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Incongruent imagery interferes with action initiation

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ABSTRACT

It has been suggested that representing an action through observation and imagery share neural processes with action execution. In support of this view, motor-priming research has shown that observing an action can influence action initiation. However, there is little motor-priming research showing that imagining an action can modulate action initiation. The current study examined whether action imagery could prime subsequent execution of a reach and grasp action. Across two motion analysis tracking experiments, 40 participants grasped an object following congruent or incongruent action imagery. In Experiment 1, movement initiation was faster following congruent compared to incongruent imagery, demonstrating that imagery can prime the initiation of grasping. In Experiment 2, incongruent imagery resulted in slower movement initiation compared to a no-imagery control. These data show that imagining a different action to that which is performed can interfere with action production. We propose that the most likely neural correlates of this interference effect are brain regions that code imagined and executed actions. Further, we outline a plausible mechanistic account of how priming in these brain regions through imagery could play a role in action cognition.

1. Introduction

It has been proposed that observing or imagining an action engages similar neural processes as those used in execution of that same action (James, 1890; Jeannerod, 1994; Prinz, 1997). Lending support to this idea, neuroimaging studies have identified a comparable network of brain regions that are active during execution, observation and imagination of actions (Grèzes & Decety, 2001). This network includes the inferior frontal gyrus (IFG) and inferior parietal lobule (IPL), which constitute the human mirror neuron system (MNS) (Rizzolatti & Craighero, 2004; Rizzolatti & Sinigaglia, 2010), and other regions associated with the control of action such as the supplementary motor area (SMA) and cingulate motor area (CMA) (Grèzes & Decety, 2001; Jeannerod, 2001; Munzert, Lorey, & Zentgraf, 2009).

There are numerous hypotheses that suggest why such a coactive mechanism might exist, which include action understanding (Fogassi et al., 2005; Iacoboni et al., 2005; Rizzolatti, Fogassi, & Gallese, 2001), action prediction (Prinz, 1997; Wilson & Knoblich, 2005), and mindreading (Gallese & Goldman, 1998). One account argues that the shared processing between action perception and production provides a means of "tuning" the motor system through repeated internal simulation (Jeannerod, 1994; Prinz, 1997). According to this hypothesis, activation of corresponding brain structures through mental simulation should prime action execution.

Testing these predictions, Kilner, Paulignan, and Blakemore (2003) theorised that if the motor system is activated by observed movements, interference should occur when observing a different action to one that is simultaneously executed. Kilner et al. (2003) recorded sinusoidal arm movements of participants whilst they observed somebody else simultaneously perform congruent, incongruent or no arm movements (control). Consistent with their hypothesis, variance in arm movement was significantly greater when observing incongruent movement compared to control; no other condition differed from control. Thus, observation interfered with action production, which is consistent with other datasets (Brass, Bekkering, & Prinz, 2001; Dijkerman & Smit, 2007; Kilner, Hamilton, & Blakemore, 2007). Observation has also been shown to facilitate action production (Brass, Bekkering, Wohlschlager, & Prinz, 2000), though most studies that showed an action-priming effect did not include a relevant baseline, which means facilitation and interference are equally plausible explanations of the data (Castiello, Lusher, Mari, Edwards, & Humphreys, 2002; Craighero, Bello, Fadiga, & Rizzolatti, 2002; Edwards, Humphreys, & Castiello, 2003; Heyes, Bird, Johnson, & Haggard, 2005). Together, these motor-priming data have been argued to be evidence for a 'motor

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contagion' when performing and observing actions (Blakemore & Frith, 2005). That is, the motor system of the observer is primed to produce the observed movement.

Based on similar shared motor processes between imagery and execution, there is evidence to support a similar line of theorising for imagery as observation. Imagined actions share neural substrates with execution (Grèzes & Decety, 2001; Jeannerod, 2001; Munzert et al., 2009) and are organised somatotopically in premotor and parietal cortices (Ehrsson, Geyer, & Naito, 2003). Consequently, imagined actions modulate muscle activity in the specific muscles that are used in the execution of the same movements (Fadiga et al., 1999). In addition to neural properties, imagery also shares functional properties with execution (Decety, 1996; Guillot & Collet, 2005). For example, breathing and cardiac frequency have been shown to increase when athletes imagine performing in a competitive environment (Gallego, Denot-Ledunois, Vardon, & Perruchet, 1996), and imagined movements follow the same biomechanical constraints as actual movements (Johnson, 2000). These lines of evidence suggest that imagery and execution share neural and functional processes (Decety, 1996; Grèzes & Decety, 2001; Jeannerod, 2001).

Further evidence for shared processes between imagery and action production has been provided by studies that show imagery and action production have a direct influence on each other. Imagery training facilitates a wide range of motor tasks (Allami, Paulignan, Brovelli, & Boussaoud, 2008; Boschker, Bakker, & Rietberg, 2000; Louis, Guillot, Maton, Doyon, & Collet, 2008; Yágüez et al., 1998), including complex sports performance (for reviews, see Cumming & Ramsey, 2008; Feltz & Landers, 1983; Murphy, Nordin, & Cumming, 2008) and muscle strength (Ranganathan, Siemionow, Liu, Sahgal, & Yue, 2004; Yue & Cole, 1992). These findings show that repeated imagery training can result in longer-term benefits to motor performance. In addition, action production has been shown to have a direct influence on imagery performance (Schwartz & Holton, 2000; Sirigu & Duhamel, 2001; Wexler, Kosslyn, & Berthoz, 1998; Wohlschläger & Wohlschläger, 1998). For example, in a mental rotation task, performing a congruent hand rotation produced faster response times and less errors than performing an incongruent hand rotation (Wexler et al., 1998). Together, these findings show that imagery can assist in skill acquisition and that performing an incongruent action interferes with imagery.

Taken together, these findings support the suggestion that observation and imagery share neural and functional processes with action production. Consequently, observing or imagining an action can influence action production (Jeannerod, 1994; Prinz, 1997). To date, numerous studies have shown a motor-priming effect from observing congruent compared to incongruent actions (Brass et al., 2000, 2001; Castiello et al., 2002; Craighero et al., 2002; Dijkerman & Smit, 2007; Edwards et al., 2003; Heyes et al., 2005; Kilner et al., 2003, 2007). However, similar motor-priming evidence, which shows that the congruency of an imagined action influences the performance of an action, has not yet been provided. As a result, although it is clear that repeated sessions of imagery (imagery training) can influence action production (Allami et al., 2008; Boschker et al., 2000; Louis et al., 2008; Murphy et al., 2008; Ranganathan et al., 2004; Yágüez et al., 1998) it is not known whether imagery, like observation, automatically primes the motor system for action. Based on the evidence for shared motor processes between imagery, observation and execution, similar motor-priming predictions follow for imagery as observation (e.g., Kilner et al., 2003). That is, imagining a different action to that which is performed should interfere with performance. By contrast, imagining a similar action should not cause interference and may facilitate performance.

To test these predictions, two experiments were performed using a similar design to that used by Jackson, Jackson, and Rosicky (1995) to study non-target interference effects. Jackson et al. (1995) presented a target object alone or alongside a non-target object, and the task for each trial was to reach and grasp the target. For both experiments in the current paper the general setup was similar: a target object was presented alongside one or two non-target objects (Fig. 1). Experiment 1 was performed to establish that action imagery could prime the initiation of grasping. One of two target objects was presented between two non-target objects. On each trial participants grasped the target object and the time taken to initiate movement was recorded. Prior to performing the grasp, participants imagined grasping the target object (congruent) or one of the non-target objects (incongruent). If imagery does prime the initiation of grasping, we would expect shorter reaction times following congruent compared to incongruent imagery.

In Experiment 2, a no-imagery control condition was added to the experimental procedures in order to examine the direction of performance modulation. If congruent imagery reduced the time taken to initiate grasping compared to control, this would suggest congruent imagery facilitated grasping. By contrast, if incongruent imagery increased the time taken to initiate grasping compared to control, this would suggest incongruent imagery interfered with grasping. If both predictions are substantiated then this pattern of results would be consistent with a prior behavioural observation study, which also showed facilitation and interference to performance (Brass et al., 2000). By contrast, if imagery only interferes with action, these data will be consistent with data that only showed an interference effect from observation (Brass et al., 2001; Dijkerman & Smit, 2007; Kilner et al., 2003, 2007).

2. Experiment 1

2.1. Methods

2.1.1. Participants

Twenty participants (18 male), aged between 18 and 32 years (mean = 22.8 years, *SD* = 3.4), took part in the experiment. All were right handed (as determined by the Edinburgh Handedness Inventory; Oldfield, 1971) and had normal or corrected to normal vision. Ethical approval was gained through the local ethics board.

2.1.2. Apparatus

A dual camera MacReflex infrared 3D motion analysis tracking system (50 Hz) was used to record the initiation of movement

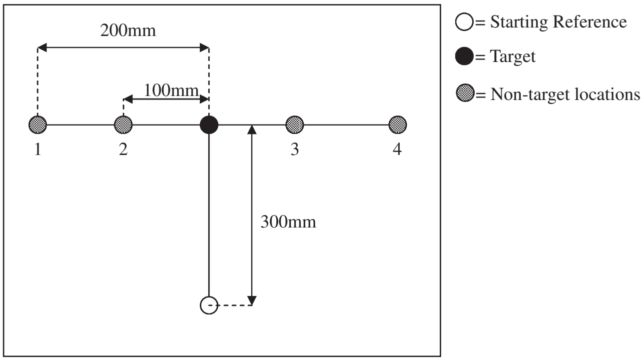

Fig. 1. The experimental setup. Experiment 1: On near configuration trials two non-targets were presented in locations 2 and 3. On far configuration trials two non-targets were presented in locations 1 and 4. On every trial one of two target objects (small or large) was presented in the same central location. Experiment 2: On each trial one non-target was presented in one of the four non-target locations (1–4). The target object was presented in the same central location on every trial. The general procedure was the same for both experiments. Participants first performed an experimental condition (Experiment 1: congruent or incongruent imagery; Experiment 2: congruent, incongruent or no imagery), before reaching and grasping the target object.