of PA interventions on cognitive and overall academic performance. […] … more ’high-quality’ research is warranted” (p. 640). Another systematic review on the subject confirms the controversy surrounding the positive relationship between sport and academic achievement, but shows that an increased curricular emphasis on physical education at the expense of other subjects does not seem to hinder overall academic achievement (Trudeau & Stephard, 2008). Apart from the controversy surrounding a positive relationship or beneficial evidence, Singh et al. (2019) also confirms that none of the studies examined report a negative effect of sport on cognition or academic performance.

In the largest systematic review including 179 studies on EF interventions, Diamond and Ling (2020) critically evaluated all peer-reviewed published (in English) intervention studies that had at least one objective EF outcome measure, had at least eight people per group, included a control group, and compared EF improvement and/or posttest performance in the experimental and control groups. In addition, the research design had to be experimental and not correlational and the intervention had to include more than one single session. Further, the study did not include clinical groups (e.g., brain damage or dementia) and the focus was on typically developing participants. Based on this analysis, the authors came to the conclusion that exercise interventions and resistance training were the least effective methods for improving EFs of any method tried. Nevertheless, this does not mean that there was no evidence for sport and exercise interventions. In their review they found that 43% of the studies on aerobic exercise interventions and 22% of resistance training studies found at least suggestive evidence that these interventions improved EF from pre- to post-test. They define suggestive evidence as greater improvement or better EF performance than the control group on at least 50% of the EF measures used in the study. However, when using stricter criteria as to what counts as evidence (i.e., more EF improvement and better EF post-test performance than control group on ≥67% of measures) they only conclude that 7% of the exercise studies and 0% of the resistance training studies provide evidence that these interventions improve EFs. The authors emphasize that these findings should not be interpreted in the way that sport and exercise do not have positive effects on cognition and mental health in general, but that experimental evidence for benefits on EFs is very weak and have generally shown “disappointing results” (Diamond & Ling, 2019. p. 1). This finding stands in strong contrast to much of the hype in the popular press and even some influential reviews in high-profile journals, that claim that sport and exercise consistently improve EFs. Diamond and Ling (2020) mention that results are slightly better for aerobic exercise with more cognitive or motor-skill challenges (e.g., sport games like basketball), suggesting that the type of intervention might be of importance (we will return to this point later).

On the one hand, there are many correlational findings, suggesting that people who are more physically active and have better aerobic fitness have been found repeatedly to have better EFs than those who are more sedentary (in children: Fedewa & Ahn, 2011; Gapin & Etnier, 2010; Hillman et al., 2005; Scudder et al., 2014; Sibley & Etnier, 2003; in older adults: Boucard et al., 2012; Chang et al., 2012; Colcombe & Kramer, 2003; Voelcker-Rehage et al., 2011; at all ages: Etnier et al., 2006; Prakash et al., 2015). This might suggest that there may be EF benefits from sport and physical activity that experimental studies have not been capturing. A further explanation for the discrepancy between experimental and correlational findings might be due to one or more other variables: e.g., potentially people who are more physically fit tend to eat better or are healthier in general. In addition, there is evidence showing that aerobic exercise improves mood (Khatri et al., 2001; Lane & Lovejoy, 2001; Williamson et al., 2001) and/or helps people sleep better (Foti et al., 2011; Loprinzi & Cardinal, 2011). As all these variables have been positively linked to EF (e.g., Borges et al., 2013; Hirt et al., 2008), it seems likely that some of the correlational variance between physical activity and EF is explained by confounded variables.

Another line of research worth discussing here are studies that show structural and functional brain changes in areas correlated with EFs as an effect of physical activity and sports (Donnelly et al., 2016; Mehren et al., 2019; Weinstein et al., 2012; summarized in Hillman et al., 2019). Some authors have argued that an effect on the brain is relevant to EFs, because EFs depend on prefrontal cortex (PFC) and other interrelated neural regions. However, we agree with Diamond and Ling (2019) that it is not warranted to conclude that an intervention that produced a change in PFC or other interrelated structures, necessarily improves EFs: "It is a basic and important principle that brain changes should not be over-interpreted as ipso facto indicating cognitive improvements" (p. 3). Hence, we consider it vital that improvements in EFs need to be empirically demonstrated since many intervention studies (e.g., Chaddock-Heyman et al., 2013; Rueda et al., 2005) showed changes in neural activity with no discernible improvement in EFs. There are many reasons for this dissociation: the brain changes might not be beneficial (e.g., Poldrack, 2015), they might not be substantial enough to affect EFs, or the change might not be relevant to improve EF, to just name a few.

Finally, Diamond and Ling (2019) also mention the possibility that the causality between sport or physical activity and EF might go in the opposite direction contributing to the positive correlation between these two variables. That is, a person that exercises regularly or plays sports on a regular basis likely needs good self-control capabilities like inhibitory control to avoid sedentary behavior and engage in more effortful physical activity (see Cheval et al., 2020, 2021a, 2021b). Similarly, it has been suggested that demands of some sports, especially team-sports like soccer or basketball require high EF functioning. Hence, it has been suggested that expert team sport athletes will likely also have superior EFs either via a selection process (i.e., athletes with good EF are more likely to be selected for teams and persist in in the effortful training activities) or via the training effects (i.e. the frequent exposure to the training demands within the sports improve the EFs). The model of physical activity adoption and maintenance also supports this assumption. It assumes that if explicit processes (e.g. self-regulation, executive functions) are high, physical activity can be maintained even against "negative" implicit processes (e.g. habit, affect or the impulse to rest on the couch). In other words, when self-control or EF are high (explicit processes), implicit processes can influence but not overpower them (Strobach et al., 2020). In the next section, we will review the evidence on the relationship between EFs and sport performance.

EF and sport performance.

Research has not only investigated if sport and exercise have the potential to improve EFs but has also suggested that success in sports is associated with superior EFs. The logic behind this research typically goes something like this: Playing sport at the highest level requires a wealth of cognitive functions such as attention, decision making, and WM to be functioning at optimal levels in highly challenging environments. As EFs have been linked to all of these facets of behavior, the most successful players should also test high on EF measures. Initially, this line of reasoning seemed to have been supported by several empirical studies.

A first study that got a lot of media attention (Vestberg et al., 2012) reported that professional soccer players had higher scores on a standardized measure of executive functioning

(D-KEFS; Delis et al., 2001) than lower level soccer players and a standardized norm population (tested several decades ago). Intriguingly, test scores of the professional soccer players were also predictive of the goals scored and assists of the tested soccer players two years later (based on a partial correlation of the square root of the goals/assists and the test scores). These findings led the authors (Vestberg et al., 2012, p. 1) to suggest that "many of the required skills in team sports may be translated to general cognitive domains where test results can be compared to a population norm. A good team player could be characterized by excellent spatial attention, divided attention, WM, and mentalizing capacity."

Although the same group of authors (Vestberg et al., 2017, 2020) and others (Romeas et al. 2016; Huijgen et al., 2015; Verburgh et al., 2014) claim to have found further evidence for a positive relationship between EF and success in elite sports, we consider the evidence for this relationship weak as it depends on low sample sizes, does not control for multiple statistical tests and only finds significant differences on a few EF tests. Not surprisingly, other studies fail to find such association and come to the conclusion that EF are not associated with superior performance in sports (Beavan et al., 2020a, 2020b; Furley & Memmert, 2010).

However, meta-analytical evidence (Kalen et al., 2021; Scharfen & Memmert, 2019; Voss, et al., 2010) on the sport/EF relationship (among other cognitive measures) find small-to-medium effects indicating that expert athletes perform better compared to non-expert or novice groups on measures of Efs. Yet, one of our central points here is that methodological flaws and measurement problems have been a great issue in the primary studies that have fed into the meta-analysis. In addition, Furley and Memmert (2011) have pointed out that publication bias is an important phenomenon when attempting to draw conclusions on the relationship of sporting success and EFs. According to Riniolo (1997), publication bias is defined as the increased likelihood of publishing a manuscript reporting statistically significant—e.g. differences between expert and novice athletes—rather than non-significant results. Publication bias is caused by both a submission bias which occurs before the review process and a selection bias that occurs during the review process (Cooper et al., 1997). Evidence for this phenomenon has not only been found in psychology but also in medicine and biology (Sterling et al., 1995; Cumming et al., 2007). As a result, publication bias can be responsible for an effect in the literature which actually does not exist, or for distorting the effect size in the literature (Rosenthal, 1979). Besides the well-documented problem of publication bias with meta-analysis many more problems with this technique have become evident in recent years leading to meaningless and misleading conclusions (Simonsohn et al., 2022). Therefore, the small-to-medium effects in the meta-analytic evidence may actually represent a much smaller effect or no effect at all as the primary literature is distorted due to publication bias and low quality primary research which is meaninglessly averaged in meta-analyses.

Publication bias might be the reason for a significant effect in the meta-analysis (Kalen et al., 2021; Scharfen & Memmert, 2019; Voss, et al., 2010) but this phenomenon cannot explain why some studies find an effect of sport expertise e.g. on executive functions (e.g. Vestberg et al., 2012, 2017, 2020) whilst other studies fail to find such an effect (Beavan et al., 2020a, 2020b; Furley & Memmert, 2010). A potential alternative explanation for significant effects of sport expertise on EFs might again be confounding variables associated with sport expertise. An important confounding variable that requires careful attention when studying the relationship of sport and cognition is health related variables like physical fitness, as we have argued in the section before. For example, aerobic fitness, sleep quality, a healthy diet, positive mood have all been shown to correlate with EF and these (arguably) also correlate with successful sport performance.

Hence, it again seems feasible that a positive relationship between EF and successful sport performance might be explained by such confounding variables. In addition, the typical between-group design employed in this line of research bares the risk for further alternative explanations for potential group differences between high-level athletes, and low-low level athletes or novices (Furley et al., 2016). For example, experimenter effects (Jussim, 2017) could be a problem if elite athletes are treated differently during the tests compared to novice participants. Also, elite athletes might be more ambitious to perform well in these cognitive performance tests compared to novice control groups.

Unfortunately, experimental evidence is unavailable and hard to optain in determining the role of EF in sport performance. However, improvements in the primary research—e.g. increased statistical power, better control of confounds, longitudinal designs—would allow to gain a better understanding on the relationship between EF and sport performance, potentially by using novel analytic techniques from the big data movement like the directed acyclic graph (DAG; Shrier & Platt, 2008).

Discussion

The central aim of this critical review was to provide a comprehensive review of the underlying theory and the typical methodology (and problems with the methodology) in the interdisciplinary study of EFs as a basis for assessing the evidence on the two most researched questions within the sports literature: 1) if the engagement in sports and exercise can enhance EFs; and 2) if and how EFs contribute to superior performance/expertise in sports. Theoretical and methodological work on EF shows little consensus on how to conceptualize and measure the popular EF construct. These problems within the basic research on EF have spilled over to applied fields like sport and exercise psychology as the literature review on the question if sport and physical exercise can be used to train EF has yielded inconclusive results. Similarly, the second question related to if EF contribute to superior performance in (some) sports has also received inconclusive empirical support.

There has been quite a hype regarding the prospect that sports and physical exercise have the potential to improve EF which in turn will positively affect performance and well-being in other domains. This hype has led to sport programs and even PE classes to be advertised as methods to improve children's (e.g., Kubesch & Walk , 2009) and adult's EF (e.g., Kubesch, 2008). However, a critical look at the scientific evidence shows a dissociation between the entire evidence base and claims made in individual studies or press releases. This discrepancy between scientific evidence and press releases has been reported to frequently occur (Sumner et al., 2014) and poses an important problem when translating science into evidence-based practice. Additional evidence showing that most readers gloss over the details and focus on the main claim when reading about scientific studies (Norris et al., 2003) might contribute to the problem that some popular beliefs in the public are not backed up by the scientific evidence. In addition, studies "that are most likely to appear in the press or high-impact journals are those that have novel, unexpected, and clearly impactful results. Studies with null effects, or those that replicate and incrementally test the boundary conditions of a finding, are perceived as much less valuable" (Katz et al., 2018, p. 9902). Hence, we consider it unwarranted at present to sell sport and exercise interventions as domain-general EF training. We do not doubt that sport and exercise has numerous positive outcomes that have the potential to contribute to mental health and cognitive functioning. Also, single bouts of sport and exercise in school might have positive effects on immediate cognitive performance (e.g., Singh et al., 2012; 2019). Nevertheless, the scientific evidence at present does not support a simple causal effect of sport or exercise interventions on enhanced EFs. To address this, future research should take a more mechanisitic approach to establishing proposed relationships between interventions, changes in brain function (e.g., neurogenesis, angiogenesis, brain-derived neurotrophic factor) and improved EFs. In the same vein, consideration of potential moderating variables of these relationships (e.g., age, sex, genetic differences, the type of exercise/sport and the intensity of such activity) would also be worthwhile.

Similar to the suggestion by Katz et al. (2018) we consider the overarching research question of "does sport and exercise improve EF?" as similarly inappropriate to the question "Does medicine cure disease?". Given the diversity of sport and exercise activities and measures of EF it is unlikely to gather sufficient evidence either in favor of the alternative hypothesis (i.e., yes) or the null-hypothesis (i.e., no). To improve matters, more differentiated research questions and theorizing is needed. In this respect, Smid et al., (2020) make some valuable suggestions in their position paper "Toward a science of effective cognitive training". For example, they suggest that it is necessary to further the understanding of the true relationship between training mechanisms and outcome variables, which is highly complicated, particularly due to the task-impurity problem in the measurement of EFs (Kane & Engle, 2003; Miyake & Friedman, 2012). Its would also be worthwhile to examine how the relationship between sport engagement and EFs influence each another over time in more longnituinal research, which is servely lacking in this area. Another problem, that is often not taken into account in training studies is evidence showing that individuals tend to respond differently to the same training intervention (Smid et al., 2020). Factors like age, baseline ability, motivation, personality, and genetic predisposition (Strobach & Karbach, in press), have been shown to influence training effects. In particular, research suggests that especially low-performing and at-risk individuals are likely to benefit more from EF training (Karbach et al., 2017).

> As in fields of medicine, which have embraced the necessity of personalizing treatment, researchers in the field of cognitive training need to consider differences in variables such as baseline ability, motivation and affect, genetic predisposition, environmental experience, and lifestyle as well as developmental stage and individually and developmentally relevant goals (Smid et al., 2020, p. 4).

Diamond and Ling (2021, p. 501) also suggest that different sporting activities will likely differently affect EF. They consider that the activities that will most successfully improve EFs will include each of the following elements: "(1) tax EFs, continually challenging them in new and different ways, (2) be personally meaningful and relevant, inspiring a deep commitment and emotional investment on the part of participants to the activity and to one another, (3) have a mentor or guide who firmly believes in the efficacy of the activity and sincerely cares about and believes steadfastly in the individual participants, and (4) provide joy, reduce feelings of stress, and inspire self-confidence and pride" (see Pesce, 2012 for a similar perspective).

Regarding the ambiguous findings on correlations between sporting success or sporting expertise and executive functions, we share the skepticism of colleagues who warn of the premature use of EF tests in talent identification (Beavan et al., 2020a, 2020b). As it is currently not sufficiently empirically established if and how EF contribute to successful sporting performance and if EF can be considered a limiting factor of sport performance, we do not consider it advisable to screen for EF within talent identification or talent development programs in sport. For similar reasons, we would currently not recommend athletes, coaches, or sport teams to invest training time and other valuable resources in commercially available EF training (e.g., cogmed.com) as there is no empirical evidence that this is likely to improve sport performance (Walton et al., 2018).

In conclusion, sport and exercise are an unlikely panacea in the quest of enhancing EF. We consider the state of affairs similar to that in the general cognitive training literature that is nicely summarized in the closing section of Katz et al. (2018, p. 9903):

> We assert that we still do not have definitive answers to questions regarding training and transfer. Researchers may not have the answers 100 y hence. But if we keep asking, simply, “Does cognitive training work?” rather than investigating the mechanisms of transfer within a coherent theoretical framework, we will never have them at all. How many more studies of this nature must be completed before we start asking the right questions”.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

References

Ahuja, A. (2019, January 23). *An evidence deficit haunts the billion-dollar brain training industry.* Financial Times. www.ft.com/content/a0166eea-1e41-11e9-a46f-08f9738d6b2b

Alloway, T. P. (2007). Working memory, reading, and mathematical skills in children with developmental coordination disorder. *Journal of Experimental Child Psychology*, *96*(1), 20-36. https://doi.org/10.1016/j.jecp.2006.07.002

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The cognitive and behavioral characteristics of children with low working memory. *Child Development*, *80*(2), 606-621. https://doi.org/10.1111/j.1467-8624.2009.01282.x

Alvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sánchez-López, M., Garrido-Miguel, M., & Martinez-Vizcaino, V. (2017). Academic achievement and physical activity: a meta-analysis. *Pediatrics*, *140*(6). https://doi.org/10.1542/peds.2017-1498

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Catroppa, C. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology*, *20*(1), 385-406. https://doi.org/10.1207/S15326942DN2001_5

Anderson, P., Anderson, V., & Lajoie, G. (1996). The tower of London test: Validation and standardization for pediatric populatons. *The Clinical Neuropsychologist*, *10*(1), 54-65. https://doi.org/10.1080/13854049608406663

Arnsten, A. F., Raskind, M. A., Taylor, F. B., & Connor, D. F. (2015). The effects of stress exposure on prefrontal cortex: Translating basic research into successful treatments for post-traumatic stress disorder. *Neurobiology of Stress*, *1*, 89-99. https://doi.org/10.1016/j.ynstr.2014.10.002

Aron, A. R. (2007). The neural basis of inhibition in cognitive control. *The Neuroscientist*, *13*(3), 214-228. https://doi.org/10.1177/1073858407299288

Asato, M. R., Sweeney, J. A., & Luna, B. (2006). Cognitive processes in the development of TOL performance. *Neuropsychologia*, *44*(12), 2259-2269. https://doi.org/10.1016/j.neuropsychologia.2006.05.010

Baddeley, A. D. (2007). *Working memory, thought, and action*. Oxford University Press.

Baddeley, A.D., & Hitch, G.J. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (vol. 8, pp. 47-89). Academic Press.

Bäckman, L., Nyberg, L., Lindenberger, U., Li, S. C., & Farde, L. (2006). The correlative triad among aging, dopamine, and cognition: current status and future prospects. *Neuroscience & Biobehavioral Reviews*, *30*(6), 791-807. https://doi.org/10.1016/j.neubiorev.2006.06.005

Baggetta, P., & Alexander, P. A. (2016). Conceptualization and operationalization of executive function. *Mind, Brain, and Education*, *10*(1), 10-33. https://doi.org/10.1111/mbe.12100

Bailey, R. P., Madigan, D. J., Cope, E., & Nicholls, A. R. (2018). The prevalence of pseudoscientific ideas and neuromyths among sports coaches. *Frontiers in psychology*, *9*, 641. https://doi.org/10.3389/fpsyg.2018.00641

Baldo, J. V., & Shimamura, A. P. (1998). Letter and category fluency in patients with frontal lobe lesions. *Neuropsychology*, *12*(2), 259-267. https://doi.org/10.1037/0894-4105.12.2.259

Baldo, J. V., Shimamura, A. P., Delis, D. C., Kramer, J., & Kaplan, E. (2001). Verbal and design fluency in patients with frontal lobe lesions. *Journal of the International Neuropsychological Society*, *7*(5), 586-596. https://doi.org/10.1017/S1355617701755063

Barkley, R. A. (2012). *Executive functions: What they are, how they work, and why they evolved*. Guilford Press.

Barnes, M. E., Gozal, D., & Molfese, D. L. (2012). Attention in children with obstructive sleep apnoea: an event-related potentials study. *Sleep Medicine*, *13*(4), 368-377. https://doi.org/10.1016/j.sleep.2011.06.007

Baron, I. S. (2004). Delis-Kaplan Executive System. *Child Neuropsychology*, *10*, 147–152. https://doi.org/10.1080/09297040490911140

Basak, C., Boot, W. R., Voss, M. W., & Kramer, A. F. (2008). Can training in a real-time strategy video game attenuate cognitive decline in older adults?. *Psychology and Aging*, *23*(4), 765. https://doi.org/10.1037/a0013494

Baumeister, R. F., & Leary, M. R. (1997). Writing narrative literature reviews. *Review of General Psychology, 1*(3), 311-320. https://doi.org/10.1037/1089-2680.1.3.311

Baumeister, R. F., Twenge, J. M., & Nuss, C. K. (2002). Effects of social exclusion on cognitive processes: anticipated aloneness reduces intelligent thought. *Journal of Personality and Social Psychology, 83*(4), 817-827. https://doi.org/10.1037/0022-3514.83.4.817

Beavan, A., Chin, V., Ryan, L. M., Spielmann, J., Mayer, J., Skorski, S., ... & Fransen, J. (2020a). A longitudinal analysis of the executive functions in high-level soccer players. *Journal of Sport and Exercise Psychology*, *42*(5), 349-357. https://doi.org/10.1123/jsep.2019-0312

Beavan, A., Spielmann, J., Mayer, J., Skorski, S., Meyer, T., & Fransen, J. (2020b). The rise and fall of executive functions in high-level football players. *Psychology of Sport and Exercise*, *49*, 101677. https://doi.org/10.1016/j.psychsport.2020.101677

Bernstein, J. H. & Waber, D. P. (2007). Executive capacities from a developmental perspective. In Meltzer L. (Ed.). *Executive Function in Education: From Theory to Practice (*pp. 39–54). Guilford Press.

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review*, *30*(4), 331-351. https://doi.org/10.1016/j.dr.2010.08.001

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development*, *81*(6), 1641-1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review*, *29*(3), 180-200. https://doi.org/10.1016/j.dr.2009.05.002

Borges, J. G., Ginani, G. E., Hachul, H., Cintra, F. D., Tufik, S., & Pompéia, S. (2013). Executive functioning in obstructive sleep apnea syndrome patients without comorbidities: Focus on the fractionation of executive functions. *Journal of Clinical and Experimental Neuropsychology*, *35*(10), 1094–1107. https://doi.org/10.1080/13803395.2013.858661

Boucard, G. K., Albinet, C. T., Bugaiska, A., Bouquet, C. A., Clarys, D., & Audiffren, M. (2012). Impact of physical activity on executive functions in aging: a selective effect on inhibition among old adults. *Journal of Sport and Exercise Psychology*, *34*(6), 808-827. https://doi.org/10.1123/jsep.34.6.808

Braver, T. S., & Barch, D. M. (2002). A theory of cognitive control, aging cognition, and neuromodulation. *Neuroscience & Biobehavioral Reviews*, *26*(7), 809-817. https://doi.org/10.1016/S0149-7634(02)00067-2

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology*, *19*(3), 273-293. https://doi.org/10.1207/S15326942DN1903_3

Burgess, P. W., & Simons, J. S. (2005). Theories of frontal lobe executive function: clinical applications. In P. W. Halligan & D. T. Wade (Eds). *Effectiveness of Rehabilitation for Cognitive Deficits*, (pp. 211–31). Oxford University Press.

Burke, S. N., & Barnes, C. A. (2006). Neural plasticity in the ageing brain. *Nature Reviews Neuroscience*, *7*(1), 30-40. https://doi.org/10.1038/nrn1809

Cacioppo J, Patrick W (2008). *Loneliness: human nature and the need for social connection*. W.W. Norton & Co., Inc.

Callan, M. J., Shead, N. W., & Olson, J. M. (2009). Foregoing the labor for the fruits: The effect of just world threat on the desire for immediate monetary rewards. *Journal of Experimental Social Psychology*, *45*(1), 246-249. https://doi.org/10.1016/j.jesp.2008.08.013

Campbell, W. K., Krusemark, E. A., Dyckman, K. A., Brunell, A. B., McDowell, J. E., Twenge, J. M., & Clementz, B. A. (2006). A magnetoencephalography investigation of neural correlates for social exclusion and self-control. *Social Neuroscience, 1*(2), 124-134. https://doi.org/10.1080/17470910601035160

Camerer, C. F., Dreber, A., Holzmeister, F., Ho, T. H., Huber, J., Johannesson, M., ... & Wu, H. (2018). Evaluating the replicability of social science experiments in Nature and Science between 2010 and 2015. *Nature Human Behaviour*, *2*(9), 637-644.

Carruthers, P. (2013). Evolution of working memory. *Proceedings of the National Academy of Sciences of the United States of America*, *110* (Suppl. 2), 10371–10378. https://doi.org/10.1073/pnas.130119511

Casey, B. J., Amso, D., & Davidson, M. C. (2006) Learning about learning and development with modern imaging technology. In Y. Munakata & M.H. Johnson (Eds.). *Processes of change in brain and cognitive development: Attention and performance XXI. Vol. 21* (pp. 513-533). Oxford University Press.

Castelli, D. M., Centeio, E. E., Hwang, J., Barcelona, J. M., Glowacki, E. M., Calvert, H. G., & Nicksic, H. M. (2014). VII. The history of physical activity and academic performance research: informing the future. *Monographs of the Society for Research in Child Development*, *79*(4), 119-148. https://doi.org/10.1111/mono.12133

Chaddock-Heyman, L., Erickson, K. I., Voss, M. W., Knecht, A. M., Pontifex, M. B., Castelli, D. M., ... & Kramer, A. F. (2013). The effects of physical activity on functional MRI activation associated with cognitive control in children: a randomized controlled intervention. *Frontiers in Human Neuroscience*, *7*, 72. https://doi.org/10.3389/fnhum.2013.00072

Chaddock, L., Hillman, C. H., Buck, S. M., & Cohen, N. J. (2011). Aerobic fitness and executive control of relational memory in preadolescent children. *Medicine & Science in Sports & Exercice*, *43*(2), 344-349.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain research*, *1453*, 87-101. https://doi.org/10.1016/j.brainres.2012.02.068

Cheval, B., Orsholits, D., Sieber, S., Courvoisier, D., Cullati, S., & Boisgontier, M. P. (2020). Relationship between decline in cognitive resources and physical activity. *Health Psychology, 39*(6), 519–528. https://doi.org/10.1037/hea0000857.

Cheval, B., Maltagliati, S., Sieber, S., Beran, D., Chalabaev, A., Sander, D., ... & Boisgontier, M. P. (2021a). Why are individuals with diabetes less active? The mediating role of physical, emotional, and cognitive factors. *Annals of Behavioral Medicine, 55*(9), 904-917. https://doi.org/10.1093/abm/kaaa120

Cheval, B., Cabral, D. A., Daou, M., Bacelar, M. F., Parma, J. O., Forestier, C., ... & Miller, M. W. (2021b). Inhibitory control elicited by physical activity and inactivity stimuli: An electroencephalography study. *Motivation Science, 7*(4), 386–399. https://doi.org/10.1037/mot0000236.

Chi, Y. K., Kim, T. H., Han, J. W., Lee, S. B., Park, J. H., Lee, J. J., ... & Kim, K. W. (2012). Impaired design fluency is a marker of pathological cognitive aging; results from the Korean longitudinal study on health and aging. *Psychiatry Investigation*, *9*(1), 59-64. https://doi.org/10.4306/pi.2012.9.1.59

Cerqueira, J. J., Mailliet, F., Almeida, O. F., Jay, T. M., & Sousa, N. (2007). The prefrontal cortex as a key target of the maladaptive response to stress. *Journal of Neuroscience*, *27*(11), 2781-2787. https://doi.org/10.1523/JNEUROSCI.4372-06.2007

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychological Science*, *14*(2), 125-130. https://doi.org/10.1111/1467-9280.t01-1-01430

Collins, A., & Koechlin, E. (2012). Reasoning, learning, and creativity: frontal lobe function and human decision-making. *PLoS Biology, 10*: e1001293. https://doi.org/10.1371/journal.pbio.1001293.

Conway, A. R. A., Jarrold, C., Kane, M. J., Miyake, A., & Towse, J. N. (2007). *Variation in working memory*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195168648.001.0001

Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, *12*(5), 769-786. https://doi.org/10.3758/BF03196772

Cooper, H., DeNeve, K., & Charlton, K. (1997) Finding the missing science: the fate of studies submitted for review by a human subjects committee. *Psychological Methods,* 2, 447–452. https://doi.org/10.1037/1082-989X.2.4.447

Cowan, N. (1995). *Attention and memory: An integrated framework*. Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780195119107.001.0001

Cremen, I. A., & Carson, R. G. (2017). Have standard tests of cognitive function been misappropriated in the study of cognitive enhancement?. *Frontiers in Human Neuroscience*, *11*, 276. https://doi.org/10.3389/fnhum.2017.00276

Cumming, G., Fidler, F., Leonard, M., Kalinowski, P., Christiansen, A., Kleinig, A., Lo, J., McMenamin, N., & Wilson, S. (2007) Statistical Reform in Psychology: Is Anything

Changing? *Psychological Science,* 18, 230–232. https://doi.org/10.1111/j.1467-9280.2007.01881.x

Dalziell, A., Boyle, J., & Mutrie, N. (2015). Better Movers and Thinkers (BMT): An Exploratory Study of an Innovative Approach to Physical Education. *Europe's journal of psychology*, 11(4), 722–741. https://doi.org/10.5964%2Fejop.v11i4.950

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review*, *12*(1), 45-75. https://doi.org/10.1016/0273-2297(92)90003-K

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Function System (D–KEFS)*. APA PsycTests. https://doi.org/10.1037/t15082-000

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135–168. https://doi.org/10.1146/annurevpsych-113011-143750.

Diamond, A. (2014). Whether coordinative (soccer) exercise improves executive functioning in kindergarten children has yet to be demonstrated. *Experimental Brain Research*, *232*(6), 2045-2045. https://doi.org/10.1007/s00221-014-3920-2

Diamond, A. (2020). Executive functions. In J.L. Michaud, C. Bulteau, D. Cohen, & A. Gallagher (Eds.), *Handbook of Clinical Neurology, 173*, 225-240. Elsevier.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959-964. https://doi.org/10.1126/science.1204529

Diamond, A., & Ling, D. S. (2019). Aerobic-Exercise and resistance-training interventions have been among the least effective ways to improve executive functions of any method tried thus far. *Developmental Cognitive Neuroscience, 37*, Article 100572. https://doi.org/10.1016/j.dcn.2018.05.001

Diamond, A., & Ling, D. S. (2020). Review of the evidence on, and fundamental questions about, efforts to improve executive functions, including working memory. In J Novick, MF Bunting, MR Dougherty, RW Engle (Eds.), *Cognitive and working memory training: perspectives from psychology, neuroscience, and human development*, (pp. 143–431). Oxford University Press.

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., ... & Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Medicine and Science in Sports and Exercise*, *48*(6), 1197. https://doi.org/10.1249%2FMSS.0000000000000901

Egger, F., Benzing, V., Conzelmann, A., & Schmidt, M. (2019). Boost your brain, while having a break! The effects of long-term cognitively engaging physical activity breaks on children's executive functions and academic achievement. *PloS one*, *14*(3), e0212482. https://doi.org/10.1371/journal.pone.0212482

Engle, R. W. (2010). Role of working-memory capacity in cognitive control. *Current Anthropology*, *51*(S1), S17–S26. https://doi.org/10.1086/650572

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*(1), 143-149. https://doi.org/10.3758/BF03203267

Eslinger, P. J. (1996). Conceptualizing, describing, and measuring components of executive function: A summary. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory and executive function* (pp. 367–395). Brookes.

Etnier, J. L., Nowell, P. M., Landers, D. M., & Sibley, B. A. (2006). A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain Research Reviews*, *52*(1), 119-130. https://doi.org/10.1016/j.brainresrev.2006.01.002

Fedewa, A. L., & Ahn, S. (2011). The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: a meta-analysis. *Research quarterly for exercise and sport*, *82*(3), 521-535. https://doi.org/10.1080/02701367.2011.10599785

Finkenzeller, T., Krenn, B., Würth, S., & Amesberger, G. (2021). The design fluency test: a reliable and valid instrument for the assessment of game intelligence?. *German Journal of Exercise and Sport Research*, *51*(2), 146-155. https://doi.org/10.1007/s12662-020-00697-0

Foroughi, C. K., Monfort, S. S., Paczynski, M., McKnight, P. E., & Greenwood, P. M. (2016). Placebo effects in cognitive training. *Proceedings of the national Academy of Sciences*, *113*(27), 7470-7474. https://doi.org/10.1073/pnas.1601243113

Foti, K. E., Eaton, D. K., Lowry, R., & McKnight-Ely, L. R. (2011). Sufficient sleep, physical activity, and sedentary behaviors. *American Journal of Preventive Medicine*, *41*(6), 596–602. https://doi.org/10.1016/j.amepre.2011.08.009

Furley, P., & Goldschmied, N. (2021). Systematic versus narrative reviews in sport and exercise psychology: Is either approach superior to the other?. *Frontiers in Psychology, 12*, 2819. https://doi.org/10.3389/fpsyg.2021.685082

Furley, P., & Memmert, D. (2010). Differences in spatial working memory as a function of team sports expertise: the Corsi Block-tapping task in sport psychological assessment. *Perceptual and motor skills*, *110*(3), 801-808. https://doi.org/10.2466/pms.110.3.801-808

Furley, P., & Memmert, D. (2011). Studying cognitive adaptations in the field of sport: Broad or narrow transfer? A comment on Allen, Fioratou, and McGeorge (2011). *Perceptual & Motor Skills,* 113, 2, 481–488. https://doi.org/10.2466/05.23.PMS.113.5.481-488

Furley, P., Schul, K., & Memmert, D. (2016). Das Experten-Novizen-Paradigma und die Vertrauenskrise in der Psychologie. *Zeitschrift für Sportpsychologie*, *23*(4), 131-140. https://doi.org/10.1026/1612-5010/a000174

Fuster, J. M. (1997). Network memory. *Trends in Neurosciences, 20*(10), 451-459. https://doi.org/10.1016/S0166-2236(97)01128-4

Gapin, J., & Etnier, J. L. (2010). The relationship between physical activity and executive function performance in children with attention-deficit hyperactivity disorder. *Journal of Sport and Exercise Psychology*, *32*(6), 753-763. https://doi.org/10.1123/jsep.32.6.753

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., ... & Rapoport, J. L. (1999). Brain development during childhood and adolescence: a longitudinal MRI study. *Nature Neuroscience, 2*(10), 861-863. https://doi.org/10.1038/13158

Gobet, F., & Sala, G. (2022). Cognitive training: A Field in Search of a Phenomenon. *Perspectives on Psychological Science*. https://doi.org/10.1177/17456916221091830

Gothe, N. P., & McAuley, E. (2015). Yoga and cognition: a meta-analysis of chronic and acute effects. *Psychosomatic Medicine*, *77*(7), 784-797. https://doi.org/10.1097/PSY.0000000000000218

Greenhalgh, T., Thorne, S., & Malterud, K. (2018). Time to challenge the spurious hierarchy of systematic over narrative reviews?. *European Journal of Clinical Investigation*, *48*(6): e12931. https://doi.org/10.1111/eci.12931

Grant, M. J., & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*, *26*(2), 91-108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Hackman, D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic status and executive function: Developmental trajectories and mediation. *Developmental Science*, *18*(5), 686-702. https://doi.org/10.1111/desc.12246

Harms, M. B., Shannon Bowen, K. E., Hanson, J. L., & Pollak, S. D. (2018). Instrumental learning and cognitive flexibility processes are impaired in children exposed to early life stress. *Developmental Science*, *21*(4), e12596. https://doi.org/10.1111/desc.12596

Harris, D. J., Wilson, M. R., & Vine, S. J. (2018). A systematic review of commercial cognitive training devices: implications for use in sport. *Frontiers in psychology*, 709. https://doi.org/10.3389/fpsyg.2018.00709

Have, M., Nielsen, J. H., Ernst, M. T., Gejl, A. K., Fredens, K., Grøntved, A., & Kristensen, P. L. (2018). Classroom-based physical activity improves children's math achievement - A randomized controlled trial. *PloS one*, *13*(12), e0208787. https://doi.org/10.1371/journal.pone.0208787

Hendry, A., Jones, E. J. H., & Charman, T. (2016). Executive function in the first three years of life: precursors, predictors and patterns. *Developmental Review, 42*. 1–33. https://doi.org/10.1016/j.dr.2016.06.005.

Hillman, C. H., Castelli, D. M., & Buck, S. M. (2005). Aerobic fitness and neurocognitive function in healthy preadolescent children. *Medicine and Science in Sports and Exercise*, *37*(11), 1967-1974. https://doi.org/10.1249/01.mss.0000176680.79702.ce

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*(1), 58-65. https://doi.org/10.1038/nrn2298

Hillman, C. H., McAuley, E., Erickson, K. I., Liu-Ambrose, T., & Kramer, A. F. (2019). On mindful and mindless physical activity and executive function: A response to Diamond and Ling (2016). *Developmental Cognitive Neuroscience*, *37*. https://doi.org/10.1016/j.dcn.2018.01.006

Hirt, E. R., Devers, E. E., & McCrea, S. M. (2008). I want to be creative: exploring the role of hedonic contingency theory in the positive mood-cognitive flexibility link. *Journal of Personality and Social Psychology*, *94*(2), 214-230. https://doi.org/10.1037/0022-3514.94.2.94.2.214

Hodel, A. S. (2018). Rapid infant prefrontal cortex development and sensitivity to early environmental experience. Developmental Review, 48, 113–144. https://doi.org/10.1016/j.dr.2018.02.003

Hommel, B. (2011). The Simon effect as tool and heuristic. *Acta Psychologica*, *136*(2), 189-202. https://doi.org/10.1016/j.actpsy.2010.04.011

Hostinar, C. E., Stellern, S. A., Schaefer, C., Carlson, S. M., & Gunnar, M. R. (2012). Associations between early life adversity and executive function in children adopted internationally from orphanages. *Proceedings of the National Academy of Sciences*, *109*(supplement_2), 17208-17212. https://doi.org/10.1073/pnas.1121246109

Huang, Y. S., Guilleminault, C., Li, H. Y., Yang, C. M., Wu, Y. Y., & Chen, N. H. (2007). Attention-deficit/hyperactivity disorder with obstructive sleep apnea: a treatment outcome study. *Sleep Medicine*, *8*(1), 18-30. https://doi.org/10.1016/j.sleep.2006.05.016

Hughes, C. (1998). Finding your marbles: Does preschoolers' strategic behavior predict later understanding of mind?. *Developmental Psychology*, *34*(6), 1326-1339. https://doi.org/10.1037/0012-1649.34.6.1326

Huijgen, B. C., Leemhuis, S., Kok, N. M., Verburgh, L., Oosterlaan, J., Elferink-Gemser, M. T., & Visscher, C. (2015). Cognitive functions in elite and sub-elite youth soccer players aged 13 to 17 years. *PloS one*, 10(12), e0144580. https://doi.org/10.1371/journal.pone.0144580

Huizinga, M., Dolan, C. V., & Van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, *44*(11), 2017-2036. https://doi.org/10.1016/j.neuropsychologia.2006.01.010

Ioannidis, J. P. (2016). The mass production of redundant, misleading, and conflicted systematic reviews and meta-analyses. *The Milbank Quarterly*, *94*(3), 485-514. https://doi.org/10.1111/1468-0009.12210

Jacques, S., & Marcovitch, S. (2010). Development of executive function across the life span. In W. F. Overton & R. M. Lerner (Eds.), *The handbook of life-span development, Vol. 1. Cognition, biology, and methods* (pp. 431–466). John Wiley & Sons, Inc. https://doi.org/10.1002/9780470880166.hlsd001013

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review*, *17*(3), 213-233. https://doi.org/10.1007/s11065-007-9040-z

Jussim, L. (2017). Précis of Social Perception and Social Reality: Why accuracy dominates bias and self-fulfilling prophecy. *Behavioral and Brain Sciences*, *40*. https://doi.org/10.1017/S0140525X1500062X

Kable, J. W., Caulfield, M. K., Falcone, M., McConnell, M., Bernardo, L., Parthasarathi, T., ... & Lerman, C. (2017). No effect of commercial cognitive training on brain activity, choice behavior, or cognitive performance. *Journal of Neuroscience*, *37*(31), 7390-7402. https://doi.org/10.1523/JNEUROSCI.2832-16.2017

Kalén, A., Bisagno, E., Musculus, L., Raab, M., Pérez-Ferreirós, A., Williams, A. M., ... & Ivarsson, A. (2021). The role of domain-specific and domain-general cognitive functions and skills in sports performance: A meta-analysis. *Psychological Bulletin*, *147*(12), 1290-1308. https://doi.org/10.1037/bul0000355

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General*, *132*, 47–70. https://doi.org/10.1037/0096-3445.132.1.47

Karbach, J., Könen, T., & Spengler, M. (2017). Who benefits the most? Individual differences in the transfer of executive control training across the lifespan. *Journal of Cognitive Enhancement*, *1*, 394–405. https://doi.org/10.1007/s41465-017-0054-z

Katz, B., Shah, P., & Meyer, D. E. (2018). How to play 20 questions with nature and lose: Reflections on 100 years of brain-training research. *Proceedings of the National Academy of Sciences*, *115*(40), 9897-9904. https://doi.org/10.1073/pnas.161710211

Karr, J. E., Areshenkoff, C. N., Rast, P., Hofer, S. M., Iverson, G. L., & Garcia-Barrera, M. A. (2018). The unity and diversity of executive functions: A systematic review and re-analysis of latent variable studies. *Psychological Bulletin*, *144*(11), 1147-1185. https://doi.org/10.1037/bul0000160

Khatri, P., Blumenthal, J. A., Babyak, M. A., Craighead, W. E., Herman, S., Baldewicz, T., . . . Krishnan, K. R. (2001). Effects of exercise training on cognitive functioning among depressed older men and women. *Journal of Aging and Physical Activity*, *9*(1), 43–57. https://doi.org/10.1123/japa.9.1.43

Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Sciences*, *14*(7), 317-324. https://doi.org/10.1016/j.tics.2010.05.002

Kobilo, T., Liu, Q. R., Gandhi, K., Mughal, M., Shaham, Y., & van Praag, H. (2011). Running is the neurogenic and neurotrophic stimulus in environmental enrichment. *Learning & Memory*, *18*(9), 605-609. . https://doi.org/10.1101/lm.2283011

Kochanska, G., Coy, K. C., & Murray, K. T. (2001). The development of self-regulation in the first four years of life. *Child Development*, *72*(4), 1091-1111. https://doi.org/10.1111/1467-8624.00336

Kovács, Á. M., & Mehler, J. (2009). Cognitive gains in 7-month-old bilingual infants. *Proceedings of the National Academy of Sciences, 106*(16), 6556-6560. https://doi.org/10.1073/pnas.081132310

Kramer, A. F., Hahn, S., Cohen, N. J., Banich, M. T., McAuley, E., Harrison, C. R., ... & Colcombe, A. (1999). Ageing, fitness and neurocognitive function. *Nature*, *400*(6743), 418-419. https://doi.org/10.1038/22682

Krikorian, R., Bartok, J., & Gay, N. (1994). Tower of London procedure: a standard method and developmental data. *Journal of clinical and Experimental Neuropsychology*, *16*(6), 840-850. https://doi.org/10.1080/01688639408402697

Kubesch, S., & Walk, L. (2009). Körperliches und kognitives Training exekutiver Funktionen in Kindergarten und Schule [Physical and cognitive training of Executive Functions in kindergarden and school]. *Sportwissenschaft*, *39*(4), 309-317. https://doi.org/10.1007/s12662-009-0079-2

Kubesch, S., Walk, L., Spitzer, M., Kammer, T., Lainburg, A., Heim, R., & Hille, K. (2009). A 30-Minute Physical Education Program Improves Students' Executive Attention. *Mind, Brain, and Education*, 3(4), 235–242. https://doi.org/10.1111/j.1751-228X.2009.01076.x

Kubesch, S. (2008). *Körperliche Aktivität und exekutive Funktionen [Physical activity and Executive Functions]*. Hofmann.

Lane, A. M., & Lovejoy, D. J. (2001). The effects of exercise on mood changes: The moderating effect of depressed mood. *Journal of Sports Medicine and Physical Fitness*, *41*(4), 539–545.

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, *21*(1), 59-80. https://doi.org/10.1348/026151003321164627

Lezak, M. (1983). *Neuropsychological Assessment*. Oxford University Press.

Liston, C., McEwen, B. S., & Casey, B. J. (2009). Psychosocial stress reversibly disrupts prefrontal processing and attentional control. *Proceedings of the National Academy of Sciences*, *106*(3), 912-917. https://doi.org/10.1073/pnas.080704110

Loprinzi, P. D., & Cardinal, B. J. (2011). Association between objectively measured physical activity and sleep, NHANES 2005–2006. *Mental Health and Physical Activity*, *4*, 65–69. https://doi.org/10.1016/j.mhpa.2011.08.001

Lord, C. G., Ross, L., & Lepper, M. R. (1979). Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of Personality and Social Psychology, 37*(11), 2098–2109. https://doi.org/10.1037/0022-3514.37.11.2098

Lövdén, M., Fratiglioni, L., Glymour, M. M., Lindenberger, U., & Tucker-Drob, E. M. (2020). Education and cognitive functioning across the life span. *Psychological Science in the Public Interest*, *21*(1), 6-41. https://doi.org/10.1177/1529100620920576

Luciana, M., & Nelson, C. A. (2002). Assessment of neuropsychological function through use of the Cambridge Neuropsychological Testing Automated Battery: performance in 4-to 12-year-old children. *Developmental Neuropsychology*, *22*(3), 595-624. https://doi.org/10.1207/S15326942DN2203_3

Ludyga, S., Gerber, M., Pühse, U., Looser, V. N., & Kamijo, K. (2020). Systematic review and meta-analysis investigating moderators of long-term effects of exercise on cognition in healthy individuals. *Nature Human Behaviour*, *4*(6), 603-612. https://doi.org/10.1038/s41562-020-0851-8

Ludyga, S., Held, S., Rappelt, L., Donath, L., & Klatt, S. (2022). A network meta-analysis comparing the effects of exercise and cognitive training on executive function in young and middle-aged adults. *European Journal of Sport Science*, 1-11. https://doi.org/10.1080/17461391.2022.2099765

Luna, B., Garver, K. E., Urban, T. A., Lazar, N. A., & Sweeney, J. A. (2004). Maturation of cognitive processes from late childhood to adulthood. *Child Development*, *75*(5), 1357-1372. https://doi.org/10.1111/j.1467-8624.2004.00745.x

Luria, A. R. (1966). *Higher cortical functions in man*. Basic Books.

Lind, R. R., Geertsen, S. S., Ørntoft, C., Madsen, M., Larsen, M. N., Dvorak, J., ... & Krustrup, P. (2018). Improved cognitive performance in preadolescent Danish children after the school-based physical activity programme "FIFA 11 for Health" for Europe–A clusterrandomised controlled trial. *European Journal of Sport Science*, *18*(1), 130-139. https://doi.org/10.1080/17461391.2017.1394369

MacLeod, C. M., Dodd, M. D., Sheard, E. D., Wilson, D. E., & Bibi, U. (2003). In opposition to inhibition. In B. H. Ross (Ed.), *The psychology of learning and motivation: Advances in research and theory,* Vol. 43. (pp. 163–214). Elsevier Science.

McTeague, L. M., Huemer, J., Carreon, D. M., Jiang, Y., Eickhoff, S. B., & Etkin, A. (2017). Identification of common neural circuit disruptions in cognitive control across psychiatric disorders. *American Journal of Psychiatry*, *174*(7), 676-685. https://doi.org/10.1176/appi.ajp.2017.16040400

Mehren, A., Diaz Luque, C., Brandes, M., Lam, A. P., Thiel, C. M., Philipsen, A. & Özyurt, J. (2019). Intensity-Dependent Effects of Acute Exercise on Executive Function. *Neural Plasticity*, *2019*, 1–17. https://doi.org/10.1155/2019/8608317

Michaelson, L., De la Vega, A., Chatham, C. H., & Munakata, Y. (2013). Delaying gratification depends on social trust. *Frontiers in Psychology*, *4*, 355. https://doi.org/10.3389/fpsyg.2013.00355

Michaelson, L. E., & Munakata, Y. (2016). Trust matters: Seeing how an adult treats another person influences preschoolers' willingness to delay gratification. *Developmental Science*, *19*(6), 1011-1019. https://doi.org/10.1111/desc.12388

Milner, B. (1964). Some effects of frontal lobectomy in man. In J. M Warren, K. Akert (Ed.) *The frontal granular cortex and behavior.* (pp. 313-334). McGraw-Hill.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49-100. https://doi.org/10.1006/cogp.1999.0734

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, *21*(1), 8-14. https://doi.org/10.1177/0963721411429458

Miyake, A., & Shah, P. (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. Cambridge: Cambridge University Press. http://dx.doi.org/10.1017/CBO9781139174909

Moreau, D. (2022). How malleable are cognitive abilities? A critical perspective on popular brief interventions. *American Psychologist*, *77*(3), 409–423. https://doi.org/10.1037/amp0000872

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*(3), 134-140. https://doi.org/10.1016/S1364-6613(03)00028-7

Mullane, J. C., Corkum, P. V., Klein, R. M., & McLaughlin, E. (2009). Interference control in children with and without ADHD: a systematic review of Flanker and Simon task performance. *Child Neuropsychology*, *15*(4), 321-342. https://doi.org/10.1080/09297040802348028

Munoz, D. P., & Everling, S. (2004). Look away: the anti-saccade task and the voluntary control of eye movement. *Nature Reviews Neuroscience*, *5*(3), 218-228. https://doi.org/10.1038/nrn1345

Norris, S. P., Phillips, L. M., & Korpan, C. A. (2003). University students' interpretation of media reports of science and its relationship to background knowledge, interest, and reading difficulty. *Public Understanding of Science*, *12*(2), 123-145. https://doi.org/10.1177/09636625030122001

Nyongesa, M. K., Ssewanyana, D., Mutua, A. M., Chongwo, E., Scerif, G., Newton, C. R., & Abubakar, A. (2019). Assessing executive function in adolescence: a scoping review of existing measures and their psychometric robustness. *Frontiers in Psychology*, *10*, 311. https://doi.org/10.3389/fpsyg.2019.00311

Oaten, M., & Cheng, K. (2005). Academic examination stress impairs self-control. *Journal of Social and Clinical Psychology*, *24*(2), 254. https://doi.org/10.1521/jscp.24.2.254.62276

O'Hare, E. D., & Sowell, E. R. (2008) Imaging developmental changes in gray and white matter in the human brain. In C. A. Nelson & M. Luciana (Eds.). *Handbook of developmental cognitive neuroscience*. 2nd ed. (p. 23-38). MIT Press. https://doi.org/10.7551/mitpress/7437.003.0005

Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science*, *349*(6251). https://doi.org/10.1126/science.aac4716

Packwood, S., Hodgetts, H. M., & Tremblay, S. (2011). A multiperspective approach to the conceptualization of executive functions. *Journal of Clinical and Experimental Neuropsychology*, *33*(4), 456-470. https://doi.org/10.1080/13803395.2010.533157

Pesce, C. (2012). Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. *Journal of Sport & Exercise Psychology, 34*(6), 766–786. https://doi.org/10.1123/jsep.34.6.766

Petrides, M. (2005). Lateral prefrontal cortex: architectonic and functional organization. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1456), 781-795. https://doi.org/10.1098/rstb.2005.1631

Phillips, L. H. (1997). Do “frontal tests” measure executive function? Issues of assessment and evidence from fluency tests. In P. Rabbitt (Ed.). *Methodology of Frontal and Executive Function*. (pp. 191-213). Routledge.

Piaget, J. (1954). *The child's construction of reality*. Basic Books.

Poldrack, R. A. (2015). Is “efficiency” a useful concept in cognitive neuroscience?. *Developmental Cognitive Neuroscience*, *11*, 12-17. https://doi.org/10.1016/j.dcn.2014.06.001

Prakash, R. S., Voss, M. W., Erickson, K. I., & Kramer, A. F. (2015). Physical activity and cognitive vitality. *Annual Review in Psychology*, *66*(1), 769-97. https://doi.org/10.1146/annurev-psych-010814-015249

Pribram, K. H. (1973). The primate frontal cortex–executive of the brain. In K.H. Pribram & A.R. Luria (Eds.), *Psychophysiology of the frontal lobes* (pp. 293-314). Academic Press.

Riniolo, T. C. (1997). Publication bias: A computer-assisted demonstration of excluding nonsignificant results from research interpretation. *Teaching of Psychology, 24,* 279–282. https://doi.org/10.1207/s15328023top2404_15

Rhodes, M. G. (2004). Age-related differences in performance on the Wisconsin card sorting test: a meta-analytic review. *Psychology and Aging*, *19*(3), 482. https://doi.org/10.1037/0882-7974.19.3.482

Röthlisberger, M., Neuenschwander, R., Cimeli, P., Michel, E., & Roebers, C. M. (2012). Improving executive functions in 5-and 6-year-olds: Evaluation of a small group intervention in prekindergarten and kindergarten children. *Infant and Child Development*, *21*(4), 411-429. https://doi.org/10.1002/icd.752

Roberts, R. J., & Pennington, B. F. (1996). An interactive framework for examining prefrontal cognitive processes. *Developmental Neuropsychology*, *12*(1), 105-126. https://doi.org/10.1080/87565649609540642

Romeas, T., Guldner, A., & Faubert, J. (2016). 3D-Multiple Object Tracking task improves passing decision-making accuracy in soccer players. *Psychology of Sport and Exercise, 22*, 1–9. https://doi.org/10.1016/j.psychsport.2015.06.002

Ronson, J. (2017, July 11) Science Proves Lumosity's Brain Training Games Are a Scam - More research smacks down an overhyped industry. https://www.inverse.com/article/34018-lumosity-brain-training-games-does-it-work.

Rosenthal, R. (1979) The "File Drawer Problem" and tolerance for null results. *Psychological Bulletin, 86*, 638–641. https://doi.org/10.1037/0033-2909.86.3.638

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences*, *102*(41), 14931-14936. https://doi.org/10.1073/pnas.0506897102

Sala, G., & Gobet, F. (2017). Working memory training in typically developing children: A meta-analysis of the available evidence. *Developmental Psychology*, *53*, 671–685. https://doi.org/10.1037/dev0000265

Sala, G., & Gobet, F. (2019). Cognitive training does not enhance general cognition. *Trends in Cognitive Sciences*, *23*, 9–20. https://doi.org/10.1016/j.tics.2018.10.004

Saunders, B., Milyavskaya, M., Etz, A., Randles, D., & Inzlicht, M. (2018). Reported self-control is not meaningfully associated with inhibition-related executive function: A bayesian analysis. *Collabra: Psychology, 4(1): 39*. https://doi.org/10.1525/collabra.134

Scharfen, H. E., & Memmert, D. (2019). Measurement of cognitive functions in experts and elite athletes: A meta-analytic review. *Applied Cognitive Psychology*, *33*(5), 843-860. https://doi.org/10.1002/acp.3526

Schonert-Reichl, K. A., Oberle, E., Lawlor, M. S., Abbott, D., Thomson, K., Oberlander, T. F., & Diamond, A. (2015). Enhancing cognitive and social–emotional development through a simple-to-administer mindfulness-based school program for elementary school children: A randomized controlled trial. *Developmental Psychology*, *51*(1), 52-66. https://doi.org/10.1037/a0038454

Schimmack, U. (2010). What multi-method data tell us about construct validity. *European Journal of Personality: Published for the European Association of Personality Psychology*, *24*(3), 241-257. https://doi.org/10.1002/per.771

Schimmack, U. (2021). The validation crisis in psychology. *Meta-Psychology*, 5. https://doi.org/10.15626/MP.2019.1645

Schmidt, M. (2003). Hit or miss? Insight into executive functions. *Journal of the International Neuropsychological Society, 9*, 962–964. https://doi.org/10.1017/S1355617703230162

Scudder, M. R., Lambourne, K., Drollette, E. S., Herrmann, S., Washburn, R., Donnelly, J. E., & Hillman, C. H. (2014). Aerobic capacity and cognitive control in elementary school-age children. *Medicine and Science in Sports and Exercise*, *46*(5), 1025–1035. https://doi.org/10.1249/MSS.0000000000000199.

Sethi, A., Mischel, W., Aber, J. L., Shoda, Y., & Rodriguez, M. L. (2000). The role of strategic attention deployment in development of self-regulation: Predicting preschoolers' delay of gratification from mother–toddler interactions. *Developmental Psychology*, *36*(6), 767-777. https://doi.org/10.1037/0012-1649.36.6.767

Shrier, I., & Platt, R. W. (2008). Reducing bias through directed acyclic graphs. *BMC Medical Research Methodology*, *8* (70), 1-15. https://doi.org/10.1186/1471-2288-8-70

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: a meta-analysis. *Pediatric Exercise Science*, *15*(3), 243-256. https://doi.org/10.1123/pes.15.3.243

Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., & Stine-Morrow, E. A. (2016). Do "brain-training" programs work?. *Psychological Science in the Public Interest*, *17*(3), 103-186. https://doi.org/10.1177/1529100616661983

Simonsohn, U., Simmons, J., & Nelson, L. D. (2022). Above averaging in literature reviews. *Nature Reviews Psychology*, *1*(10), 551-552. https://doi.org/10.1038/s44159-022-00101-8

Simpson, A., Riggs, K. J., Beck, S. R., Gorniak, S. L., Wu, Y., Abbott, D., & Diamond, A. (2012). Refining the understanding of inhibitory processes: How response prepotency is created and overcome. *Developmental Science*, *15*(1), 62-73. https://doi.org/10.1111/j.1467-7687.2011.01105.x

Singh, A., Uijtdewilligen, L., Twisk, J. W., Van Mechelen, W., & Chinapaw, M. J. (2012). Physical activity and performance at school: a systematic review of the literature including a methodological quality assessment. *Archives of Pediatrics & Adolescent Medicine*, *166*(1), 49-55. https://doi.org/10.1001/archpediatrics.2011.716

Singh, A. S., Saliasi, E., Van Den Berg, V., Uijtdewilligen, L., De Groot, R. H., Jolles, J., ... & Chinapaw, M. J. (2019). Effects of physical activity interventions on cognitive and academic performance in children and adolescents: a novel combination of a systematic review and recommendations from an expert panel. *British Journal of Sports Medicine*, *53*(10), 640-647. http://dx.doi.org/10.1136/bjsports-2017-098136

Smid, C. R., Karbach, J., & Steinbeis, N. (2020). Toward a science of effective cognitive training. *Current Directions in Psychological Science*, *29*(6), 531-537. https://doi.org/10.1177/0963721420951599

Smithers, L. G., Sawyer, A. C., Chittleborough, C. R., Davies, N. M., Davey Smith, G., & Lynch, J. W. (2018). A systematic review and meta-analysis of effects of early life non-cognitive skills on academic, psychosocial, cognitive and health outcomes. *Nature Human Behaviour*, *2*(11), 867-880. https://doi.org/10.1038/s41562-018-0461-x

St Clair-Thompson, H. L., & Gathercole, S. E. (2006) Executive functions and achievements in school: Shifting, updating, inhibition, and WM. *The Quarterly Journal of Experimental Psychology, 59*, 745–759. https://doi.org/10.1080/17470210500162854

Stepankova, H., Lukavsky, J., Buschkuehl, M., Kopecek, M., Ripova, D., & Jaeggi, S. M. (2014). The malleability of working memory and visuospatial skills: a randomized controlled study in older adults. *Developmental Psychology*, *50*(4), 1049. https://doi.org/10.1037/a0034913

Sterling, T. D., Rosenbaum, W. L., Weinkam, J. J. (1995) Publication decisions revisited: The effect of the outcome of statistical tests on the decision to publish and vice versa. *The American Statistician,* 49, 108–112. https://doi.org/10.1080/00031305.1995.10476125

Strobach, T., & Karbach, J. (Eds.) (in press). *Cognitive training: An overview of features and application* (2nd ed.). Springer.

Stuss, D. T., & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. *Psychological Bulletin*, *95*(1), 3-28. https://doi.org/10.1037/0033-2909.95.1.3

Stuss, D. T., Levine, B., Alexander, M. P., Hong, J., Palumbo, C., Hamer, L., ... & Izukawa, D. (2000). Wisconsin Card Sorting Test performance in patients with focal frontal and posterior brain damage: effects of lesion location and test structure on separable cognitive processes. *Neuropsychologia*, *38*(4), 388-402. https://doi.org/10.1016/S0028-3932(99)00093-7

Strobach, T., Englert, C., Jekauc, D., & Pfeffer, I. (2020). Predicting adoption and maintenance of physical activity in the context of dual-process theories. *Performance Enhancement & Health*, *8*(1), 100162. https://doi.org/10.1016/j.peh.2020.100162

Sumner, P., Vivian-Griffiths, S., Boivin, J., Williams, A., Venetis, C. A., Davies, A., ... & Chambers, C. D. (2014). The association between exaggeration in health related science news and academic press releases: retrospective observational study. *Bmj*, *349 (g7015)*. https://doi.org/10.1136/bmj.g7015

Tennstedt, S. L., & Unverzagt, F. W. (2013). The ACTIVE study: study overview and major findings. *Journal of Aging and Health*, *25*(8 suppl), 3S-20S. https://doi.org/10.1177/0898264313518133

Titz, C., & Karbach, J. (2014). Working memory and executive functions: effects of training on academic achievement. *Psychological Research*, *78*(6), 852-868. https://doi.org/10.1007/s00426-013-0537-1

Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International journal of behavioral nutrition and physical activity*, *5*(1), 1-12. https://doi.org/10.1186/1479-5868-5-10

Tun, P. A., Miller-Martinez, D., Lachman, M. E., & Seeman, T. (2013). Social strain and executive function across the lifespan: The dark (and light) sides of social engagement. *Aging, Neuropsychology, and Cognition*, *20*(3), 320-338. https://doi.org/10.1080/13825585.2012.707173

Van der Niet, A.G., Hartman, E., Smith, J., & Visscher, C. (2014). Modeling relationships between physical fitness, executive functioning, and academic achievement in primary school children. *Psychology of Sport and Exercise, 15*(4), 319–325. https://doi.org/10.1016/j.psychsport.2014.02.010

Van den Berg, V., Saliasi, E., de Groot, R. H. M., Chinapaw, M. J. M. & Singh, A. S. (2019). Improving Cognitive Performance of 9–12 Years Old Children: Just Dance? A Randomized Controlled Trial. *Frontiers in Psychology*, *10*, 174. https://doi.org/10.3389/fpsyg.2019.00174

Vazou, S., Pesce, C., Lakes, K., & Smiley-Oyen, A. (2019). More than one road leads to Rome: A narrative review and meta-analysis of physical activity intervention effects on cognition in youth. *International Journal of Sport and Exercise Psychology*, *17*(2), 153-178. https://doi.org/10.1080/1612197X.2016.1223423

Vazou, S., & Smiley-Oyen, A. (2014). Moving and academic learning are not antagonists: acute effects on executive function and enjoyment. *Journal of sport & exercise psychology*, 36(5), 474–485. https://doi.org/10.1123/jsep.2014-0035

Verbruggen, F., & Logan, G. D. (2008). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences*, *12*(11), 418-424. https://doi.org/10.1016/j.tics.2008.07.005

Verburgh, L., Scherder, E. J., van Lange, P. A., & Oosterlaan, J. (2014). Executive functioning in highly talented soccer players. *PloS one*, *9*(3), e91254. https://doi.org/10.1371/journal.pone.0091254

Vestberg, T., Gustafson, R., Maurex, L., Ingvar, M., & Petrovic, P. (2012). Executive functions predict the success of top-soccer players. *PloS one*, *7*(4), e34731. https://doi.org/10.1371/journal.pone.0034731

Vestberg, T., Reinebo, G., Maurex, L., Ingvar, M., & Petrovic, P. (2017). Core executive functions are associated with success in young elite soccer players. *PloS one*, *12*(2), e0170845. https://doi.org/10.1371/journal.pone.0170845

Vestberg, T., Jafari, R., Almeida, R., Maurex, L., Ingvar, M., & Petrovic, P. (2020). Level of play and coach-rated game intelligence are related to performance on design fluency in elite soccer players. *Scientific Reports*, *10*(1), 1-10. https://doi.org/10.1038/s41598-020-66180-w

Voelcker-Rehage, C., Godde, B., & Staudinger, U. M. (2011). Cardiovascular and coordination training differentially improve cognitive performance and neural processing in older adults. *Fronties in Human Neuroscience*, *5*, 26. https://doi.org/10.3389/fnhum.2011.00026

Von Hecker, U., & Meiser, T. (2005). Defocused attention in depressed mood: evidence from source monitoring. *Emotion*, *5*(4), 456-463. https://doi.org/10.1037/1528-3542.5.4.456

Voss, M. W., Kramer, A. F., Basak, C., Prakash, R. S., & Roberts, B. (2010). Are expert athletes 'expert'in the cognitive laboratory? A meta-analytic review of cognition and sport expertise. *Applied Cognitive Psychology*, *24*(6), 812-826. https://doi.org/10.1002/acp.1588

Wass, S., Porayska-Pomsta, K., & Johnson, M. H. (2011). Training attentional control in infancy. *Current Biology*, *21*(18), 1543-1547. https://doi.org/10.1016/j.cub.2011.08.004

Walton, C. C., Keegan, R. J., Martin, M., & Hallock, H. (2018). The potential role for cognitive training in sport: more research needed. *Frontiers in Psychology*, *9*, 1121. https://doi.org/10.3389/fpsyg.2018.01121

Watson, A. J., & Bell, M. A. (2013). Individual differences in inhibitory control skills at three years of age. *Developmental Neuropsychology, 38*, 1–21. https://doi.org/10.1080/87565641.2012.718818

Waxer, M., & Morton, J. B. (2011). The development of future-oriented control: An electrophysiological investigation. *NeuroImage*, *56*(3), 1648-1654. https://doi.org/10.1016/j.neuroimage.2011.02.001

Weinstein, A.M., Voss, M.W., Prakash, R.S., Chaddock, L., Szabo, A., White, S.M., Wojcicki, T.R., Mailey, E., McAuley, E., Kramer, A.F., et al. (2012) The association between aerobic fitness and executive function is mediate by prefrontal cortex volume. *Brain. Behav. Immun*., 26, 811–819. https://doi.org/10.1016/j.bbi.2011.11.008

Welsh, M. C., Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology*, *7*(2), 131-149. https://doi.org/10.1080/87565649109540483

Westfall J, Yarkoni T (2016) Statistically controlling for confounding constructs is harder than you think. *PloS one, 11*(3), e0152719. https://doi.org/10.1371/journal.pone.0152719

Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental psychology, 44*(2), 575-587. https://doi.org/10.1037/0012-1649.44.2.575

Williamson, D., Dewey, A., & Steinberg, H. (2001). Mood change through physical exercise in nine-to ten-year-old children. *Perceptual and Motor Skills*, *93*(1), 311–316. https://doi.org/10.2466/pms.2001.93.1.311

Wylie, G., & Allport, A. (2000). Task switching and the measurement of “switch costs”. *Psychological Research*, *63*(3), 212-233. https://doi.org/10.1007/s004269900003

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). II. NIH Toolbox Cognition Battery (CB): Measuring executive function and attention. *Monographs of the Society for Research in Child Development*, *78*(4), 16-33. https://doi.org/10.1111/mono.12032