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Is social inhibition of return due to action co-representation?

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ABSTRACT

When two individuals alternate reaching responses to visual targets presented on a shared workspace, one individual is slower to respond to targets occupying the same position as their partner's previous response. This phenomenon is thought to be due to processes that inhibit the initiation of a movement to a location recently acted upon. However, two distinct forms of the inhibition account have been posited, one based on inhibition of an action, the other based on inhibition of an action and location. Furthermore, an additional recent explanation suggests the phenomenon is due to mechanisms that give rise to action congruency effects. Thus the three different theories differ in the degree to which action co-representation plays a role in the effect. The aim of the present work was to examine these competing accounts. Three experiments demonstrated that when identical actions are made, the effect is modulated by the configuration of the visual stimuli acted upon and the perceptual demands of the task. In addition, when the co-actors perform different actions to the same target, the effect is still observed. These findings support the hypothesis that this particular joint action phenomenon is generated via social cues that induce location-based inhibition of return rather than being due to shared motor co-representations.

1. General introduction

The past decade has seen increasing interest in the effect of interpersonal interaction on human cognition (Atmaca, Sebanz, & Knoblich, 2011; Atmaca, Sebanz, Prinz, & Knoblich, 2008; Frischen, Loach, & Tipper, 2009; Schuch & Tipper, 2007; Tsai, Sebanz, & Knoblich, 2011; Skarratt et al., 2012; Welsh et al., 2005). Such research has revealed novel insights concerning cognitive processes that have previously been studied with individuals, including visual attention and motor performance. Focusing upon the latter behaviors, recent interest in 'joint action' is in part due to the acknowledgement that many everyday human visuomotor behaviors involve interaction with others, or acting in the close presence of others.

Joint action work has most often been placed within the context of models that link action and perception (Hommel, 2009; Jeannerod & Frak, 1999; Knoblich & Sebanz, 2006; Prinz, 1997). The basis of these models is that rather than being separate, perception and action share cognitive representations. It follows that when two or more people act together, the observation of one individual's action by another activates the motor system of the observer. Co-representation of perceived and performed actions has received much support (see Blakemore & Frith, 2005; Wilson & Knoblich, 2005 for reviews). Sebanz, Knoblich, and Prinz (2003) demonstrated this phenomenon using the Simon spatial compatibility task (Simon, 1970). When this task is performed alone, a discrimination of a stimulus is made that has two dimensions. The dimension to be discriminated (for example, a color) is non-spatial but the other dimension is spatial (for example, an arrow). Participants make discriminations using buttons placed spatially so that they can be spatially congruent or incongruent with the stimuli. Typically, congruent responses are faster than those that are incongruent. Sebanz, et al. found that this occurred when two individuals were each responsible for making a single discrimination response but did not do so when a single person performed one such response, i.e., in the absence of a co-actor. The so-called Social Simon Effect (SSE) has been interpreted as evidence that individuals represent the actions and/or task of another, as if they were their own (Dolk et al., 2011; Sebanz, Knoblich, Prinz, & Wascher, 2006 but see Dolk, Hommel, Colzato, Schütz-Bosbach, Prinz and Liepelt, 2011).

Another example of a joint action effect that has generated a considerable amount of interest, and central to the present work, concerns social inhibition of return (social IOR); in which the actions of one individual can lead to inhibition in an observer. In the basic experiment, participants sit facing each other and take turns to respond to targets presented on a flat workspace positioned between them (Fig. 1). Results typically show that an individual is slower to initiate a response to a stimulus presented at the same location as their partner's previous response. Welsh et al. explained the effect with a combination of the action-perception models referred to above, the mirror neuron system, and inhibition of return (IOR; Posner & Cohen, 1984). Specifically, since

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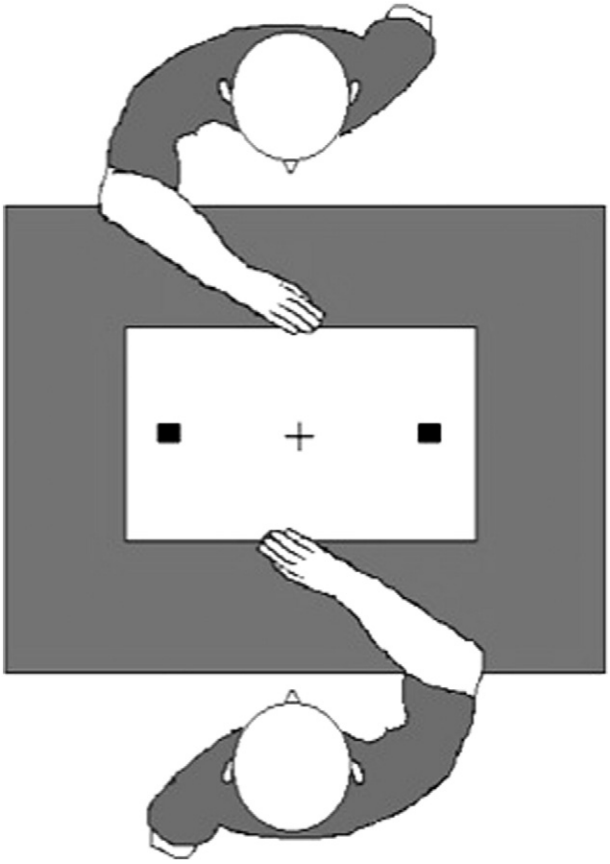

Fig. 1. The response environment. Participants are depicted with their preferred hand resting in the "home" position, before they alternated responses to targets appearing in the left or right positions. Measurements are not drawn to scale.

inhibition is a known consequence of action (e.g., Howard, Lupáñez, & Tipper, 1999; Tremblay, Welsh, & Elliott, 2005; Welsh & Pratt, 2006), the authors argued that the observer may inhibit an action based on one previously observed. In other words, the same inhibitory processes are evoked when a participant observes another person act on a location and when they act upon the location themselves. Furthermore, Welsh et al. posited that the mirror neuron system (Fogassi et al., 2005; Rizzolatti & Craighero, 2004) could play a role in this process. Mirror neurons are found in parietal and premotor areas of macaque monkeys and recently in a network of cortical and subcortical areas in humans (Fabbri-Destro & Rizzolatti, 2008; Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). These neurons are activated both during the performance and execution of a specific action and may be responsible for directly creating motor representations when an action is observed (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Filimon, Nelson, & Hagler, 2007; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). The final aspect of Welsh et al.'s theory concerns IOR. It is been well-established that after shifting attention to a location, a person will inhibit responses to stimuli appearing at the same location (Kingstone & Pratt, 1999; Klein, 2000; Posner & Cohen, 1984; Rafal, Calabresi, Brennan, & Sciolto, 1989). Although the precise mechanisms underlying IOR are debated, it is widely thought that attentional and oculomotor processes are slowed in reorienting to previously cued regions of space. This phenomenon is manifested by a delay in manual response time (RT) to respond to targets that are previously cued, relative to those that are uncued. Thus, Welsh et al. argued that the above processes act together to generate the basic effect.

In later work, Welsh and colleagues have provided further evidence that action co-representation can influence social IOR (Welsh, McDougall & Weeks, 2009). In a modification to the basic social IOR paradigm, participants now sat side-by-side rather than facing one another. As before, each took turns to reach out to one of two targets appearing on a tabletop. One target could occur on the right of the participant sitting on the right, another target could appear on the left of the participant sitting on the left, and a third target could appear at a position located between the two and was used by both participants. In accordance with the usual social IOR finding, results showed that responses were relatively slow when a reaching response was made to the same target as their partner's previous response. However, participants were also slower when making the same egocentric response as their partner. In other words, a participant sitting on the right would be slower to respond to their right hand target when their partner had also just made a rightward response. Thus, a partner's arm action movement appeared to be represented, rather than simply their response location.

The action co-representation account of social IOR does not however concur with recent work examining whether social IOR represents other aspects of actions. Cole, Skarratt and Billing (2012); see also Ondobaka, de Lange, Newman-Norlund, Wiemers & Bekkering, 2012) undertook a variant of the basic social IOR procedure in which participants reached to a location and either performed the same end-point action as their partner (e.g., both writing a digit with a pencil) or performed a different end-point action (e.g., one writes a digit, the other erases a digit). This was partly motivated by evidence showing that perceptuo-motor representations are sensitive to action goals and end states (e.g. Fogassi et al., 2005; Iacoboni et al., 2005). Cole et al. however showed that the magnitude of social IOR was independent of action goal compatibility. Although it could be argued that the mechanisms that cause social IOR do represent actions but not their goals, these findings fit better with the alternative inhibitory account of the basic effect. Cole et al. (2012) suggested that when an individual responds to a spatial location this will direct an observer's perceptuo-motor processing to that location. Consequently, IOR will be generated resulting in slower RTs to targets appearing at the responded-to location. In effect, the target and the subsequent arm reach elicits the same orienting response as does the central or peripheral cue in the standard IOR paradigm.

Ondobaka et al. (2012) have recently presented a further account of the basic arm movement phenomenon in which the effect was placed within the context of action congruency mechanisms. Performing an action is known to facilitate the initiation of a similar action in an observer. For instance, Liepelt, von Cramon, and Brass, (2008; see also, Brass, Bekkering, Wohlschlager & Prinz, 2000; Kilner, Paulignan & Blakemore, 2003) presented photographs of a hand that had a target number placed over the image. Observers were required to discriminate the target and make a response by lifting either their index or middle finger. The important manipulation was that the hand on the photograph had either its index or middle finger raised. Results showed that when the target required the middle finger to be raised reponses were faster if the depicted hand also had the middle finger raised. The same effect occurred for the index finger. With respect to the present effect, Ondobaka et al. argued that when a participant sees their co-actor perform a particular action this facilitates the same action performed themselves within an egocentric framework. For instance, if a co-actor sees their partner reach to their right this facilitates a rightward reach when they themselves are required to reach to their right on the next trial. Indeed, as well as describing social IOR in terms of slowed responses, the effect can also be described as an effect in which RTs are shorter when a co-actor performs the same action as their partner. This description, favoured by Ondobaka et al. is therefore a *pure* co-representation account, where only action congruency mechanisms are implicated.

The principal aim of the present work was to directly examine whether social IOR depends on the representation of an observed action, as suggested by Welsh et al. and Ondobaka et al. or can be accounted for by orienting mechanisms representing spatial locations. In three experiments participant pairs performed variants of the