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REVIEW

Commentary on Frank et al., (2003): where does learning through motor imagery lie on the perceptual–motor continuum?

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Abstract

In this issue, Frank et al. (2023) propose that motor imagery provides a perceptual–cognitive scaffold allowing 'perceptual' learning to transfer into 'motor' learning. The present commentary explores the perspective that changes in *perception itself* are often critical to the development of motor skills. Motor imagery may therefore be most beneficial for developing motor skills with high perceptual demands, such as requiring rapid action selection. Potential challenges for the perceptual–cognitive scaffold approach are identified based on the possible involvement of mechanisms involved in motor learning through movement execution, and how they may be recruited through the use of motor imagery.

Introduction

In the present issue, (Frank et al., 2023) propose that motor imagery provides a perceptual–cognitive scaffold allowing 'perceptual' learning to transfer into 'motor' learning. This model provides an intriguing proposal that challenges previous models of the effects of motor imagery on skill acquisition, which primarily focus on direct functional equivalence between the mechanisms involved in executed and imagined actions (e.g., Jeannerod et al., 2001). The present commentary attempts to provide constructive criticism to aid the development of this new model, including attempts to identify possible limitations of the proposal in its current form. Note that by its nature, this commentary does not provide an exhaustive review, but instead aims to identify several distinct areas where the model may be further developed, or may not be fully able to account for the results of existing studies.

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Perceptual cognitive scaffolding as *perceptual to motor* learning, or *direct* motor skill acquisition?

The new model proposed by Frank et al. (2003) questions whether learning through motor imagery is driven by perceptual or motor learning. Specifically, the authors propose that motor imagery provides a perceptual–cognitive scaffold, which may allow 'perceptual' learning to transfer to 'motor' learning. This proposal is notable in relation to an ongoing debate regarding the scope of motor learning, and whether perceptual and motor skills are truly distinct. For example, a basketball player may be skilled in the patterns of movement that allows them to pass, dribble, and shoot the ball but depends critically upon perceptual abilities allowing them to process information and determine which of these actions is the most appropriate to perform in a given situation. Consequently, recent work argues that development of perceptual abilities is an aspect of motor learning that is essentially inseparable from acquiring movement patterns themselves (for a review see Krakauer et al., 2019).

When viewed within this framework, rather than providing a way for perceptual skills to transfer to motor learning, motor imagery could provide a scaffold that allows 'direct' learning of perceptual components that are critical to motor skills. This would suggest that motor imagery would be most effective in developing motor skills based on selecting and responding to sensory stimuli (e.g., identifying the relevant action to select based on stimulus identification; for example, selecting the appropriate task to imagine when being

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required to choose between passing, dribbling, shooting, …). Motor imagery would therefore provide a way to strengthen stimulus–response relationships in the absence of physical practice.

Expertise effects in motor skill learning and motor imagery

A notable difference between the predictions of the perceptual–cognitive scaffold theory and the results of work examining physical practice relates to the effects of prior experience on a task. Frank et al. (2023) propose that motor imagery should have limited effects on novices compared to people with experience on the task. This is in strong contrast with most work on physical practice, which appears to be governed by a 'power law' of learning (Snoddy, 1926) whereby the rate of learning is higher in novices, but lower in those with prior experience, who have come closer to their performance ceiling. While it is difficult to meaningfully compare changes in performance between novices and experts (i.e., a novice can show a mathematically greater learning—expressed as a change in performance—in a session than an expert, yet is still likely to have an inferior level of performance than an expert), comparing the effectiveness of motor imagery interventions across multiple groups with similar levels of baseline performance may be a fruitful way to examine this hypothesis in further detail. This could be further extended by determining whether the type and content of imagery that is most beneficial differs according to the level of expertise of the performers (Paivio, 1985).

Interactions between the perceptual–cognitive scaffold and mechanisms of motor learning

The perceptual–cognitive scaffold theory suggests that learning through motor imagery uses mechanisms that are distinct from those identified during physical practice. In particular, recent work has argued that motor skill learning occurs primarily through error-based, use-dependent, reinforcement, and strategic mechanisms (for a review see (Spampinato & Celnik, 2020). Subsequent research has followed the plausible hypothesis that these same mechanisms that underlie motor learning are recruited during motor imagery (c.f. Classen et al., 1998; Ruffino et al., 2019; Yoxon et al., 2022). The manner in which these mechanisms could be accounted for by (or would interact with aspects of) the framework of a perceptual–cognitive scaffold model remains to be elaborated. For example, studies examining error-based learning have identified two major mechanisms. An explicit, consciously controlled approach through which strategies can be applied to counteract errors in performance, and a simultaneous implicit mechanism that occurs without conscious control to make minor adjustments to bring actions closer to their intended target (Taylor et al., 2014). While explicit, consciously controlled mechanisms of learning would seem to fit well within the perceptual–cognitive scaffold model, the manner in which the perceptual–cognitive scaffold framework could account for implicit mechanisms of learning remains to be elucidated. This could be tested using interventions that reduce the contribution that implicit learning can have on tasks, such as through increasing environmental noise or introducing a secondary task (Galea et al., 2010).

The perceptual–cognitive scaffold framework proposes that motor imagery may in fact invoke separate learning mechanisms to those used in motor learning, and further suggests that this could potentially lead to super-additive effects. This is an intriguing proposal, though evidence regarding whether this effect is apparent beyond the sporting domain is mixed (c.f. Hird et al., 1991; Simonsmeier et al., 2021). These effects may therefore be dependent upon the task, or the performer's level of experience.

Possible differences for kinesthetic vs visual imagery?

Visual imagery can be used to generate a wide range of perceptual experiences, including those completely dissociated from movement of the human body. By contrast, kinesthetic imagery is an inherently inseparable from sensorimotor sensations. We may therefore predict that the more 'perceptual' nature of visual imagery may render it more likely to benefit from ideas outlined by the perceptual–cognitive scaffold framework; in comparison, kinesthetic imagery may be more likely to be governed by the same learning mechanisms involved in physical practice. While this could in part be addressed by a review of the existing literature, we note that at the present time the distinction between the use of these forms of imagery, (and the extent to which they may induce other associated aspects of tasks, such as auditory imagery) is relatively poorly described (Van Caenegem et al., 2022). Recent attempts to improve study reporting in this area (Moreno-Verdú et al., 2022) may allow more clear delineation of these effects in future.

Conclusions

The perceptual–cognitive scaffold framework provides an intriguing alternative to established views of motor imagery. This adds to an increasing body of work which proposes that cognitive processes may have been relatively overlooked in motor imagery (Glover & Baran, 2017). An important challenge for this novel framework is to determine to what extent it can account for results of previous work that have attributed the results of motor imagery practice to the recruitment of mechanisms involved in physical practice.

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