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*Editorial*

# Giving physical activity and cognition research 'some soul': focus on children and adolescents

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This editorial is a storytelling aimed to learn from the past "what's next" and how to move forward in research and praxis, trying to avoid just rehashing what has been done in the past with a "new edition of nothing new".

Physical activity (PA) and cognition research has its origins half a century ago, with a mixed focus on the transient effects of a single PA bout and the longer-lasting effects of chronic PA participation on brain and cognition (Etnier et al., 2020; McMorris, 2016). Both lines of acute and chronic PA-cognition research were 'adult-born'. Later on, authors extended their focus to the developmental age, with a major spotlight on preadolescent children (Pesce & Ben-Soussan, 2016) driven by the converging interest of developmental and exercise neuroscientists (Diamond and Lee, 2011; Hillman et al., 2008), and educational psychology scientists (Mavilidi et al., 2018; Vazou et al., 2019). Most of this research concentrated on executive functions (i.e., high-level cognitive skills responsible for cognitive control), because they are important predictors of functional outcomes such as academic achievement and overall regulation of goal-oriented behaviors.

Consistent evidence from a first line of research highlighted that physical fitness is associated with brain health, executive function and memory in preadolescent children (Chaddock et al., 2011). While this line mostly focused on cardiovascular fitness, later publications encompassed children's muscular fitness and motor coordination, showing benefits to specific brain structures and functions (Esteban-Cornejo et al., 2019; Ludyga et al., 2021; Meijer et al., 2021). A narrow focus on cardiovascular fitness has been further challenged by evidence obtained with behavioral assessments of cognition. Studies with school-aged children suggest a stronger relation of executive functions with motor coordination rather than with energetic-determined facets of fitness (e.g., Schmidt et al., 2017). Studies with young athletes, beyond suggesting that sport practice provides children and adolescents a general cognitive advantage (Contreras-Osorio et al., 2021), also highlight that the cognitive demands of sports are a more powerful predictor of cognitive performance than cardiovascular fitness

(Ballester et al., 2015; Sanabria et al., 2019). Executive control benefits have been consistently observed, as early as childhood (e.g., Ballester et al., 2018; Moratal et al., 2020), as in young adults (e.g., Ballester et al., 2019), in athletes with expertise in open skill sports (e.g., soccer, basketball) that require more cognitive engagement and flexibility to face situational uncertainty than closed skill sports (e.g., track and field, cycling).

Progressively, the search for mechanisms underlying the PA-cognition relation was no longer limited to the "cardiovascular fitness hypothesis" related to PA dose, but complemented with the "cognitive stimulation hypothesis" related to the cognitive and coordinative demands of PA (Best, 2010; Pesce, 2012). This more nuanced level of investigation unveiled a divergence between the two neuroscientific 'souls' of PA and cognition research (i.e., developmental and exercise neurosciences) in the importance attributed to parameters of PA dose (Hillman et al., 2019) vs. cognitive, coordinative and emotional PA features (Diamond & Ling, 2016, 2019). Building bridges between the two 'souls', the allocation of mental resources required during skill acquisition may lead, interactively with the level of physical energy expenditure, to largest executive function benefits (Tomporowski & Pesce, 2019). Meta-analyses of intervention research supported the role of cognitive engagement in PA to aid the development of executive functions as the ability to inhibit interference, routine thoughts and impulsive behaviors (Álvarez-Bueno et al., 2017; Vazou et al., 2019).

The benefits of cognitive engagement, however, emerge from chronic PA (e.g., Egger et al., 2019; Schmidt et al., 2015). As regards acute PA, the pattern of results is mixed or even reverse, with some studies showing larger cognitive benefits elicited by simply aerobic than by cognitively engaging PA (De Greeff et al., 2018; Paschen et al., 2017). Likely depending on age and developmental status, cognitive engagement while moving may be "too much of a good thing" (Egger et al., 2018, p. 178). At preschool age, it seems adequate to fulfil a minimum complexity threshold (Ureña et al., 2020). At adolescent age, a high cognitive complexity in PA may represent the optimal challenge (Benzing et al., 2016). Overall, the effect of acute cognitively demanding PA on cognitive performance is expected to be curvilinear (Schmidt et al., 2021). It is determined by several variables such as PA intensity, duration, and cognitive engagement, which should consequently be considered together to avoid overload.

Thus, the take-home message is the recommendation to expose children and adolescents to quality PA that elicits challenging levels of physical effort and cognitive (especially executive function) engagement (García-Hermoso et al., 2021; Pesce et al., 2021), finely tuning physical, cognitive and emotional demands to the developmental level and expertise to reach and maintain an optimal challenge point. This is, for example, a peculiar feature of virtual reality PA games (Benzing & Schmidt, 2018), which seem useful to boost cognition also in children and adolescents with special needs (e.g., cancer survivors: Benzing et al., 2020), both acutely and chronically (e.g., Attention Deficit Hyperactivity Disorder: Benzing et al., 2018, 2019). The usefulness of this evidence for practice depends on the pursued goal of acute and chronic PA. A single PA session can be used in a learning context to elicit a transient cognitive enhancement that helps children concentrate optimally on a following lesson. Regular PA can be exploited to gain longer-lasting functional (especially executive function) outcomes that are relevant for academic and sport achievements.

However, the storytelling does not end here. Using the wide-angle lens of a meta-review, we can detect a disproportional growth of reviews, compared to primary studies at the base of the pyramid, with partially different foci and inconsistent conclusions (Pesce et al., 2021). The first position stand of the American College of Sports Medicine concerning PA effects on children's cognition reported positive conclusions (Donnelly et al., 2016) that were disconfirmed by the inconsistent outcomes of successive reviews,

one of which conducted by a wide international expert panel (Singh et al., 2019; Wassenaar et al., 2020). This does not mean that after half a century of developmental exercise and cognition research, we must agree on that "The only thing that I know is that I know nothing" (putative proposition by the Greek philosopher Socrates). Nor can we agree on the simplistic conclusions of reviews that more high-quality studies are needed. Even lesser can we transition empirical evidence into practice simply taking it as granted that findings obtained in standardized conditions may inform practice and policy development. We must evaluate whether the significant effects of individual efficacy studies are robust and of meaningful size, which factors may amplify or attenuate the effects and through which mechanisms (Caballero- Roman et al., 2021).

The emergence of inconsistencies in conclusions of evidence syntheses should encourage addressing the complexity of the PA-cognition relation with a joint empiricist and constructivist account of scientific explanation (Pawson et al., 2006). This realistic approach allows not only exploring *what* works, that is, which physical, cognitive, emotional or social features of PA may act as an enrichment that benefits cognitive development. It also allows understanding *for whom* it works from an individual difference perspective and *under which circumstances* of delivery and setting it works, since causal mechanisms in complex interventions as PA programs may be triggered in one but not in another context (Pesce et al., 2018, 2021). Thus, we call for the promotion of an integrative and multidimensional perspective. This might be a way – novel in PA and cognition research - to address the questions that animate (literally "give some soul" to) the research with children and adolescents: understanding the impact of PA on the brain in a phase of ongoing maturation and plasticity, and capitalizing on the practical implications for the promotion of health development and educational/sport achievement.

**Conflicts of Interest:** The authors declare no conflict of interest.

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