Imagery ability: the individual difference gradient and novel training methods

(Commentary on Kraeutner et al. (2018))

D.L. Eaves[1]*, J. Emerson[1], J. Binks[1], M. Scott[1], R.P.W. Kenny[1,2]

[1]School of Social Sciences, Humanities and Law, Teesside University, Middlesbrough, UK
[2]School of Health and Social Care, Teesside University, Middlesbrough, UK

*Corresponding Author
School of Social Sciences, Humanities and Law, Teesside University, TS1 3BX, UK.
Email address: d.eaves@tees.ac.uk

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In this commentary on Kraeutner et al.'s (2018) paper we first outline a popular theoretical framework, which is useful for conceptualising their findings. We then discuss the implications of their data for contemporary perspectives on imagery ability, which promote an individualised account. Finally, we describe novel methodologies for enhancing imagery ability within this context.

According to Jeannerod's (2006) principle of functional equivalence, executing, imagining and observing action involves motor regions in the brain that at least partially overlap with one another. While 'actual' actions involve a covert phase (e.g., motor planning) followed by overt execution, action 'simulation states' (derived through imagery and/or observation) are primarily covert, in that they typically occur in the absence of motor execution (Frank & Schack, 2017). Simulation states can vary in the degree to which they involve covert activation of the motor system, **and** the factors that moderate this variation are a topic of great discussion. For instance, relatively little is known about the effects of motor experience (e.g., in elite athletes) for a given simulation state.

In general terms, motor imagery (MI) elicits cortical activity that is more bilateral and widespread compared to motor execution. Similarly, the activation of brain regions during MI is more bilateral and diffuse in novice performers, compared to their more experienced counterparts (Burianová *et al.*, 2013). Presumably a novice with little experience of physically executing the imagined action will have an inefficient and/or unorganised network of neurocognitive processes underlying their imagery (Bar & DeSouza, 2016). Physical practice should therefore serve to refine and organise these neural networks (i.e., a *neural efficiency* effect). Indeed, studies have shown physical practice reduces the neurophysiological activity present during imagery of the practiced action, in regions specific to the task (Lacourse *et al.*, 2005). Kraeutner *et al.*'s (2018) data help to rule out the potential confound in cross-sectional studies that used only a between-group (expert vs. novice) design. While they found no clear differences during MI of two highly practiced action types (sport-specific vs. non-sport specific) within two expert groups (basketball vs. volleyball players), neurophysiological involvement was comparatively more widespread and bilateral within both expert groups when **they imagined performing** an unpracticed action. Notably, these cortical activation patterns for the unpracticed actions resembled those in a novice group during imagery of the same unpracticed action.

While those authors did not asses their participants' ability to physically execute nor imagine these actions, the more specific activation patterns for practiced actions conceivably reflect an enhanced ability to both perform and therefore imagine these actions. Accordingly, *imagery ability*, at least in the motor domain, appears dependent on a performer's prior physical exposure to the imagined action. While motor abilities are typically defined in terms of movement outcomes, a key question is how should we define the ability to imagine movements?

Theoretical accounts often remain vague or unresolved regarding the nature of imagery ability. A long-standing assumption, however, is that the capacity for imagery is not simply an undifferentiated general skill, but rather it is a skill that can be parsed into a series of sub-attributes. Cumming and Eaves (2018) recently proposed that the ability to imagine something relates to more than image generation and maintenance over time, but also to how we might inspect, transform and repurpose these images for specific outcomes. It follows that undertaking mental practice, as it relates to one or more of these cognitive **sub-**components, should produce an individual difference gradient of imagery ability within each **facet**.

It was Galton (1880) who first observed that the detail and clarity with which individuals experience mental imagery will involve an individual difference gradient across any given population. Here we argue this gradient effect should be examined not only at some global level of imagery ability, but it should also be quantified independently within each of the sub-attributes as well. An intriguing question arising from Kraeutner *et al.*'s (2018) work is how these independent cognitive processes might be reflected in the differential activations of neural substrate for practiced vs. unpracticed actions, and how these patterns might change over time due to the nature of training undertaken within specific sub-sets of imagery skills. Ultimately, the development of a more nuanced definition of imagery ability will in turn help us to identify the most appropriate tools to both measure and improve the core characteristics.

One imagery training protocol that is well-suited to a more individualised account of imagery ability is Layered Stimulus Response Training (LSRT). LSRT is intended to help people more easily generate and control their imagery experience by breaking down different elements of an image, before bringing them together again in progressive layers (Cumming & Eaves, 2018). To improve its effectiveness, this method can also be used in conjunction with the instruction to perform motor imagery *during* action observation (AO+MI). This entails imagining the kinaesthetic sensations of action, while synchronising this simulation with the concurrently observed action (Eaves *et al.*, 2016a).

A strong evidence base of multimodal neurophysiological studies now demonstrates cortico-motor activity is significantly increased during AO+MI compared to either independent imagery or observation of the same action (e.g., Eaves *et al.*, 2016b; Macuga & Frey, 2012; see Eaves *et al.*, 2016a), and that this moderates behavioural outcomes such as force production (Scott *et al*., 2017) and automatic imitation (Eaves *et al*., 2014). The suggested benefits of using combined AO+MI, rather than MI independently, is that it promotes an increase in on-going attention to the observed action, which will intuitively offer continuous and helpful opportunities for refining and updating the imagined (yet independent) internal representation of the same action in real-time. In a sense, the action simulation derived through observation might act as a type of scaffolding upon which the imagery-driven simulation can be structured. In line with Kraeutner and colleagues' findings, this method would appear particularly useful for constructing action representations that are not currently in the performer's repertoire, that is, those characterised by the more diffuse and bilateral activation patterns.

Combining LSRT with AO+MI methods now represents a clear opportunity to investigate and train specific components of imagery ability. A fruitful avenue for future research, which is motivated (at least in part) by Kraeutner *et al.*'s (2018) timely paper, will be to examine how these methods might impact neural efficiency effects over time.

Conflict of interest

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Author contributions

All authors developed the main ideas behind the paper, before helping to draft and proof-read the paper. DE led manuscript preparation and re-drafting, with contributions from JE, JB, MS, RK.

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