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Thibault Deschamps

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Perspectives

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Thibault Deschamps *

Nantes Université, Movement - Interactions – Performance, MIP, EA 4334, F-44000 Nantes, France; E-Mail: thibault.deschamps@univ-nantes.fr

* **Correspondence:** Thibault Deschamps; E-Mail: thibault.deschamps@univ-nantes.fr

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Let's consider the issues of exercise and cognitive function from a different angle, for instance, by moving from a sitting position to standing. Seeing something from different perspectives not only reflects our cognitive flexibility [1] but also has a direct impact on executive performance. Interestingly, some recent studies have reported a smaller Stroop effect when standing than sitting [2-3] or stepping backward [4]. This evidences that body posture enhances selective attention and cognitive control. Through these examples, the assumption presented here is that our daily cognitive functioning is closely linked to our sensorimotor present and vice-versa. Our abilities to move are cognitively vital. Hence a call for a new psychology of movement and, by extension, of exercise emerges [2], with consequences for how to address the role and the effects of movement and exercise on cognitive function.

1. Movement and Cognition are Intertwined: An Important Illustration in Older Adults

The understanding of the relationship between age-associated declines in cognitive function, impaired (loco) motor function, and reduced mobility is evolving. These major (pathological) features have generally been viewed as distinct and separate domains for a long time. As a specific

example, fall risk in older adults—a major cause of morbidity and mortality [5]—has typically been considered to be unrelated to age-associated changes in cognitive function. However, extensive epidemiological studies have shown that cognition and mobility (and the functional changes underlying the reorganization of the neuro-musculoskeletal system) are intertwined, particularly as the age increases [6]. Thus, older adults with cognitive impairments have been found to have a 10 to 15 times greater risk of developing Alzheimer's disease, as well as a higher risk of gait decline and falls [7-9].

Undoubtedly, thinking, information processing, and moving share behavioral and etiological factors that can evoke further research for the prevention and treatment of these disorders. Mechanistically, brain networks that control movement overlap with the networks involved in the executive performance. For instance, gait slowing and dementia, which often co-exist, have been attributed to the changes in specific brain regions [10-11]. Damage to the microstructural integrity of white matter nerve fibers, whose connections are important for the integration of information from large-scale networks in the brain, is associated with slower walking in older adults and culminates in disorders of cognition, movement, and mood [12-13]. Hence, a challenge that must continue to be addressed concerns the identification of motor signatures that may guide diagnosis and treatment decisions [14-15]. For example, recent studies focusing on such markers have already found that gait control under different (dual-task) conditions could aid in detecting patients with mild cognitive impairment who are at a higher risk of progression to dementia [16], and specific adverse health outcomes (e.g., basic activities of daily life and disability) [17].

2. Toward a Multidimensional Approach of Individual Cognitive-Motor Functioning

Besides the fundamental ethical issues that it raises, it would be premature, perhaps presumptuous to say to a person that "show me how you walk, and I will tell your future health outcomes". However, a movement-based approach for clinical and basic research in understanding the cognitive-motor interactions that can affect pathways to disability should involve a "minimum-battery" of tests [18] at different specific, but interconnected, levels of analysis (balance between muscle force, muscular coordination, executive functions and brain activity, and typical signatures in behavioral motor tasks). For example, recent studies have shown that muscle coordination signatures (defined as the distribution of muscle force among individual muscles to produce a locomotor task [19]) can be used with a high accuracy to identify the corresponding individual [20-21], with the assumption that the identification of these individual signatures will ultimately help diagnose and predict the outcomes of musculoskeletal diseases [22]. Hence, an improved individual-level prediction may lead to improved clinical care and clinical trials [23]. It becomes highly intriguing to adopt a more holistic approach to address how the neuro-cognitive-musculoskeletal system transiently assembles and dismantles its components into functional units to meet task demands, and to better challenge new insights into personalized prevention, management, and rehabilitation of the cognitive and motor impairments in individuals at the risk of developing a chronic condition.

3. Does a Movement Really Work to Maintain Your Brain?

The sedentary lifestyle and insufficient participation in physical activity have become a real health problem. Although the positive effects of regular physical activity on the physical and

mental health and on the prevention of chronic diseases are well documented in the literature [24], the benefits of aerobic-exercise and resistance-training interventions for executive functions are more controversial [25-26]. It can be admitted that the current debate is largely inconclusive but provides promising research opportunities [27-29]. The main starting point that I currently advocate is a new psychology of movement and exercise that would extend beyond a simple and basic physical activity, like walking, cycling or swimming. These activities are necessary (for being physically active, having better aerobic fitness, and gaining health benefits) [30], but are presumably inefficient in maintaining cognitive plasticity and improving executive functions at all stages of life [31-32]. This may look a minor issue but the ability to overcome the impulse not to go for running or to resist the strong urge of not going to swimming, when those physical activities have been planned, even socially declared (such as a New Year resolution, or forced by an old habit), underlines the major interest to challenge and improve the executive functions. This cycle is even more virtuous in that physical activity may facilitate the self-regulation and adoption of positive health behaviors, in addition to a probable exercise-related improvement in executive functions across the whole life span [33-34].

Hence, developing new efficient cognitive enhancement strategies needs to be discussed through the promising concept of (sequential or simultaneous) motor-cognitive training [e.g., 35-37]. No one can reasonably imagine the positive effects that might arise by supervised exercise activities on the global cognition or executive function in small groups of “seated” older people at a nursing home. Such supervised simple exercises might include passing a ball to a seatmate, rising from the chair, stepping, or walking a little further. It seems to be still too limited and vastly inefficient, even in the case of high-intensity functional exercise programs [38]. The executive demands are very often insufficient. When considering the cognitive training studies in older adults, in which specific targeted cognitive processes (e.g., working memory) are thought to be boosted using in-house computer programs and video games, some improvements were shown in the trained executive functions, associated with great transferability to untrained skills [39-41]. Beyond the current debate on the robustness of these results (e.g., [42]), the movement control demands are inadequate.

4. The Relevance of Physical-Cognitive Dual-Task Training

Movement is more than a mere link between cognition and physical activity; it is the core element with mutual implications. This issue has widely been addressed in the literature through dual-task training [37, 43-44]. For example, specific nonmotor dual-task training has a positive influence on motor control in healthy older adults, as evidenced by significant improvements in postural balance only in the training group [45]. Besides this, several other studies have shown that motor control of daily motor tasks (gait, balance, etc.) depends, at least in part, on executive functions [46-49]. Accordingly, since executive functions are strongly altered in older adults, motor control is impaired, which is manifested by impairments in balance or locomotory tasks [50-51]. Thus, the question arises whether gait and postural control in “unstable” older adults can be improved by training executive functions. Of course, it is possible [45]; however, a different approach, consisting of training cognitive functions through the practice of complex motor skills, has also been proposed. Although this approach is not a novel one [52], the purpose of such a cognitive-motor training program, compared to the classic ones using mental tasks, is to target

cognitive functions as they are specifically involved in movement control and *de facto* in physical activities and most sports.

The promising approach of "thinking while moving or moving while thinking" [53] is of major interest from at least two standpoints. First, it would address the cognitive plasticity and executive function issues in a new psychological perspective of movement that is involved at any time [2], rather than assessing the executive measures outside a real daily life context. Second, it reaffirms one of the central purposes in sports sciences, namely, to better understand the sensorimotor mechanisms in relation to executive function. Interestingly, most physical activities and sports meet these "specifications" [see 27 for details]. They require a strong involvement of the executive functions due to the need to keep focusing on what we choose, meanwhile suppressing attention to other stimuli such as not to act impulsively (from the first feint of opponent's attack), to translate instructions (of a coach) to a plan action, to hold information in mind and work with it, and to be flexible enough to adjust efficiently to the changing physical and social environment (e.g., change in strategy of opponents). Inhibition, working memory, and cognitive flexibility are intrinsically essential to meet the changing demands. Hence, investigating the impact of an enhanced cognitively challenging physical activity or an enhanced cognitive training with real motor demands (i.e., combined multi-domain interventions [54-55]) offers promising research opportunities. Let us keep in mind that human beings have not evolved for alighting or resting but for moving [56]; movement is cognitively vital.

In summary, the development of new efficient cognitive enhancement strategies can be addressed by employing the concept of (sequential or simultaneous) motor-cognitive training. Admittedly, some relevant research gaps pertaining to the interaction between everyday movements or physical activity and cognitive plasticity are now better identified. However, concrete knowledge based on research evidence is still required to investigate in-depth, for example, whether the personalized motor-cognitive training-related improvement in executive functions plays a pivotal role in a long-term commitment to physical practice.

Author Contributions

Drafting of the article: T. Deschamps.

Competing Interests

The author reports no conflicts of interest.

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