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***i-Comment***

## Neurophysiological studies may provide a misleading picture of how perceptual-motor interactions are coordinated

David Mann

MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands;  
e-mail: [d.mann@vu.nl](mailto:d.mann@vu.nl)

Matt Dicks

MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands;  
e-mail: [matt.dicks@vu.nl](mailto:matt.dicks@vu.nl)

Rouwen Cañal-Bruland

MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands;  
e-mail: [r.canalbruland@vu.nl](mailto:r.canalbruland@vu.nl)

John van der Kamp

MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University, Amsterdam, The Netherlands,  
and Institute of Human Performance, University of Hong Kong, Hong Kong SAR; e-mail: [j.vander.kamp@vu.nl](mailto:j.vander.kamp@vu.nl)

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**Abstract.** Neurophysiological measurement techniques like fMRI and TMS are increasingly being used to examine the perceptual-motor processes underpinning the ability to anticipate the actions of others. Crucially, these techniques invariably restrict the experimental task that can be used and consequently limit the degree to which the findings can be generalised. These limitations are discussed based on a recent paper by Tomeo et al. (2012) who sought to examine responses to fooling actions by using TMS on participants who passively observed spliced video clips where bodily information was, and was not, linked to the action outcome. We outline two particular concerns with this approach. First, spliced video clips that show physically impossible actions are unlikely to simulate a “fooling” action. Second, it is difficult to make meaningful inferences about perceptual-motor expertise from experiments where participants cannot move. Taken together, we argue that wider generalisations based on these findings may provide a misunderstanding of the phenomenon such a study is designed to explore.

**Keywords:** anticipation, transcranial magnetic stimulation, motor, action, vision, football.

A range of neurophysiological measurement techniques offer novel opportunities to better understand the neural mechanisms associated with different perceptual phenomena. For those investigating the ability to anticipate the actions of others, techniques like fMRI and TMS may provide a potentially insightful way to uncover the neural mechanisms that underpin the comprehension of social interactions (e.g., Aglioti, Cesari, Romani, & Urgesi, 2008; Tomeo, Cesari, Aglioti, & Urgesi, 2012; Wright, Bishop, Jackson, & Abernethy, 2010). However, the experimental requirements imposed by these techniques can be restrictive. This often results in experimental tasks that are necessarily simplified and may fail to sample the natural task they seek to study, especially when the task involves whole-body motor actions. As a result, we believe that caution should be taken when making generalisations about the findings of these studies.

A case in point is the approach of Tomeo et al. (2012) who recently sought to evaluate the impact of motor facilitation when predicting the outcome of real and fooling actions. They used TMS to test the corticospinal excitability of skilled and novice soccer players who observed video footage of kicks where the correspondence between the kicker’s body kinematics and the subsequent ball-flight trajectory was either congruent (“real” kicks) or incongruent (“fooling” kicks). Skilled kickers and goalkeepers outperformed novices when judging kick direction based on kinematic information alone; however, kickers were “fooled” more often than goalkeepers and novices when viewing the

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incongruent stimuli with ball-flight information. When compared with the observation of congruent actions, the level of motor facilitation induced by TMS for the incongruent actions was similar for the kickers, but lower for the goalkeepers. These results were said to reflect the ability of goalkeepers—but not kickers—to update their motor representation of the kicker's action. Although this design nicely addresses how motor excitation can be associated with perception when passively watching video clips, we were left questioning whether the wider conclusions were supported by the empirical findings. In particular, Tomeo et al. (2012) conclude that “*responding to fooling actions* requires updation of simulative motor representations of others' actions” (p.1; italics added). Based on this conclusion, we raise two concerns: (i) whether an incongruent video stimulus really does present a *fooling action*, and (ii) whether passively observing videos provides a genuine representation of how experts *respond*.

First, the conclusion that “responding to *fooling actions* requires updation” assumes that a video clip containing incongruent kinematic and ball-flight information authentically replicates a natural fooling action. We argue that this assumption is problematic because the stimuli did not contain authentic fooling actions, but contain only actions that were spliced into physically possible and impossible outcomes. Notably, the biomechanical constraints imposed on an action ensure that action outcomes are specified by particular kinematic invariants. That is, a specific action outcome can only be realised if certain biomechanical constraints are abided to. A true fooling action cannot and does not violate these biomechanical constraints (or lawfulness), but rather exploits variation in the action, particularly early on in the action sequence. Hence, a true “fooling” action would present (i) kinematic information that is intended to deceive the observer but is not (or is minimally) correlated with the actual outcome, *and* (ii) kinematic information that is inextricably correlated (one-to-one) with the true action outcome. Neither was present in the incongruent (“fooling”) stimuli employed by Tomeo et al. (2012).

An important consequence when using an incongruent (spliced) stimulus is that skilled performers are likely to be at a distinct *disadvantage* when observing an action outcome that is not lawfully linked to the preceding kinematic information. A skilled footballer, for example, will learn to differentiate kinematic information that is, and is not, reliably correlated to the action outcome. Likewise, when presented with a fooling action, a skilled footballer will learn to rely on the information that is reliably correlated with the action outcome, and will ignore that which is poorly or not at all correlated. Accordingly, almost all existing studies of action anticipation have shown that skilled athletes are less fooled by deceptive intent than novices are (e.g., Cañal-Bruland & Schmidt, 2009; Jackson, Warren, & Abernethy, 2006). In the incongruent stimulus shown by Tomeo et al. (2012), the kinematic information that should reliably relate to the ball being directed to one side was not linked to the ultimate direction of the ball-flight trajectory. We believe that this may explain why the skilled kickers were even worse than novice players when anticipating the outcome of the incongruent actions. The best strategy was to fully ignore the kinematic information and to wait for ball flight, a task that the skilled kickers were not accustomed to. If there were to be a reliable relationship between the kinematic and ball-flight information in the fooling stimuli (as is the case in the natural environment), then it is difficult to envisage that a skilled player who has learned to differentiate non-deceptive from deceptive actions would need to decrease their motor facilitation when viewing a genuine deceptive action.

We now turn to our second concern. By seeking to make a generalisation about “*responding to fooling actions*,” Tomeo et al. (2012) appear to assume that the neural activity invoked when sitting and passively observing a video stimulus will faithfully replicate that found when a *motor action* is performed. We believe this is also a tenuous assumption. The visual brain organises itself in fundamentally different ways when it exploits information for motor actions or perceptual judgements (e.g., van der Kamp, Rivas, van Doorn, & Savelsbergh, 2008). Recent work confirms that the action that a performer can realise strongly influences the pick-up of information, and importantly it influences the ability to anticipate the actions of others. For example, the gaze pattern of a soccer goalkeeper attempting to physically stop a penalty kick *in-situ* is not replicated by the visual search behaviour seen when verbally predicting the direction of the same kick (Dicks, Button, & Davids, 2010). Furthermore, the ability of experts to anticipate actions is underrepresented when a simplified movement response is produced, and can even disappear when using a verbal judgement (Mann, Abernethy, & Farrow, 2010). It is clear from the findings of Tomeo et al. (2012) that motor facilitation occurs when participants sit and watch video footage. However, we believe it is likely that markedly different neural activity would be found if participants were to perform motor interactions.

Perceptual judgements have been a popular and methodologically convenient means of investigating the ability to anticipate the actions of others. However, the usefulness of video-based judgement paradigms has been questioned for some time (e.g., Abernethy, Thomas, & Thomas, 1993) and, as a consequence, a central research issue over the past two decades has been to develop appropriate methodological approaches for the study of action anticipation. The culmination of these efforts has led to an increasing realisation that experiments designed to understand the nature of perceptual-motor expertise should employ conditions that preserve the natural information–movement coupling underlying a motor action (Dicks et al., 2010; Mann et al., 2010). Of course it may not be practical—or possible—for scientists to utilise neural imaging techniques while participants perform interceptive actions. However, it is reasonable to ask to what degree a neural technique should dictate an experimental task, particularly if there is a good chance that the experimental task does not replicate the fundamental aspects of the skill it is seeking to understand.

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