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Registered Report

Anticipating actions and corticospinal excitability: A preregistered motor TMS experiment

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ABSTRACT

Past research on action observation and imitation suggests that observing a movement activates a corresponding motor representation in the observer. However, recent research suggests that individuals may not only reflexively simulate the observed behavior but also simulate and engage in anticipated action without another person actually engaging in it. For example, it has been demonstrated that observing a triggering event (i.e., nose wrinkling) that potentially leads to the anticipation of an action (i.e., nose scratching) increases the likelihood that the observer will perform that action. In the present research, we applied motor Transcranial Magnetic Stimulation TMS to investigate such anticipated social action effects at the neurophysiological level within a trial-by-trial measure. While a pilot study suggests that observing nose wrinkling elicits stronger motor evoked potentials MEPs in participants' biceps muscles than observing control events, this effect could not be fully replicated in a preregistered study. Although a post hoc meta-analysis across both studies supports the general hypothesis, these results need to be taken cautiously. Implications of the results reported in the manuscript are discussed.

Individuals tend to automatically imitate a wide range of different behaviors (Cracco, Bardi, Desmet, Genschow, Rigoni, & De Coster, 2018a), such as facial expressions (Dimberg, 1982), language (Cappella & Planalp, 1981; Giles & Powesland, 1975; Webb, 1969, 1972), emotions (for an overview, see Hess & Fischer, 2013), postures (LaFrance, 1982), gestures (Bernieri, 1988; Cracco, Genschow, Radkovaa, & Brass, 2018b), or simple movements (Brass, Bekkering, Wohlschläger, & Prinz, 2000; Genschow & Florack, 2014; Genschow & Schindler, 2016; Genschow, Florack, & Wänke, 2013; Genschow et al., 2017)—to name just a few examples.

Classical perception-action theories in social psychology (for an overview, see Chartrand & Dalton, 2009) and cognitive psychology (for an overview, see Heyes, 2011) suggest that such imitative phenomena are based on shared representations of observed and executed actions. Ideomotor theory (Greenwald, 1970; Prinz, 1990, 1997), for example, explains imitative response tendencies by stating that the observation of an action primes and thus facilitates the execution of a compatible action, because observed and executed actions activate the same sensory representations.

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At the neurophysiological level, imitation has predominantly been explained in relation to the mirror neuron system (e.g., Bien, Roebroeck, Goebel, & Sack, 2009; Brass & Heyes, 2005; Catmur, Walsh, & Heyes, 2009; Cook & Bird, 2011). Q3 The mirror neuron system refers to a network of motor areas in the frontal and parietal cortex that do not only respond to action execution but also to action observation (Rizzolatti & Craighero, 2004; Rizzolatti & Sinigaglia, 2010). Although the mirror neuron system was initially documented in the monkey brain (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996), there is now converging evidence that a similar system exists in humans as well (Molenberghs, Cunnington, & Mattingley, 2012). Particular support for the idea that the motor system is active during action execution as well as action observation was provided by different neurophysiological experiments (for a review, see Caspers, Zilles, Laird, & Eickhoff, 2010), including motor TMS (Fadiga, Craighero, & Olivier, 2005; Naish, Houston-Price, Bremner, & Holmes, 2014; Urgesi, Candidi, Fabbro, Romani, & Aglioti, 2006a). For example, Fadiga, Fogassi, Pavesi, and Rizzolatti (1995) stimulated the primary motor cortex of human subjects with (Transcranial Magnetic Stimulation TMS) during the observation of hand movements and measured motor evoked potentials (MEPs) from subjects' hand muscles. The researchers found during action observation an increase in the MEP amplitude in participants' hand muscles that would be used to execute the observed movements (see also Urgesi et al., 2006a).

In sum, the above-reviewed literature indicates that observing a whole action sequence in someone else directly activates the corresponding action plans in the observer. However, would already the anticipation of a future action be sufficient to activate corresponding motor actions too? Although there is not yet a clear answer to this question, there is reason to believe that this might, indeed, be the case. For instance, recent theoretical models (e.g., Kilner, Friston, & Frith, 2007; Wilson & Knoblich, 2005) assume that during action observation, individuals tend to constantly simulate other persons' ongoing actions and infer its behavioral outcomes in order to prepare one's own actions (see also Lamm, Fischer, & Decety, 2007). Kilner et al. (2007) propose a computational approach, which assumes that the mirror neuron system (Rizzolatti, Fogassi, & Gallese, 2001) infers the most likely intention of an observed action by minimizing the prediction error at all levels of the cortical hierarchy involved in action observation. Similarly, Wilson and Knoblich (2005) propose a so-called emulator that internally simulates others' action execution. This simulation process then provides immediate information about the ongoing course of the observed action as well as its probable immediate future.

Evidence for such a physiological simulation process comes from a series of neurophysiological experiments (e.g., Cardellicchio, Sinigaglia, & Costantini, 2013; Kilner, Vargas, Duval, Blakemore, & Sirigu, 2004; Pierno et al., 2006; Umilta et al., 2001; Urgesi et al., 2010). For instance, in a seminal study, Umilta et al. (2001) measured mirror neuron activations in macaque monkeys while the monkeys observed a fully visible action directed towards an object or the same action with its endpoint being hidden. The results show that the majority of mirror neurons became active during the whole action presentation, but also when the final action towards the object was hidden. This result was taken as evidence for the hypothesis that motor representations of an action performed by others can be internally generated in the observer even when the complete visual description of the action is lacking.

In a related study, Kilner et al. (2004) measured the (readiness potential RP)—an electrophysiological marker of motor preparation—while human participants observed different video clips of another person. In half of the video clips, participants observed a hand movement grasping an object. In the other half of the videos the hand remained stationary. At the beginning of each clip, a color cue indicated whether the hand would move or remain in the same position. When the onset time of the upcoming arm movement was predictable, a rise of the RP was observed before the actual movement's onset. This result suggests that the mere knowledge of an upcoming movement is sufficient to activate one's own motor system. In a similar study, Urgesi et al. (2010) presented participants snapshots of hand movements while applying motor TMS. The snapshots either depicted the starting, the middle or the end phase of a movement. The researchers found that observing a movement's start phase and middle phase engendered significantly higher motor facilitation than observing the final phase.

In sum, neurophysiological studies indicate that the motor system is active when individuals observe an action. Moreover, recent research suggests that individuals also simulate anticipated actions activating the motor system as well. However, despite first support for anticipative mechanisms, it is important to note that in most of the previous experiments participants were aware of the next following action. That is, participants knew what kind of movement would follow, because they had seen the model executing the movement in previous trials, or a cue announced the movement.

With reference to “anticipated action” we went one step further and recently demonstrated that when observing another person, individuals actually engage in the action that the other person might show in the near future although the other person never engages in this action and no cue announces the action (Genschow & Brass, 2015; Genschow, Klomfar, d'Haene, & Brass, 2018). For instance, in two experiments Genschow and Brass (2015) tested whether the observation of an event that could potentially trigger another person's action is sufficient to produce the anticipated action in the observer. Importantly, participants were never exposed to the actual movement. In a first experiment participants watched two 10 min lasting videos of a female model who was reading a story. In one video, the model was constantly wrinkling her nose and in the other video her hair was constantly falling into her face. While watching the two videos, participants were videotaped. Afterwards, we coded how often participants engaged in anticipated actions related to nose wrinkling (e.g., nose scratching) and hair falling (e.g., hair stroking). The results gave first evidence for our hypothesized anticipated action effect: when watching the nose wrinkling video, participants engaged in more nose scratching actions than hair stroking actions and vice versa for watching the hair falling video. In a second experiment we tested whether anticipated action is based on the inference of the model's desire to act. The results demonstrated that

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