Motor imagery, inhibition and action execution: When motor imagery goes rogue

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In his "Motor imagery and action execution", Bence Nanay proposes that motor imagery, the counterpart of mental imagery on the output side of our cognitive machinery, plays an important role in action initiation, can contribute to explaining akratic or relapse actions, and through its role in action initiation illustrates potential splits between action causation and action motivation.

In this short commentary, I propose to explore a potential tension between Nanay's characterization of motor imagery (§2) and the role he claims it can play in explaining action execution (§3-5). I also propose that one can alleviate this tension by explicitly considering motor imagery as one among several types of mental states that tap motor representation resources and by characterizing the cognitive control and regulation processes that shape this particular type of mental state and distinguish it from related mental states.

To introduce the concept of motor imagery (§2), Nanay draws on an analogy with mental imagery (e.g., closing one's eyes and visualizing an apple). He notes that while in paradigmatic cases, mental imagery is voluntary and conscious, it can also be involuntary and unconscious. Following the steps of psychologists and neuroscientists, he proposes that mental imagery, qua natural kind, be defined in functional terms as early perceptual processing without sensory input, rather than phenomenologically in terms of features such as voluntariness or consciousness. Likewise, according to Nanay, while paradigmatic examples of motor imagery (e.g., closing one's eyes and imagining reaching for an apple) are voluntary and conscious, motor imagery can also be involuntary and unconscious. Following Jeannerod's suggestion that motor imagery relates to motor physiology in the same way visual imagery relates to visual physiology (Jeannerod, 1994), Nanay proposes that motor imagery should be defined as late motor processing without motor output (i.e., without the production of movements).

It seems to follow from this functional characterization of motor imagery that it is essential for a state to qualify as an instance of motor imagery that it does not trigger actual movement,

just as it essential for a state to count as an instance of mental imagery that it is not triggered by sensory input. If we relax these constraints on what counts as imagery, we lose the distinction between motor imagery and motor intentions[1], just as we lose the distinction between actual perception and mental imagery.

If we want to preserve these distinctions, as I suppose Nanay does, then we face an apparent tension between a characterization of motor imagery as late motor processing without motor output and the claim he makes that motor imagery plays an important role in action initiation, suggesting that this claim demands careful unpacking. Nanay is obviously not unaware of this difficulty, reporting evidence showing that motor imagery increases spinal excitability but also noting that this increase is necessary but not sufficient for action initiation (§3). Yet, he also suggests that motor imagery may play an important role in triggering akratic actions (§4) or relapse actions (§5).

One way to try and get a more precise picture of how motor imagery may contribute to action initiation is to offer a fuller functional characterization of motor imagery. Nanay's characterizations of mental and of motor imagery are in part only negative. Mental imagery is defined as early perceptual processing not triggered by corresponding sensory stimulation, but a functional characterization of mental imagery should tell us what instead triggers this processing. Likewise, a fuller functional characterization of motor imagery would be expected to tell us not just that it is late motor processing that does not trigger bodily movement, but also something about what it is that prevents it from triggering bodily movement.

Nanay, in his article, operates with a distinction between two kinds of mental states, motor imagery and motor representations, the latter being responsible for actual action execution. I think it preferable to use the term motor representations to refer to elements of an action representation system that depends on processing in motor areas and is shared between action generation, action observation and action simulation (Grèzes & Decety, 2001), but also perception of object affordances (Maranesi et al., 2014) and processing of action-related verbs (Andres et al., 2015). This terminological choice helps highlight the fact that different types of psychological states tap the same representational resources. It also highlights the need to

[1] I use the term "motor intentions" to refer to motor representations that are directly causally implicated in action execution (e.g., Pacherie, 2006, 2008). Brozzo (2017) has objected that my motor intentions fail to meet several constraints that genuine intentions should satisfy. I will not enter into this debate here (but see Mylopoulos & Pacherie, 2018). For present purposes, it is enough that those who share Brozzo's qualms replace "motor intentions" with "executive motor representations".

characterize the ways in which these states actually differ. Part of the answer lies, I submit, in how they are shaped by control and regulative processes.

If we concentrate on motor imagery and motor intentions (aka, executive motor representations), one crucial difference between them is that motor imagery requires that the execution of actual movements be prevented, while in contrast the job of motor intentions is to insure the execution of movements. What this means is that the involvement of inhibitory processes is a central characteristic of motor imagery. Guillot et al. (2012) discuss three possible inhibitory mechanisms in motor imagery. First, because people know in advance that they will imagine and not execute a movement the need for active inhibition may not arise and inhibition be integrated into imagination, with only subthreshold motor activation occurring (*subthreshold*). Second, all motor activity may be inhibited (*global inhibition*) Third, inhibition may be specific for the effector used in the imagined movement or for the complete action imagined (*specific inhibition*). Importantly, these inhibitory mechanisms need not be exclusive. They may operate together or in different instances of motor imagery. For instance, subthreshold motor activation may be more likely to operate on instances of voluntary motor imagery. While a number of recent studies have started teasing apart these possibilities in an effort to further elucidate inhibitory mechanisms in motor imagery (e.g., Bart et al., 2021; O'Shea & Moran, 2018; Rieger et al., 2017), we still lack a complete picture of the inhibitory mechanisms at work in motor imagery.

In contrast, executive motor representations are supposed to trigger action initiation but also to coordinate with intentions and pull in the same direction. What exact form this interface problem takes and how it is solved is currently a matter of intense debate (e.g., Butterfill & Sinigaglia, 2014; Mylopoulos & Pacherie, 2017; Fridland, 2019; Shepherd, 2019; Christensen, 2020). Executive motor intentions may be shaped by intentions in a number of ways, directly by triggering goal-relevant motor representations with goal-relevant content, more indirectly through selective top-down attention to goal-relevant features of the environment that increases the saliency of pertinent action affordances, or more indirectly still through the active inhibition of competing motor representations.

How does that relate to the role motor imagery may play in the initiation of akratic or relapse actions? First, it is not well-behaved motor imagery that triggers action initiation in these cases, for inhibition preventing action execution is precisely part and parcel of well-behaved motor imagery. Rather what may play a role in the initiation of akratic or relapse action is motor simulation gone rogue. What requires explaining then is why in these contexts

inhibitory processes don't play their part. Second, akratic and relapse actions differ from ordinary action slips or actions performed routinely or absent-mindedly in that they typically involve conflicting or at least ambivalent motivations. The presence of motivational conflict or ambivalence may contribute, on the one hand, to explaining why, to borrow Shepherd's phrase (Shepherd, 2017) our attempts to act on our avowed intentions (working on our grant proposal rather than watching television, drinking a coke rather than having a beer) are only halfhearted and thus do not fully engage the processes (triggering of goal-relevant motor representations, top-down attention to goal-relevant features of the situation, inhibition of competing motor representations) a wholehearted intention would. It may also contribute to explaining why the inhibition processes that are normally a hallmark of motor imagery are weakened. After all, in contrast to a recovering alcoholic, we should not expect that imagining drinking a glass of beer would trigger action initiation in a lifelong teetotaler.

In a nutshell, then, motor imagery may well, as Nanay proposes, play an important role in the initiation of certain actions but to get a better sense of how it plays this role, one shouldn't lose sight of the fact that motor imagery requires that movements are prevented and thus that the involvement of inhibitory processes is as much a hallmark of motor imagery as the fact that it involves late motor processes. An important issue then is why in some cases these inhibitory processes are overridden. Finally, Nanay may be right that motor imagery is not in itself a motivating state (§6), but this doesn't necessarily mean that a motivational story is out of place in explaining why the inhibitory processes associated with motor imagery are sometimes overridden.

Acknowledgements: this work was supported by grants ANR-10-LABX-0087 IEC and ANR-10-IDEX-0001-02 PSL from the French Agence Nationale de la Recherche.

References

Andres, M., Finocchiaro, C., Buiatti, M., & Piazza, M. (2015). Contribution of motor representations to action verb processing. *Cognition, 134*, 174-184.

Bart, V. K., Koch, I., & Rieger, M. (2021). Decay of inhibition in motor imagery. *Quarterly Journal of Experimental Psychology*, 1747021820949388.

Brozzo, C. (2017). Motor intentions: How intentions and motor representations come together. *Mind & Language*, 32(2), 231–256.

Butterfill, S., & Sinigaglia, C. (2014). Intention and motor representation in purposive action. *Philosophy and Phenomenological Research*, 88(1), 119–145.

Christensen, W. (2020). The skill of translating thought into action: framing the problem. *Review of Philosophy and Psychology*, 1-27. https://doi.org/10.1007/s13164-020-00517-2
Grezes, J., & Decety, J. (2001). Functional anatomy of execution, mental simulation, observation, and verb generation of actions: A meta-analysis. *Human brain mapping*, *12*(1), 1-19.
Fridland, E. (2019). Intention at the Interface. *Review of Philosophy and Psychology*, 1-25. https://doi.org/10.1007/s13164-019-00452-x
Guillot, A., Di Rienzo, F., MacIntyre, T., Moran, A., & Collet, C. (2012). Imagining is not doing but involves specific motor commands: a review of experimental data related to motor inhibition. *Frontiers in Human Neuroscience*, *6*, 247.
Jeannerod, Marc (1994). The Representing Brain: Neural Correlates of Motor Intention and Imagery. *Behavioral and Brain Sciences*, 17, 187–245.
Maranesi, M., Bonini, L., & Fogassi, L. (2014). Cortical processing of object affordances for self and others' action. *Frontiers in Psychology*, *5*, 538.
Mylopoulos, M., & Pacherie, E. (2017). Intentions and motor representations: The Interface challenge. *Review of Philosophy and Psychology*, 8(2), 317–336.
O'Shea, H., & Moran, A. (2018). To go or not to go? Pupillometry elucidates inhibitory mechanisms in motor imagery. *Journal of Cognitive Psychology*, 30(4), 466-483.
Pacherie, E. (2006). Towards a dynamic theory of intentions. In S. Pockett, W. P. Banks, & S. Gallagher (Eds.), *Does consciousness cause behavior? An investigation of the nature of volition* (pp. 145–167). Cambridge, MA: MIT Press.
Pacherie, E. (2008). The phenomenology of action: A conceptual framework. *Cognition*, 107(1), 179–217.
Rieger, M., Dahm, S. F., & Koch, I. (2017). Inhibition in motor imagery: a novel action mode switching paradigm. *Psychonomic Bulletin & Review*, *24*(2), 459-466.
Shepherd, J. (2017). Halfhearted action and control. *Ergo*, 4. http://dx.doi.org/10.3998/ergo.12405314.0004.009
Shepherd, J. (2019). Skilled action and the double life of intention. *Philosophy and Phenomenological Research*, *98*(2), 286-305.