Theoretical explanations and the availability of information for learning via combined action observation and motor imagery: A commentary on Eaves et al. (2022)

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Abstract

The recent review by Eaves et al. (Psychological Research/Psychologische Forschung, 2022) outlines the research conducted to-date on combined action-observation and motor imagery (AOMI), and more specifically, its added benefit to learning. Of interest, these findings have been primarily attributed to the dual action simulation hypothesis, whereby AO and MI activate separable representations for action that may be later merged when they are congruent with one another. The present commentary more closely evaluates this explanation. What's more, we offer an alternative information-based argument where the benefit to learning may be served instead by the availability of key information. Along these lines, we speculate on possible future directions including the need for a transfer design.

The review by Eaves et al. (2022) is primarily steered by the added benefit to motor learning following a combination of action observation (AO) and motor imagery (MI) compared to each of these modes of simulation on their own. The aims of the current commentary are twofold: evaluate the dual action simulation hypothesis as it is perhaps the most dominant theoretical explanation presented to-date (1), and consider the role of available sources of information (2).

Dual Action Simulation Hypothesis

According to this framework, there are parallel processing streams stemming from AO and MI, which manifest from the initiation of independent or separable representations for action (Eaves et al., 2016; Bruton et al., 2020). Here, the two streams can either merge together to improve behavioural outcomes in the case of congruent AOMI, or compete against each other to the detriment of behavioural outcomes in the case of incongruent AOMI. This logic is heavily adapted from the biased competition framework (Cisek & Kalaska, 2010), where a single action unfolds as a product of competition between multiple potential actions at the neuronal level (for a similar concept involving directionally-tuned neurons, see Georgopoulas et al., 1986).

However, when conceiving of this framework based solely on the literary accounts or wording used to-date, we argue that its explanatory power may require further consideration. Specifically, the proposed initiation of separable representations for both AO and MI would imply that there are at least multiple representations for a single category of action (e.g., golf putt). Alternatively, prevailing views of motor learning would have it that actions are stored in a more generalizable form, which can then lend itself to the re-parameterization and transfer of skill for multiple scenarios (e.g., near/far putt) (Schmidt, 1975). In a similar vein contemporary models of motor control suggest we hold more finite representations; otherwise referred to as internal models (Ghahramani & Wolpert, 2000). These models permit comparisons between the predicted and actual 'state' of the system (e.g., arm position during the back swing), as well as the sensory consequences (e.g., deltoid stretch during the backswing), which can facilitate control without having to access multiple stores that are responsible for seemingly countless motor parameters. In other words, it is not necessary to store and initiate separable representations for a particular action even if it is deployed in different ways including AO and MI (for a similar argument, see Frank et al., 2020).

That said, it is well noted by Eaves et al. (2022) that there are currently few empirical studies to have specifically tested this dual action simulation hypothesis with existing attempts being limited to the measure of corticospinal excitability involving transcranial magnetic stimulation (TMS) over the primary motor cortex (M1) (e.g., Meers et al., 2020; Bruton et al., 2020). Hence, they recognise the need to examine the neural processes that unfold further "upstream" and before these later stages of processing. Along these lines, we fully concur with their proposed use of multi-voxel pattern analysis (MVPA) to try to shed light on the possibility for dual action simulation.

Information Perspective

As stated by Eaves et al. (2022), another possible explanation for the added benefit to learning following AOMI compared to AO and MI alone involves the different sources of information that are made available by each of these modes of simulation (*additive effect*). In this regard, the benefit is not necessarily served by interacting processes (*super-additive effect*),[1] but in line with the motor learning literature, the availability of information that is specific to the task needing to be learned (e.g., Schmidt, 1975; Guadagnoli & Lee, 2004; Mackrous & Proteau, 2007). Thus, upon reflection, we recognise that AO can uniquely provide an external visual referent, while MI can uniquely provide sub-threshold efference and physical reafference (Fig. 1A) (for a similar argument, see Wright et al., 2018; Meers et al., 2020; Frank et al., 2020). In combination, these different sources of information can be combined to enrich the representation for action, and effectively bring the learner closer to the abundance of information that would otherwise be available if they had physically practiced (PP) (Deakin & Proteau, 2000; Trempe et al., 2011) (Fig. 1B). Put simply, we may conceive of the possible modes of simulation and their related learning outcomes on a continuum based on access to information that is specific to motor learning.

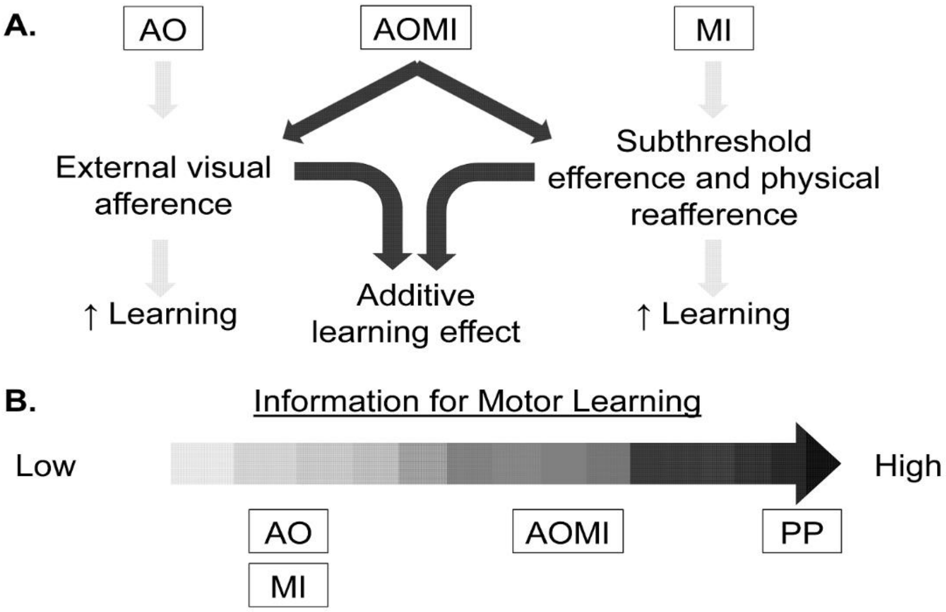

Fig. 1 Conceptual illustration of the different modes of simulation (AO, MI, AOMI), their available sources of information and subsequent effects on motor learning (A). In addition, there is a motor learning information continuum with AOMI more closely reflecting the high-volume of information that is also available in physical practice (PP) (N.B., there are perhaps other distinctions along this continuum depending on person-perspective (i.e., first-/third-person), although it is not of interest here).

In support of this conjecture, it has been shown that the benefit to learning following AOMI is not solely limited to a synchronous form of delivery (simultaneous AO+MI), but also extends to asynchronous (alternate AO ⇄ MI) (Romano-Smith et al., 2019, 2022; see also, Kim et al., 2020). Thus, despite the comparatively disrupted dual action simulation processes that can be most typically associated with synchronous AOMI, the continued presence of information for learning during asynchronous AOMI has proved sufficient enough for there to still be an added benefit to learning (for an alternative argument, see Azaad & Sebanz, 2023).

With this in mind, there are a number of studies identified by Eaves et al. (2022) that have tried to elucidate the added benefit to learning following AOMI. This interest has naturally steered researchers toward the level of the independent variable (i.e., mode of simulation), where they have specifically manipulated the congruency of the AO or MI component in an attempt to decouple their relative contribution during AOMI. For example, in a dart-throwing task, individuals that were asked to observe a separately incongruent shoulder rotation while imagining the required dart throw showed no longer any benefit to their learning (Romano-Smith et al., 2022; see also, Meers et al., 2020; Bruton et al., 2020).

However, it is perhaps also worthwhile considering the value of introducing additional measures at the dependent level,[2] including a transfer design whereby the learner would have to adapt any of their learning to an alternative task setting. Perhaps surprisingly, there have been comparatively few studies involving AOMI that have adopted such a design, which could arguably limit any conclusions drawn about motor learning per se (e.g., Marshall et al., 2020) (see Schmidt et al., 2019). Of interest, an additional transfer test can often highlight the source of information that the learner is most sensitive to, and with it, the very nature of the representation that they hold. For example, following the learning of a novel movement pattern (e.g., dart throwing), previous studies have manipulated the physical response characteristics in transfer (e.g., novel throwing technique or weighted dart) (Shea et al., 2000; Heyes & Foster, 2002; Bird & Heyes, 2005; Osman et al., 2005; Boutin et al., 2010; Hayes et al., 2012a, b). As a result, if the learner were to find themselves suddenly unable to transfer, then it stands to reason that they initially developed a motor-specific, as opposed to -nonspecific, representation. Thus, it is possible that learners could respond better to this sort of transfer test having undergone AOMI compared to AO and MI alone.

Conclusion

We concur with many of the points raised by Eaves et al. (2022). However, we raise at least some questions around the underlying logic surrounding the dual action simulation hypothesis, while advocating for a potential information-based explanation for the benefits served by AOMI. In order to learn more about AOMI, Eaves et al. (2022) indicate some interesting possibilities for future research, although we emphasise the importance of incorporating an additional transfer.

Footnotes

1) The super-additive effect primarily relates to the potential combination or interaction of processes that are elicited by AO and MI. At the same time, according to Sternberg's (1969) logic, it is possible that such processes would assume a statistical interaction as opposed to sole main effects.
2) There have been some minor attempts already to capture eye movements using optical tracking (Marshall et al., 2020; Bruton et al., 2020), and muscle function using surface electromyography (EMG) (Romano-Smith et al., 2019, 2022), which have coincided with performance-related measures following an AOMI intervention.

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