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POSITION PAPER

Physical Activity Meets Creativity: A "CreActive" Motor Development and Learning Perspective

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The purpose of this position paper is to raise awareness of intriguing interdisciplinary intersections among physical activity, motor learning/development, creativity, and cognition. A major intersection is the potential of physical activity that involves the effortful learning of novel and/or complex movement actions to elicit cognitive engagement and influence brain structure and function. Exploring this intersection is meaningful when considering the increasingly holistic understanding of motor learning/development that requires being able to think across boundaries. Indeed, a holistic view means adopting a multidisciplinary approach to address the changes in both motor and nonmotor skill domains triggered by motor learning/development and an interdisciplinary approach to address the interconnected nature of those changes. We see motor skills as having a broader scope, encompassing the functionality and originality that characterize creative movement actions subserved by both deliberate, cognitively demanding and unintentional, sensorimotor processes. To inform practice development, we highlight where physical activity meets creativity: at the crossroad of kinesiology, developmental neuroscience, and pedagogies that embrace an exploration-based, creativity-enhancing approach to motor learning. Finally, we propose how working at this crossroad may allow us to take a transdisciplinary step forward in evolving practices of holistic development promotion that have creative motor skill acquisition at their core.

Keywords: motor creativity, executive function, exploration, holistic, motor learning

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Key Points

- Intersections of physical activity, motor learning/development, creativity, and cognition research can contribute to an increasingly holistic view on development.
- An intersection converges on a common denominator—the mechanism of skill acquisition—as a potential pathway through which physical activity may benefit cognition and creativity.
- A perspective on motor skill acquisition that encompasses complementary pathways to creativity—conscious cognitive and unconscious sensorimotor—may inform the development of movement education and holistic education through movement.

An Intriguing Convergence of Research Lines

Our storytelling starts at the time when research lines, which have their origins in different fields, led on the one side by motor development scientists and on the other side by physical activity and cognition scientists, gradually converged toward a shared interest. Motor development scientists paved the way for motor skill competence to enter the public health arena, first proposing (Stodden et al., 2008) and then accumulating further evidence that motor competence predicts positive trajectories of physical health (Barnett et al., 2022; Robinson et al., 2015). This flourishing of research naturally expanded toward the predictive role of motor skill competence for the development of cognitive and socioemotional skills (Hill et al., 2024; Van der Fels et al., 2015). On the other side, among physical activity and cognition researchers, first claims were made to consider the role of the qualitative characteristics of physical activity (Best, 2010; Pesce, 2012), going beyond a metabolic understanding of the effects of physical activity on cognition (Meijer et al., 2020; Stillman et al., 2020). Such claims paved the way for growing research and intense debate (e.g., Diamond & Ling, 2016, 2019; Hillman et al., 2019; Vazou et al., 2019) on whether and to what extent the motor coordination demands of physical activity and the related acquisition of motor skill competence can explain its beneficial effects on cognition.

The intersection of these related yet distinct lines of research converges on a common denominator, that is: skill acquisition. The processes of skill acquisition that begin with a high reliance on conscious control and a still low efficiency in cognitive control of movement planning and execution (Immink et al., 2020) are hypothesized as one of the pathways through which physical activity may benefit cognition (Tomporowski & Pesce, 2019). This hypothesis received confirmation in meta-analyses performed by physical activity and cognition scientists. Coordinative physical activity, implicitly referring to the demands of physical activities that inherently involve motor skill learning, seems to be more beneficial for cognition than other physical activity types with predominately metabolic and muscular demands (Ludyga et al., 2020). This conclusion is also confirmed in children and adolescents for high-level cognition—that is, executive function—(Ludyga et al., 2022), which is most relevant for academic and social fulfillment.

Indeed, coordinatively demanding physical activity types involve multiple, often novel and/or complex movements, which require executive control resources early in learning and, after the progression toward automaticity, every time movement actions need to be consciously attended to in dynamic environments (Buszard et al., 2017; Immink et al., 2020).

A Research Crossroad Emerging in the *Journal of Motor Learning and Development*

Interest in the role played by coordinative and motor skill acquisition demands in the observed cognitive benefits of physical activity is rooted in physical activity and cognition research. Intriguingly, however, the first review that has the merit to have explicitly addressed the causal role played by motor skills learning for executive function development has been performed by motor learning scientists and recently published in the *Journal of Motor Learning and Development* (Richter et al., 2024). Although in their systematic review of programs, evidence of beneficial effects of motor learning on executive function was found, these effects seem unaffected by training features such as program duration, openness/closeness of the environmental motor skill context, training conditions, and degree of variability in practice design (Richter et al., 2024).

Thus, motor learning demands per se, rather than any specific feature of motor learning programs, seem to benefit children's and adolescents' executive function. Nevertheless, most studies do not consider the interplay between the motor learning demands and the characteristics of the learner, neglecting the functional task difficulty—that is, the individually different optimal challenge in practice needed to facilitate learning (Guadagnoli & Lee, 2004; Hodges & Lohse, 2020). In developmental physical activity and cognition research, it has been proposed that a given level of motor task difficulty is needed to find an association with cognitive, especially executive functions (Willoughby & Hudson, 2023). However, interventional studies that search for a cognitively optimal challenge point to reap the largest cognitive benefits from physical activity are still the exception (Pesce et al., 2013). Also, there are only very few studies assessing motor learning outcomes and directly testing whether they can explain executive function outcomes (e.g., Pesce et al., 2016). This paucity limits the possibility to draw conclusions on a causal association of cognitive benefits with motor learning.

Moreover, Richter et al. (2024) highlighted the frequent lack of details on the motor learning design characteristics that, being classified as "unclear," have likely reduced the discriminability of relevant task- and context-level moderators. This aligns with the claim to consider the still neglected role of contextual factors that may moderate physical activity effects on cognition and trigger mechanisms, such as motor learning, that explain them (Pesce et al., 2023). In the studies reviewed by Richter et al. (2024), information on the fundamental versus sport-specific type of motor skill training is provided. However, this distinction—commonly made in physical activity and cognition research—does not suit the increasingly differentiated classification scope of motor skills noted in recent motor development literature. In the last few years, motor development scientists have proposed the construct of "foundational" motor skills, which

expand the typical fundamental—locomotor, object-control, and stability—skills categories (Hulteen et al., 2018). These skills are considered important for promoting lifetime physical activity and for exploring and discovering a variety of functional motor solutions in dynamic environments (Ng & Button, 2018; Rudd et al., 2021).

A Place for Creativity in the Interrelations Among Physical Activity, Motor Competence, and Cognition

We make the case that the issue of exploring to learn and, relatedly, learning to explore (Hacques et al., 2021; Stodden et al., 2021) expands the frame of the interrelations among physical activity, motor skills, and cognition by encompassing not only the functionality of movements but also the originality of movement solutions that characterizes motor creativity (Orth et al., 2017). Motor creativity is the ability to produce functional solutions to movement tasks that are novel, original, and pertinent (Tocci et al., 2022). Orth et al. (2017) proposed a bidimensional model of motor creativity in which creative actions are granted by the inherent complexity and variability in coordination and control (Tuller et al., 1982; Turvey et al., 1982). In different phases of a motor learning task, which inherently includes exploration to detect and pick up information relevant to action control, we can explore and find a brand new coordination type (originality) as well as refine it, exploring how to optimize aspects of its control (functionality; Orth et al., 2017). From this perspective, motor learning is conceived of as a process of exploration of opportunities for action in the learning environment and discovery of motor solutions that satisfy the constraints posed by the physical activity task and environment (Hacques et al., 2021).

This exploration-based, creativity perspective on motor skill acquisition is best suited to bridge research lines of motor development/learning scientists and physical activity and cognition scientists interested in whether the nature and magnitude of the cognitive benefits of physical activity depend on the motor learning demands (Richter et al., 2024) and the creativity demands of the physical activity interventions (Vasilopoulos et al., 2023). Like Richter et al. (2024), Vasilopoulos et al. (2023) also could not find evidence that specific physical activity characteristics may render the interventions more efficacious to promote children's cognitive development. The characteristics of the reviewed interventions were classified using the lens of creativity demands: the variation of physical activity tasks, the interaction with mates and opponents, the use of divergent tasks, open-ended instruction and props, and the affordances of outdoor environments. Both reviews (Richter et al., 2024; Vasilopoulos et al., 2023) classified the studies as a function of the degree of variability of practice. This is a relevant feature of practice in two main accounts of motor learning: one grounded in cognitive information theory (Shea & Kohl, 1990), proposing that experiencing task variations leads to the development of the memories (schemata) relevant to motor learning, and the other grounded in dynamical systems theory (Newell & Slifkin, 1998), proposing that exposure to variations in task constraints facilitates the emergence of solutions in motor learning. Variability of practice is not only considered an efficacious feature of practice design to motor skill acquisition but is also commonly reported in motor learning and creativity interventions designed to

foster cognition (Lage et al., 2015; Pesce et al., 2019). However, the description of the way "variability" was applied in the individual studies reviewed in Richter et al. (2024) and Vasilopoulos et al. (2023) did not allow, in the most cases, for the identification of the underlying pedagogy. The latter, however, could be crucial in making the practice design more or less effective in fostering children's cognition (Pesce et al., 2019; Rudd et al., 2019).

Different Pathways to Creativity and the Role of Behavioral Flexibility

In creativity-fostering physical activity interventions, the underlying pedagogy mostly applies variability of practice in a "nonlinear" and "productive" manner wherein physical activity tasks are open ended, designed to challenge the learner's ability to produce their own solutions (i.e., not to reproduce observed movement patterns, following a "direct instruction" model). Nevertheless, creativity is too often identified with the sole divergent discovery of multiple solutions that are not right or wrong but all equally right as far as they are pertinent to the task. There is a frequent neglect of the complementary role of convergent processes along a divergent–convergent continuum (Eymann et al., 2024) in which divergently generated, novel, and loose solutions are evaluated to generate an original and functional product (Dietrich & Zakka, 2023). Moreover, it is often neglected that different strategies along the creative process can vary in the degree of cognitive engagement. The dual pathway to creativity model developed in the creative thinking domain (Nijstad et al., 2010) assumes that we can achieve originality by exploring either several categories of ideas with flexibility or few categories in depth with persistence. Applied to the motor creativity domain (De Fano et al., 2023; Richard et al., 2018), this corresponds to exploring qualitatively different categories of movement coordination and new control solutions of the same coordination pattern, respectively. A common historical example of this process is the discovery of the Fosbury flop versus the variations of the arm movement control to further optimize the parametrization of the flop performance (Orth et al., 2017).

Both pathways of surveying several movement categories (flexibility) or variations of the same movement pattern (persistence) to generate original solutions converge into what motor learning scientists define as behavioral flexibility in motor skills, which is "the ability to achieve the same task outcome using different movement solutions" (Ranganathan et al., 2020, p. 1). To distinguish substantial qualitative motor coordination changes from small variations of the same movement pattern (i.e., changes in parametrization), motor learning scientists make the case that behavioral flexibility can be explicit or implicit. Explicit flexibility can be operationally defined as more "strategy-like" and better suited to qualitative coordination changes that rely on cognitive skills. Implicit flexibility can be described as more "synergy-like" and better suited to variations in movement parametrization that do not require cognitive control (Ranganathan et al., 2020). The different involvement of cognition in behavioral flexibility strategies is consistent with evidence that a broad focus of attention (Wulf, 2013) is engaged for surveying different movement coordination categories (Moraru et al., 2016).

For example, using a broad attention to overcome an obstacle close to a wall, we can make an "explicit" decision on whether to walk around the obstacle, considering the wall as a mere limit of the movement space available, or exploit the wall as a support surface to spring over the obstacle, as in parkour. Instead, a broad attention is likely not needed to explore variations within the same movement category, as when a too "short" throw to a target merely requires an increase of force output (i.e., making an "implicit" change in parameterization of a same coordination pattern). This suggests the need for a more nuanced description of intervention paradigms to make appropriate and differentiated hypotheses on their effects on cognitive functions.

Arguments Against Siloed Thinking in Motor Creativity Research

The level of engagement of cognitive functions in motor creativity unveils intriguing commonalities with Dietrich's (2019) view on creativity. This view distinguishes between the extremes of a deliberate and effortful search for creative solutions that requires cognitive control and a spontaneous, unintentional emergence of creative ideas. In his neuroscientific approach, Dietrich (2019) provides evidence that the deliberate and spontaneous modes of creativity are supported by distinct neural networks involving different brain areas. The cognitive control needed for generating and processing creative ideas in a deliberate manner is ensured by the activation of the executive control network (Dietrich, 2019), whereas its deactivation and the activation of the default mode network facilitate the unconscious associations of ideas and mind wandering (Dietrich, 2019; Shofty et al., 2022), and the dynamic interaction of the two networks (Spreng et al., 2013) underlies and supports overall creative processes (Beaty et al., 2018).

Here, one more time, the usefulness of looking at scientific intersections emerges. Dietrich (2019)—who also performed research on the physical activity–cognition relation and, therefore, does not disregard the role played by action-related neural networks in creative thinking (Matheson & Kenett, 2020)—has proposed a third "flow" mode of creativity, which is hybrid and embodied and involves both conscious cognitive and unconscious sensorimotor processes. According to Dietrich (2019), the flow mode of creativity can be engaged when a learner who is consciously focused on an exploratory task perceives opportunities for action in the environment that trigger sensorimotor processes. Thus, Dietrich's (2019) neuroscientific language sounds intriguingly similar to the language of motor learning scientists who conceive motor learning as a process of exploration and discovery, observed with the lens of the widespread approach named "Ecological Dynamics" (Hacques et al., 2021; Seifert et al., 2017).

Outlook

This last crossroad between cognitive and motor learning science in the study of top-down (i.e., cognitively demanding) and bottom-up (i.e., sensorimotor) processes that contribute to creativity is synthesized in the title of a paper that reports the effects of a creativity-enhancing physical activity intervention: "Giving ideas

some legs, of legs some ideas?" (Tocci et al., 2022). In other words: Are creative actions generated consciously as creative ideas that are thereafter enacted? Or do they unconsciously emerge in the attempt to satisfy task constraints without an antecedent creative idea? These pathways to creativity—the effortful cognitive and the cognitively effortless sensorimotor—are not mutually exclusive but complementary (Pesce & Tocci, 2024). Training their interplay, rather than exercising the sole ability to sustain effortful cognitive control along a creative motor learning process, may be a key to reap the largest cognitive benefits along with motor development and learning benefits.

To move steps forward in this direction, more transdisciplinary research that encompasses and intersects motor development and learning and neurocognitive sciences may support movement education and holistic education through movement (Anderson, 2020). Indeed, motor learning occurs within the backdrop of motor development, which, in turn, is influenced by exposure to motor learning experiences, and both are intertwined with the development of cognitive skills and creativity. From a motor learning perspective, it is worthy to investigate whether we can capitalize, as early as childhood, on mutually reinforcing relations of the acquisition of motor skills with executive function skills and creativity. A bidirectional pathway may build not only on the potential of motor learning activities to foster executive control skills (Richter et al., 2024) needed to be creative but also on the potential of creative thinking skills to foster motor learning strategies (Ghanamah, 2024). It is our hope that these considerations will inform the development of new cross-boundary research that may find an optimal venue in the *Journal of Motor Learning and Development*, which especially encourages "research that crosses traditional divides between physical, cognitive, and social domains in motor learning and development."

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