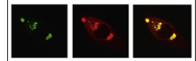


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Research Report

Visual influences on sensorimotor EEG responses during observation of hand actions

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ABSTRACT

There is growing interest within the field of social-cognitive neuroscience in the dynamics of sensorimotor EEG rhythms during the observation of actions performed by others. However, there remain important gaps in the literature regarding the effects of perceptual aspects of the observed hand movements. This study investigated two visual influences on the EEG response to hand actions. Specifically, the perspective of the action in relation to the participant (egocentric/allocentric) was varied and the effect of the hand used to carry out the action (left/right) was also assessed. While EEG was recorded, 28 undergraduate participants observed video clips showing an actor's hand reaching for, grasping, and lifting a cylindrical object across four conditions (right-hand egocentric, left-hand egocentric, right-hand allocentric, and left-hand allocentric). For actions viewed from an egocentric perspective, significantly greater event-related desynchronization (ERD) was present in the 7–9 Hz range over right mid-frontal, right central, and bilateral mid-parietal sites for right-handed actions compared to left-handed actions. In addition, greater ERD was observed within the 7–9 Hz band during the observation of right-handed egocentric actions compared to actions viewed from the allocentric perspective. This finding was present at bilateral central and mid-parietal sites, and emerged as an anticipatory effect prior to the onset of the observed hand movements.

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1. Introduction

1.1. Linkages between action production and action perception

There continues to be a good deal of interest across the field of social-cognitive neuroscience in delineating the brain

networks that are active during the observation of others' actions (Molenberghs et al., 2012). This interest has been partly driven by the suggestion that neural processes involved in executing an action are also active while watching others perform a similar action (Rizzolatti and Sinigaglia, 2010). Although the nature and function of these neural overlaps remain a topic of debate, they have been proposed

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as being important for understanding the processes involved in human social learning and communication (Keysers and Perrett, 2004; Kourtis et al., 2013). Learning new skills, perceiving the goals and intentions of others, and communicating via gestures all involve an understanding that can be facilitated by observing the actions of others. By gaining basic knowledge about the neural processing involved in action observation, we can also work toward understanding how these processes may come to be impaired in certain disorders.

1.2. Sensorimotor EEG rhythms

Patterns of brain activation during action observation have been studied using various imaging methodologies, including the electroencephalogram (EEG). Related studies of action processing have placed a particular focus on sensorimotor brain rhythms such as the mu rhythm, which oscillates in the alpha frequency range over central electrode sites (Pfurtscheller and Lopes da Silva, 1999; Pineda, 2005). The mu rhythm has been used to examine the coupling between action perception and action production through examining similarities in patterns of mu desynchronization between the observation of an action and the execution of a similar action (Muthukumaraswamy et al., 2004; Orgs et al., 2008; Perry et al., 2011). However, despite sustained interest in the responses of mu and other sensorimotor rhythms (e.g., beta) during the observation of others' actions, there remain various basic questions about the patterning of EEG activity during action observation. One such question concerns how the response of the mu rhythm to action observation may be modulated by the visual perspective from which an action is viewed as well as which hand (left vs. right) the person carrying out the action is using. In the current study, the response of the mu rhythm to observed hand actions was assessed to probe specific questions about how these responses vary according to the visual perspective from which the action was observed, as well as the hand (left vs. right) that was used to carry out the action.

1.3. Visual perspective of observed actions

One open question concerning brain activity during action observation is how the perspective, or viewpoint, of an observation affects the neural processing of the action. Evidence from recordings of mirror neurons in premotor areas of macaque monkeys suggests that the activity of approximately three quarters of the neurons in these areas during action observation is dependent on the perspective from which a grasping action was viewed by the monkey (Caggiano et al., 2011). In humans, EEG studies have examined differences in responses between viewing actions from an egocentric (first-person) perspective vs. an allocentric (third-person) perspective, although results have been inconsistent. In one study, greater mu rhythm suppression was apparent when participants viewed reaching and grasping actions from an allocentric perspective compared to when they viewed similar actions from an egocentric perspective (Frenkel-Toledo et al., 2013). These authors proposed that compared with actions viewed from an egocentric perspective, the visuospatial transformation

required for actions viewed from an allocentric perspective involves a heavier processing load, which may account for greater mu suppression during allocentric actions. They also suggested that an allocentric perspective would present a more familiar perspective than an egocentric perspective, which could also account for greater mu suppression during the observation of allocentric actions.

In a similar EEG study, Fu and Franz (2014) had participants view simple action scenes in which both hands were visible and one hand moved from one spot to another in a reaching trajectory (but without the presence of an object). In contrast to Frenkel-Toledo et al. (2013), the authors observed greater mu suppression over sensorimotor areas while participants viewed these hand movements from an egocentric compared to an allocentric perspective. These findings are supported by a related fMRI study by Jackson et al. (2006) who found greater activation in sensorimotor areas during the observation of hand actions presented from an egocentric perspective. These authors proposed that the first-person perspective may be more directly mapped onto the sensorimotor system, whereas information gained from an allocentric perspective would have to undergo a visuospatial transformation to be aligned with the observer's own viewpoint.

In considering the similarities and differences in findings between these prior studies, it is worth noting the specific stimuli that were used in each investigation. In the studies by Fu and Franz (2014) and Jackson et al. (2006), the egocentric views only showed the hand and forearm, such that participants saw a first-person view that was similar to watching themselves perform the hand movement. In addition, the actions were limited to simple hand movements, without the grasping or manipulation of an object. However, in the study by Frenkel-Toledo et al. (2013), the video clips in the egocentric condition included part of the actor's shoulder, which changes the view from approximating that of one's own actions to a view of someone else, as if the participant was looking over the shoulder of another person. This study also used object-directed hand actions rather than the more intransitive movements in the other reports. In the current study, we attempted to reconcile the various differences in the literature by recording EEG while participants viewed object-directed hand actions from egocentric and allocentric perspectives, where the egocentric perspective was a first-person view similar to that used in Fu and Franz (2014) and Jackson et al. (2006).

1.4. Observation of left or right hand

In addition to the effect of perspective on neural activity during the observation of hand actions, another unresolved question concerns the patterning of brain responses in relation to the specific hand being used to carry out an observed action. Using fMRI, early work in this area in adults suggested a somatotopic organization of sensorimotor cortex activity during action observation (Buccino et al., 2001), with recent EEG findings in infants supporting this organization and adding a developmental aspect (Saby et al., 2013). However, this work focused on contrasting activity during actions carried out with different effectors (e.g., hand vs. foot) rather

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