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REVIEW ARTICLE

Integrating Human Movement in Learning: Advancements in Language Instruction, Multimedia, and Theory

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Abstract

Human movement plays a foundational role in cognition and learning. This topical collection brings together theoretical and empirical work examining how gestures, physical activity, and virtual movement enhance learning in language, multimedia, and activity-based learning. Regarding language learning, interacting with virtual object improves vocabulary learning, especially for learners with low language aptitude. Additionally, emotional narratives support memory more effectively than neutral ones, while instructed gesturing may hinder recall for some learners. In multimedia learning, pointing improves attention and comprehension, whereas tracing can impede learning due to cognitive overload. For activity-based learning, theoretical contributions offer frameworks for integrating movement into learning tasks, emphasizing mechanisms such as generative learning, social cognition, and offloaded processing in areas ranging from digital education to stimming behaviors. Together, these studies offer insights for designing effective, movement-based instruction across diverse learning environments and populations, underscoring the dynamic relationship between bodily action and cognitive development in education.

Keywords Human movement · Gestures · Learning · Language instruction · Multimedia

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Introduction

Physical movements have played a role in our communication, learning, and cognition throughout our history. In early conceptualizations of learning and development, human movement was already considered fundamental to children's cognition. For example, Vygotsky discussed gestures as a means to support linguistic and cognitive development (1978). Similarly, Piaget mentions gestures and imitation of human movement as foundational to a child's cognitive development (1952). Over the years, the ways in which we move our bodies and how this affects learning have grown to encompass a much-investigated area of educational research. Whether this involves fine movements, such as hand gestures and facial expressions, or gross movements such as full body enactment and physical exercise. One simple example of this in application is how Maria Montessori first embedded the tracing of letters on sandpaper to support children's writing more than 100 years ago (1912). Since then, inquiry into the role that human movement plays has grown widespread. This issue shows how movement—like gestures or activity—helps learning in language, multimedia, and ideas, from Montessori to virtual reality (VR).

Theoretical Foundations of Movement and Learning

From a theoretical viewpoint, embodied cognition (Foglia & Wilson, 2013; Wilson, 2002) offers a commonly cited conceptual link between human movement and learning that cognition is situated in a real-world environment where bodies and brains are inextricably linked. This has important implications for education. The movements we make with our body, are not only the output of thinking processes (cognition → movement) but also have the potential to impact cognitive processing (movement → cognition). This line of thinking has been expanded into evolutionary educational psychology (Geary, 2002, 2008). It is posited that humans are predisposed to learning certain types of knowledge, with the use of movements that require minimal, if any, cognitive resources to perform (Paas & Sweller, 2012). Specifically, theorizing within Cognitive Load Theory (CLT; Sweller et al., 2019) distinguishes between biologically primary knowledge and biologically secondary knowledge. Biologically primary knowledge refers to knowledge and skills that people have evolved to acquire and require little cognitive effort and no explicit instruction (e.g., gesturing). Biologically secondary knowledge refers to knowledge and skills that can only be acquired with instruction and deliberate cognitive investment (e.g., arithmetic). Key in the argument is that biologically primary knowledge (e.g., using the hands to represent an object in space) can be used to support the acquisition of biologically secondary knowledge (e.g., learning the meaning of the French word "maison").

Empirical Work on Movement And Learning

Increasing numbers of studies have evaluated the effects of physical movement interventions on a range of cognitive outcomes including memory, comprehension, executive functioning, and academic performance (for a meta-analysis, see Mavilidi et al., 2022). Studies range from using metaphoric gesture to support the learning of mathematics (Cook et al., 2012; Goldin-Meadow et al., 2001, 2009) to hand gestures and full-body enactment to learn an additional language (Mavilidi et al., 2015). From a psychophysiology and sports psychology perspective, physical activity outside of the classroom has been found to affect attention and cognition (Schmidt et al., 2016). Particularly executive function has been shown to benefit from exercise across age groups (Ludyga et al., 2016) and even support emotional recognition for younger adults (Aguirre-Loaiza et al., 2019). This has resulted in an increasing knowledge base of research into the educational benefits that movement may bring in general.

Building upon this foundation, researchers have also explored how different types of movement affect learning and cognition in different ways. Among both researchers and educational professionals, there is a continuing uncertainty regarding the extent to which physical movement needs to be aligned with the content of the learning task (i.e., content-alignment; Skulmowski & Rey, 2018) and whether these movements should be temporally connected to the learning task (i.e., content-integration; Mavilidi et al., 2018)). Recent work indicates that it is particularly relevant for physical movements to be integrated into the learning activity; the relevance of the movement to the content of the learning task appears less relevant (Mavilidi et al., 2022).

Research into the use of gestures and other human movements (e.g., finger tracing) has expanded into how such movements can support learning and cognition within different domains, as well as effects for individuals of different ages, and abilities. For example, gestures have been found to bring benefits to those with lower visual working memory capacity (Pouw et al., 2018) and to help the recognition performance of children with autism spectrum disorder (Goldin-Meadow & Alibali, 2013). Hand movements in particular have also been suggested to support storage and processing of information externally when cognitive demands are high (Pouw et al., 2014).

Given these robust theoretical and empirical foundations, the research investigating the effects of human movement to support learning and cognition is varied and complex. This line of research involves a variety of research methods, instruments, approaches, and applications. Because of this diversity, the continually rich and insightful research conducted on human movement and its role in cognition and learning is worthy of continued attention. Particular emphasis should be placed on new and emerging approaches in this field. This issue contributes to this by looking at how movement helps learning in different areas.

New and Emerging Approaches to Human Movement Research

The contributions in this topical collection provide both empirical and theoretical perspectives on human movement and learning. They cover the areas of language (ranging from word level to narratives), multimedia learning, and activity-based learning. In what follows, we discuss the contributions within each of these categories.

Language

The review article by Sadoski and Lawrence (2023) highlights the critical role of nonverbal sensory, sensorimotor, and affective experiences in abstract word development. Compared to concrete words, abstract verbal learning is challenging due to its limited connections to direct perceptual experience. Nevertheless, by integrating frameworks such as dual coding theory (DCT; Paivio, 1971; Sadoski & Paivio, 2013) and embodied cognition (Hald et al., 2016), along with evidence from neuropsychology (e.g., Buccino et al., 2019), the authors explore the theoretical foundations of abstract vocabulary development. The authors also summarize interventions grounded in the embodied theoretical framework that effectively enhance the teaching and learning of abstract words.

The empirical contribution by Macedonia et al. (2023) shows that VR grasping can boost language learning for weaker learners. They examined the impact of sensorimotor interaction on foreign language vocabulary learning in a virtual reality environment, focusing on learners with varying language aptitude levels. Adult participants were trained in a virtual reality environment under three conditions: audiovisual (written and spoken vocabulary), audiovisual with visual object observation, and audiovisual with grasping virtual objects. Results indicated that grasping virtual objects improved vocabulary retention for learners with low language aptitude, but not for those with high aptitude. Furthermore, in the grasping condition, the typical correlation between language aptitude and learning outcomes was disrupted. The findings suggest that physical interaction, even without tangible feedback, enhances foreign language vocabulary learning, particularly for low-aptitude learners.

Thakore et al. (2024) indicate in their empirical contribution that gesturing does not unequivocally support narrative recall. The authors conducted two experiments to explore how gesture production, emotional valence, and individual differences, including verbal memory (VM) and propensity to gesture, influence narrative recall. The rationale proposed that gesturing might reduce cognitive load, particularly for emotionally neutral tasks or individuals with lower VM. University students recalled three narratives (positive, negative, and neutral) that were read aloud under either instructed or spontaneous gesture conditions. Across both studies, emotional valence consistently influenced recall, with negative narratives being the most memorable. However, the effectiveness of gesturing as an instructional strategy was mixed: instructed gestures sometimes hindered recall, particularly for individuals with high VM (Studies 1 and 2) or low natural propensity to gesture (Study 2). These findings indicate that while emotional content reliably enhances recall, gesturing may need to align with individual learners' natural tendencies or cognitive abilities to be effective.

Multimedia Learning

The empirical contributions by Park et al. (2023) and Sepp et al. (2024) show that hand movements (i.e., tracing and pointing) can support and hinder multimedia learning (i.e., simultaneously presented textual and graphical information). Park et al. (2023) show that pointing improves understanding, depending on the situation. They reviewed prior research and identified three potential mechanisms underlying the effects of tracing and pointing: attention-guiding, multimodal memory enhancement, and cognitive load reduction. To test these mechanisms, they conducted an eye-tracking study comparing tracing, pointing, and no hand movements while learning about the human heart. The results replicated previous findings, demonstrating the benefits of hand movements, particularly pointing, which led to superior comprehension and was associated with increased attentional focus and cognitive activity. The authors argue that the three theoretical explanations may be complementary rather than mutually exclusive.

Sepp et al. (2024) demonstrate that tracing on a touchscreen hinders learning from timed worked examples. They investigated the effects of mimicking tracing and pointing gestures during timed multimedia worked examples on an iPad, specifically in the context of geometry learning. Contrary to prior findings, adolescent participants who performed these gestures scored lower than those who did not. The authors attributed these results to factors such as redundancy between observed and mimicked gestures, the management of multiple modalities, and the optimized nature of the learning materials.

Activity-Based Learning

The review by Castro-Alonso et al. (2024), outlines six interrelated research avenues that explain why embodied cognition can enhance learning and instruction. Three avenues focus on the mechanisms underlying making movements, categorized as *physical activity*, *generative learning*, and *offloaded cognition*. Two avenues pertain to observing movements, represented by the *specialized processor* and *signaling*. The final avenue, *social cognition*, applies to both making and observing movements. For each avenue, Castro-Alonso and colleagues discuss supporting evidence, key influencing factors, and instructional implications. They conclude by emphasizing the need for future research to consider instructional, cognitive, and cultural aspects to deepen the understanding of embodied cognition or embodiment in learning.

While engaging learners in activities involving physical movements—learning by doing—is widely recognized as beneficial, Skulmowski (2024) examines the potentials and challenges associated with instructional design in this approach. In this review, types of activity-based learning are categorized and discussed, including *motor-based learning*, *generative learning*, and *mental activities*. Drawing on cognitive load theory, the distinction between biologically primary and secondary knowledge (Geary, 2008) and the phenomenological model of action layers (Pacherie, 2008), Skulmowski emphasizes that well-integrated activities can facilitate learning, whereas poorly designed activities may burden learners with excessive extraneous cognitive load. The review also explores challenges of transferring activity-based learning to digital environments, highlighting the cognitive processes and demands introduced by different mediums and tools.

The final piece of this topical collection is a critical-pedagogy conceptual paper by Tancredi and Abrahamson (2024). In this paper, the authors re-evaluate the historically marginalized activity of stimming activity (e.g., rocking and fidgeting) in learning, drawing on post-cognitivist embodied cognition theory (Newen et al., 2020; Troncoso et al., 2023) and neuro-cognitive empirical studies (e.g., Buzsáki, 2006). They argue that stimming is an intrinsic part of adaptive cognitive functioning and should be embraced as a form of thinking, particularly for neurodivergent individuals. They advocate for a pedagogical shift that recognizes stimming as a legitimate epistemic resource. To illustrate this, the authors present Balance Board Math, a pedagogical intervention that integrates stimming as a learning tool.

Human Movement in Educational Practice

The articles presented in this topical collection offer several important contributions to the field. These include empirical, theoretical and practical insights that enrich the existing body of research on human movement in educational psychology research. Together they, employ a variety of methods and approaches, reflecting the interdisciplinary nature of this area. Moreover, the studies span across different domains of learning, highlighting the broad relevance of movement in educational contexts.

The four intervention studies presented offer insight into supporting cognitive processing via human movement for different types of learning tasks. These studies approach the integration of physical movement into the learning task at various levels. They cover the effectiveness of physical movement integration when learning new vocabulary (the word-level; Macedonia et al., this issue), comprehension of narrative text (sentence/text level; Thakore et al., this issue), and multimedia learning (Park et al., this issue; Sepp et al., this issue). These contributions advance the field in a number of interesting areas, which can inform both teaching and instructional design practice. Together, the empirical studies offer the following practical tips for teachers:

- Use virtual reality (VR) environments to support vocabulary learning, especially for students with lower language proficiency. Interacting physically with virtual objects—even without real-world touch—can enhance word retention and understanding. This tech-based approach can make abstract words more concrete and memorable. (Macedonia et al., 2023).
- When teaching with short written texts (i.e., narratives), use emotionally engaging stories—both positive and negative—to enhance students' memory

and recall. Be cautious with asking students to gesture while reading, as it might distract rather than help some learners. Tailor your approach based on how individual students respond. (Thakore et al., 2024).
- When using video-based learning materials on a screen, encourage students to point to key elements rather than just looking at or tracing them. Research shows that pointing helps boost attention and understanding more effectively. Try modeling this behavior during lessons to guide students' focus and improve engagement. (Park et al., 2023).
- For learning mathematics, do not instruct learners to trace on a (touch) screen when engaging with timed multimedia lessons that include animated hands. This likely hinders learning due to a potential redundancy of visual cues and the requirement to process multiple modalities (Sepp et al., 2024).

The four theoretical contributions broaden and deepen our knowledge about how to best integrate human movement into learning tasks to support cognitive processing. Sadoski and Lawrence (2023) build upon previous research on embodied language and vocabulary learning (Mavilidi et al., 2015) to offer broad insights into cognitive mechanisms involved in learning and instruction varying using hand and arm movement to support word learning, extending it to the domain of learning abstract words. They suggest that when learning abstract vocabulary (i.e., words that have few or no links to direct perception) performance is improved when performing an embodied gesture that aligns with the meaning of the word or phrase in context such as a word that has a metaphorical meaning or culturally relevant gestures that accompany them such as "shooing" or "beckoning."

Beyond the learning of vocabulary, contributions also provide general instructional perspectives informing the design of learning environments that rely on performing and observing movements. This includes physical and generative activities such as sketching, drawing, gesturing, and the acting out of concepts and processes which have also been shown to benefit learners, with a discussion of promising implications for social aspects, such as learning from others in our community (Castro-Alonso et al., 2024). Further, a typology of human-movement-based instructional approaches in physical and digital learning environments provides important considerations for how cognitive load and learning are affected based on the interplay between movement, cognition, and learning context (Skulmowski, 2024).

Theorising and researching embodied learning experiences can thus continue to be considered multidisciplinary, connecting to related fields that have previously and continue to investigate aspects of human movement, interpersonal interaction as well as the use of multimedia materials to support learning. Importantly, Tancredi and Abrahamson (2024), provide an important reflection on the field, by asserting that stimming—an often-stigmatized physical behavior generally associated with neurodivergent children—should be re-examined for potential benefits in all populations of learners with wide-reaching implications for inclusive education and instructional design.

Conclusion

From language learning and virtual reality to touch-based technologies, and a reassessment of repetitive movement and its role for all learners, the presented articles push into emerging areas in the field, while also expanding its scope. From a methodological perspective, the inclusion of eye tracking and touch-based technologies allows researchers the opportunity to record and analyze potential relationships between visual attention and movement, with implications for learning and cognition. In terms of practical applications, studies exploring emotional learning experiences, grasping of objects and other gestures to support learning provide important considerations for educators across a number of domains. These insights effectively demonstrate the maturity and continued expansion of research that human movement in educational settings continues to provide, while also moving theoretical concepts such as attention, affect, neurodiversity, culture, and evolutionary factors into new and exciting empirical work. The work presented here further demonstrates that individual differences between learners, and different approaches to teaching across learning domains mean that there is always nuance in results. The current collection of studies offers theoretical and empirical bases on which further research can build to inform instructional design, and teaching and learning practice.

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Declarations

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