



## The role of selective attention in matching observed and executed actions

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### ABSTRACT

Substantial evidence suggests that observed actions can engage their corresponding motor representations within the observer. It is currently believed that this process of observation–execution matching occurs relatively automatically, without the need for top-down control. In this study we tested the susceptibility of the observation–execution matching process to selective attention. We used a Go/NoGo paradigm to investigate the phenomenon of ‘automatic imitation’, in which participants are faster to initiate a hand movement that is congruent with a concurrently observed action, relative to one that is incongruent. First, we replicated previous findings of automatic imitation, and excluded the possibility that spatial compatibility effects might explain these results (Experiment 1). We then presented participants with the same goal-directed actions while directing their attention to an imperative stimulus that spatially overlapped, but was distinct from, the observed actions (Experiment 2). Crucially, automatic imitation no longer occurred when participants directed their attention away from the displayed actions and towards the spatially overlapping stimulus. In a final experiment, we examined whether the automatic imitation of grasp persists when participants attend to an irrelevant feature of the observed action, such as whether it is performed by a left or right hand (Experiment 3). Here we found that automatic imitation is contingent on participants attending to the feature of the observed hand that was relevant to their responses. Together these findings demonstrate the importance of selective mechanisms in the filtering of task-irrelevant actions, and indicate a role for top-down control in limiting the motoric simulation of observed actions.

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### 1. Introduction

The notion that actions are intrinsically linked to perception is not new (Darwin, 1872/1965; James, 1890). Classical theorists noted that observers are prone to mentally simulating and imitating the actions of others (Carpenter, 1874; Chevreul, 1833; James, 1890; Lotze, 1852; Smith, 1759/1976). Darwin (1872/1965), for example, noted that spectators at leaping matches move their own feet as if imitating the athletes, and argued that man has a ‘strong tendency to imitation, independently of the conscious will.’ More recently, it has been shown that humans have a tendency to unconsciously and non-strategically mimic the bodily postures (Chartrand & Bargh, 1999), facial expressions (Dimberg, 1982; Vaughan & Lanzetta, 1980) or gross arm movements of other individuals (Kilner, Paulignan, & Blakemore, 2003). Furthermore, human neuroimaging studies have indicated that the process by which an observed action is transformed into its motor equivalent

is mediated by the mirror neuron system—a network of parietal and premotor areas that respond both to the observation and execution of action (Chong, Cunnington, Williams, Kanwisher, & Mattingley, 2008; Dinstein, Gardner, Jazayeri, & Heeger, 2008; Grezes, Armony, Rowe, & Passingham, 2003; Iacoboni et al., 1999, 2001; Koski, Wohlschläger, Bekkering, Woods, & Dubeau, 2002; Rizzolatti & Craighero, 2004; Rizzolatti, Fadiga, Matelli et al., 1996).

It has been suggested that perceiving an action activates the corresponding motor representations within the observer automatically and without conscious effort (Buccino et al., 2001; Coricelli, 2005; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Gallese & Metzinger, 2003; Rizzolatti & Craighero, 2004; Rizzolatti, Fadiga, Matelli et al., 1996; Wilson & Knoblich, 2005). Evidence in favor of this proposal comes from studies that have recorded motor-evoked potentials (MEPs) during the passive observation of action, and which have shown increases in motor excitability specific to the muscles involved in performing those actions (Fadiga, Craighero, & Olivier, 2005; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). In addition, electroencephalography (EEG) and magnetoencephalography (MEG) studies indicate that the passive observation and active execution of action have similar effects on rhythmic oscillations originating from central regions of the brain (the mu and 20 Hz

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rhythms, respectively) (Cochin, Barthelemy, Roux, & Martineau, 1999; Hari et al., 1998).

Behaviorally, a consistent finding in favor of the automaticity hypothesis arises from studies of so-called ‘automatic imitation’. This is the observation that participants are typically faster to execute an action that is congruent with one that is concurrently observed, relative to one that is incongruent (Brass, Bekkering, & Prinz, 2001a; Brass, Bekkering, Wohlschläger, & Prinz, 2000; Craighero, Bello, Fadiga, & Rizzolatti, 2002; Heyes, Bird, Johnson, & Haggard, 2005; Press, Bird, Flach, & Heyes, 2005; Press, Gillmeister, & Heyes, 2006; Stürmer, Aschersleben, & Prinz, 2000; Vogt, Taylor, & Hopkins, 2003). Importantly, this effect is found even when the observed action is entirely irrelevant to participants’ responses. Many studies on automatic imitation have utilized simple intransitive actions, such as a lifting/tapping movement of a finger, or an opening/closing movement of the hand (Brass et al., 2000; Brass, Bekkering et al., 2001; Heyes et al., 2005; Press et al., 2005, 2006; Stürmer et al., 2000). By comparison, fewer studies have examined the automatic imitation effect with more naturalistic, goal-directed movements, such as reach-to-grasp hand actions (Craighero et al., 2002; Vogt et al., 2003).

A representative example of an automatic imitation paradigm with goal-directed hand actions is the Go/NoGo task used by Craighero et al. (2002). In this paradigm, right-handed participants were trained to perform a precision grasp towards a clockwise- or counterclockwise-oriented bar that was positioned out of sight. Participants performed these movements in response to a ‘Go’ signal that was either the mirror image of their right hand in its final position or the mirror image of the right hand in the alternate end position. As predicted, reaction times were faster during the observation of congruent relative to incongruent hand postures. Furthermore, this congruency effect persisted even when the end positions of the hands were similar but rotated rightwards by 90°, which the authors argued excluded the possibility that their results were caused by mere spatial compatibility (i.e., by simple matching of the end positions of the fingers and thumb to the imperative stimulus). In a subsequent study, Vogt et al. (2003) extended the findings of Craighero et al. (2002) in a simple reaction-time task. In this study, participants grasped a vertical or horizontal rod that was occluded from sight, in response to the appearance of any hand stimulus whatsoever, which could have been either congruent or incongruent with the executed action. The authors found that the automatic imitation of goal-directed actions persists even when no visual discrimination of the target stimulus is required.

Although such congruency effects suggest an underlying automaticity to the observation–execution matching process, the extent of this automaticity remains unclear. The traditional distinction between automatic and controlled processes is that the former are triggered involuntarily and do not require attention for their execution (Bargh, 1992; Cohen, Dunbar, & McClelland, 1990; Hasher & Zacks, 1979; Posner, 1978). A corollary of this definition is that automatic processes do not draw on general cognitive resources, and thus do not interfere with, nor are they subject to interference from, other concurrent perceptual or cognitive demands. Consequently, several such processes can operate in parallel in the absence of capacity limitations (Pashler, 1998). If the automaticity of the visuomotor transformation process is strong, an observed action should be processed independently of whether that action is selectively attended.

Crucially, however, previous experiments have not explicitly manipulated the allocation of attentional resources during the processing of an observed gesture. Thus, the role of selective mechanisms in the observation–execution matching process is uncertain. For example, some studies have required participants to perform a simple finger movement (e.g., lifting or tapping a finger) in response to a symbolic cue (such as a numeric prime which denotes the fin-

ger to be moved) or a spatial cue (such as a cross on an image of the finger to be moved) (Bertenthal, Longo, & Kosobud, 2006; Brass et al., 2000). While participants attended to these cues, they were concurrently presented with the image of a congruent or incongruent finger movement. The typical finding is that automatic imitation occurs even when participants’ attention is directed towards the secondary symbolic or spatial cue, and away from the observed finger movement. Superficially, this would appear to be evidence in favor of automaticity of the visuomotor transformation process. However, such findings usually arise in the presence of attentionally salient actions (e.g., those with a component of motion). Because moving stimuli may act as powerful exogenous cues (Posner & Cohen, 1984), it is unclear whether these apparent congruency effects arise as a result of some inherent automaticity to the visuomotor transformation process, or simply due to the involuntary capture of attention by the moving (albeit task-irrelevant) actions.

It has also been shown that automatic imitation persists when participants attend to a feature of an observed action that is orthogonal to the required response (e.g., attending to the *color* of a hand to execute the appropriate hand *movement*, Stürmer et al., 2000). Often, however, the orthogonal discrimination imposes a low processing load on cognitive resources. Previous studies on selective attention have shown that such low processing loads can allow attentional resources to ‘spill over’ to the processing of other irrelevant features of a stimulus (Lavie, 1995, 2000). In the present context, the consequence would have been to allow attentional resources not already consumed by the response-orthogonal discrimination to be engaged in processing the response-relevant feature of the observed action.

To summarize, the effect of selective attention on visuomotor transformations of observed actions remains unclear. Nevertheless, there are strong *a priori* reasons for supposing that the processing of observed actions should be susceptible to top-down modulation. In the natural environment, for example, we are typically confronted with several actions and gestures simultaneously, of which only a fraction are behaviorally relevant. Selective mechanisms should be critical in enhancing the processing of these actions, while suppressing those that are irrelevant or otherwise distracting. In fact, the importance of selective attention in processing observed actions was demonstrated in a recent functional magnetic resonance imaging (fMRI) study, which found that increasing the attentional load of a secondary task suppressed activity within left inferior frontal gyrus (IFG, BA 45; Chong, Williams, Cunnington, & Mattingley, 2008)—an area that has previously been implicated in the action observation network.

In addition to the neuroimaging study of Chong, Williams et al., 2008, emerging behavioral data have provided evidence that spatial attention may be important in the perception of body parts in general. Bach, Peatfield, and Tipper (2007) required participants to respond to the color of a target disc by pressing a corresponding button with either their foot or their finger. The authors’ manipulation was to superimpose the colored targets on either the foot or hand on a whole-body display. They found that reaction times were faster when the attended body part (e.g., the hand) matched the corresponding effector (e.g., a button press with one’s finger). This result shows that attending to a body part non-specifically primes motor responses involving that particular effector. However, the authors also found that attending to a neutral body part (e.g., the head) completely suppressed this visuomotor priming effect. This result emphasizes the role of spatial attention in action observation, by showing that only those body parts that appear within the spotlight of attention get processed. However, it is currently uncertain whether selective processes continue to be important when observed actions can be specifically mapped onto participants’ own motor responses (i.e., in automatic imitation). Furthermore, the question remains as

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