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MULTIFOCAL INTRAPARIETAL ACTIVATION DURING DISCRIMINATION OF ACTION INTENTION IN OBSERVED TOOL GRASPING

G. VINGERHOETS,[a,b]* P. HONORÉ,[a,b] E. VANDEKERCKHOVE,[a,b] J. NYS,[a,b] P. VANDEMAELE[b,c] AND E. ACHTEN[b,c]

[a]*Laboratory for Neuropsychology, Department of Internal Medicine, Ghent University, Ghent, Belgium*

[b]*Ghent Institute for Functional and Metabolic Imaging, Ghent University, Ghent, Belgium*

[c]*Department of Radiology, Ghent University, Ghent, Belgium*

Abstract—The way we grasp an object varies depending on how we want to use that object, and this knowledge can be used to predict the object-related behavior of others. In this study, we assessed the neural correlates that determine the action intention of another person based on observed prehensile movements. Fourteen right-handed volunteers watched video clips of a person performing right-handed transitive grasping gestures that were either aimed at displacing or using a tool-object. Clips showing the grasping and displacement of neutral shapes served as a control condition. By discrimination of the actor's intention, three roughly symmetrical foci were activated in the anterior, middle, and caudal segments of the intraparietal sulci, and in the fusiform gyri and parts of the lateral occipital complex. Anterior intraparietal activation has been associated with the representation of object goals (object specific), and the present findings extend its involvement to functional goals (use-specific). Activation in the middle intraparietal region during intention discrimination was very similar to the activation elicited in a saccadic localizer task, suggesting a relation with spatial attention and eye movements. The caudal intraparietal region has been related with visuospatial guidance of reaching, and its activation during action intention discrimination indicates that the visuospatial properties of the observed reaching movement contribute to understanding of actions. As these parietal regions are strongly linked with motor behavior, our results appear to support the motor simulation hypothesis for action understanding with the preferential recruitment of the mirror-neuron system. This could at least be the case when no contextual information other than the visual properties of the movement is provided to discriminate the intention of an observed hand action.

Key words: action understanding, action intention, tool use, posterior parietal lobe, intraparietal sulcus, transitive gestures.

The ability to understand the intentions of others is crucial for self preservation and adequate social interaction. Given the importance of object use in the human species, the observation of prehensile gestures can be relevant to predict someone else's behavior. Monitoring the properties of a prehensile movement may convey the intentions of the actor toward the object: touch, use, move, drop, throw? In the present study, we will focus on the human capacity to discriminate action intention based on the observation of reach and grasp movements and we will explore the neural correlates underlying this ability.

In the non-human primate brain, it is a region in the anterior-lateral intraparietal sulcus, usually referred to as AIP, which plays a significant role in grasp formation, as had been illustrated in single unit recordings and pharmacological lesions (Gallese et al., 1994; Murata et al., 2000; Sakata et al., 1995). In humans, neuroimaging studies have revealed activation of the anterior segment of the intraparietal sulcus, commonly termed aIPS, when healthy participants perform simple prehensile actions (Begliomini et al., 2008; Binkofski et al., 1998; Culham et al., 2003; Frey et al., 2005). These studies thus suggest that aIPS is the human homologue of monkey AIP, and that this region is involved in grasp-related actions. Recent research has already broadened the role of human aIPS in action planning and recognition of goal dependent hand-object movements (Tunik et al., 2007). In one study, transcranial magnetic stimulation (TMS) of the aIPS region disrupted adaptive responses of grasp aperture and forearm orientation during a grasping task, suggesting that aIPS is also involved in the representation of action goals and underlies on-line control toward the intended goal (Tunik et al., 2005). Other neuroimaging studies have used repetition suppression (RS) when exploring the role of aIPS beyond a repository for grasp configurations triggered by object features. This approach is based on the finding that the repeated presentation of a stimulus feature results in a decrease in the BOLD signal in the exact same region where that particular stimulus feature is encoded. Shmuelof and Zohary reported fMRI adaptation in the aIPS during repeated viewing of the same object-grasping movement and concluded that aIPS is involved in action recognition (Shmuelof and Zohary, 2005). Using a similar RS-approach, Hamilton and Grafton found evidence for BOLD adaptation in the aIPS during repeated presentation of the same goal (a target object), irrespective of the trajectory taken by the actor's hand. These results suggested that the aIPS has a central role in representing and interpreting the goals of observed hand actions (Hamilton and Grafton, 2006).

*Correspondence to: G. Vingerhoets, Ghent University, Laboratory for Neuropsychology, De Pintelaan 185 4K3, B-9000 Ghent, Belgium. Tel: +32-9-240-45-87; fax: +32-9-240-45-55.
E-mail address: guy.vingerhoets@ugent.be (G. Vingerhoets).

Abbreviations: aIPS, anterior segment of the intraparietal sulcus; cIPS, caudal segment of the intraparietal sulcus; CoGr, control for general object grasping; FDR, false discovery rate; FuGr, functional grasp condition; mIPS, middle segment of the intraparietal sulcus; MoGr, move grasp condition; PEF, parietal eye fields; RS, repetition suppression; TMS, transcranial magnetic stimulation.

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So far, most studies focusing on goal representations in aIPS have used object goals, where the intention of the actor is to grasp one particular object, rather than another. In these cases, it is the identity of the object that determines the intention of the actor. Yet, our goals also influence our interactions with a single object. The way we grasp an object varies depending on how we want to use that object (Ansuini et al., 2006, 2008). By observing the grasping behavior of another person, we can make predictions about the intentions of that person with the object. To date, only one RS-study investigated intention understanding of transitive gestures and found left inferior frontal, bilateral aIPS, and right superior temporal activation (Ortigue et al., 2009). The present study aims to investigate this subtle aspect of goal representation further. Rather than using different objects to achieve goal differentiation, we chose stimuli consisting of single tool objects that were grabbed by an actor who intended either to use or to displace the tool. By viewing the way in which the object was seized, participants had to decide what the intention of the actor was: to use or to move the object. Neutral shapes were taken to control for the observation of reaching movements and hand configurations in object grasping. Instead of disrupting the discrimination process by using TMS or measuring BOLD adaptation by repeated presentation, we opted for a classic subtraction design to evaluate converging evidence of different neuroimaging techniques. In addition, a saccade task was employed to localize the parietal eye fields. Tool identification and intention discrimination in the experimental conditions is likely to bring about increased eye movements in the observers and these additional saccades could influence the resulting parietal activation. In short, the study aimed to broaden the involvement of the anterior intraparietal region to the encoding of an observed functional intention (rather than a target intention), while controlling for prehensile actions in general. In addition, its goal was to distinguish the resulting activation from parietal regions that are used for eye movements. We predicted that discrimination of action intention based on observed prehensile shaping would also activate the anterior intraparietal region.

EXPERIMENTAL PROCEDURES

Stimuli

Discrimination of action intention paradigm. Sixty video clips were made with a Canon XM2 video camcorder showing a female person perform grasping movements toward a tool object that was placed before her on an empty table. Thirty different familiar tools were used, a list of which can be found in the Appendix. In 30 clips, the person grasped the tool with the intention of using the object for its appropriate function: these clips constituted the functional grasp condition (FuGr). In a second set of 30 clips, the same person grasped the same tools but this time with the intention of displacing the object: these clips served as the move grasp condition (MoGr). Although at the start both kinds of clips showed very similar reaching movements of the arm and hand aiming for the object, over time, the position of the wrist, hand, and fingers gradually differentiated into either a functional or a more mechanical grasp posture, and by the time the object was actually held, the intention of the actor became clear (Fig. 1). In addition to these 60 tool clips, we also made 12 video clips in which the actor performed grasping movements toward neutral shapes. As neutral shapes are not associated with a specific function, the movements were always intended to displace the neutral shape and these stimuli served as a condition to control for general object grasping (CoGr). All stimuli had an average duration of 4000 ms and consisted of a video clip of exactly 3500 ms followed by a random interstimulus interval (indicated by a blank grey screen) with a mean duration of 500 ms. Video clips were cropped to reveal only the actor's hands, arms and upper trunk, but not the face. The face was deliberately not shown to avoid activation of face areas and to focus the participants' attention on the grasp movements.

Saccadic eye movement paradigm. Stimuli consisted of a yellow dot that jumped randomly to different eccentric positions on a black screen with a frequency of 2 Hz (saccade condition), or that remained fixed in the middle of the screen (rest condition). The number of saccadic eye movements to each quadrant (and within the quadrants of each quadrant) were equated, with a maximal amplitude of 17.2° in the horizontal and 12.1° in the vertical dimension. The size of the yellow dot was 0.4°.

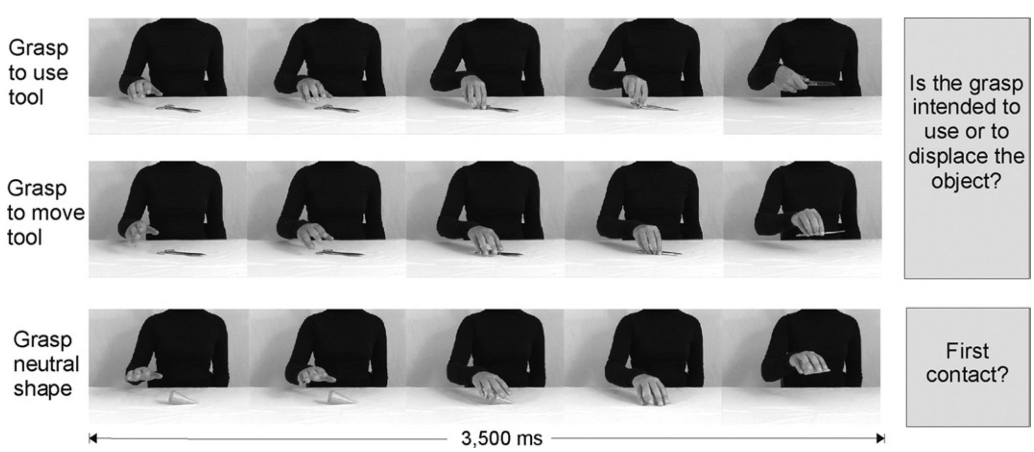

Fig. 1. Examples of the three different grasp conditions: five frames taken from each movie illustrate the grasping movements. In the tool conditions, participants had do decide as quickly as possible whether the intention of the actor was to use or to displace the object by means of a button press. In the control condition, a button press (random choice) was required the moment the neutral shape was grasped.