Social Inhibition of return: Causes and properties

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DECLARATION

I declare that this thesis, *Social Inhibition of return: Causes and properties*, represents my own work, except where otherwise stated. None of the work referred to in this thesis has been accepted in any previous application for a higher degree at this or any other University or institution. All quotations have been distinguished by quotation marks and the sources of information specifically acknowledged.

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ABSTRACT

The present thesis was dedicated to examining individuals' performance on a low-level reaching task conducted under social-interactive conditions. In this paradigm named Social Inhibition of Return (social IOR) two individuals, sitting opposite each other take turns to respond to targets appearing on either side of a visual display. Typical results reveal that reaction times are longer when responses are directed to where the co-actor just responded. Despite being fairly simple, this task is intriguing to examine as it potentially incorporates features of both an inhibition of return (IOR) effect and, a joint-action phenomenon, due to its interactive nature. Indeed, the results of the standard social IOR paradigm where participants sit opposite are consistent with both explanations as the potential involvement of attentional inhibition and/or action co-representation cannot be disentangled. The present work examined the causes and properties of this intriguing effect over the course of four empirical chapters. First, Chapter 2 revealed that social IOR possesses a number of properties, characteristic of traditional IOR. Second, Chapter 3 convincingly demonstrated that action co-representation does not seem to contribute to the phenomenon. Furthermore, Chapter 4 confirmed these findings by revealing that social IOR does not depend on the socialness of the co-actor. Finally, Chapter 5 showed that it could even bias a range of free choice decisions which revealed another novel property of the effect. Taken together these findings were interpreted as mostly consistent with a low-level inhibitory account as opposed to a theory, advocating an involvement of action imitation/co-representation in the effect. The present work had a number of theoretical and methodological implications for the better understanding of social IOR. In more general terms, it also contributed to the quickly developing, alternative literature to the action co-representation account, advocating a bottom-up basis of some joint-action effects.

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'Inhibitory processes associated with selective attention are not confined to a single nervous system … these processes cross nervous systems during conditions where a performer observes another person engage in goal-directed reaching'

(Hayes, Hansen & Elliott, 2010, p. 303)

1.0 GENERAL INTRODUCTION

As outlined in the Abstract, the present thesis explored an effect standing at the boundaries of attentional orienting/inhibition of return on one side and joint-action/action co-representation on another. To understand better why and how these two separate branches of literature relate to the social IOR effect, the present General Introduction succinctly outlines their foundation, key principles and suspected neural mechanisms through which these operate. Following a bottom to top logic, the review commences with an introduction into the human visual attentional system and the basic inhibition of return effect. Then it continues with a thorough description of social IOR, as the name of the phenomenon suggests an involvement of inhibitory effects. Finally, the General Introduction ends with a review of joint-action with a particular focus on the action co-representation account which has been used to explain an identical effect to social IOR.

1.1 The Visual Attentional System and Social Cues

Attention optimizes the processing resources of the individual by enhancing the information of interest at a given moment and inhibiting the stimuli, identified as task-irrelevant at that time (Lavie, Hirst, de Fockert & Viding, 2004). Thus, if one can prioritise the processing of the relevant information on a task and completely ignore all irrelevant information, they are said to have *perfect attentional selection*. However, in reality, the attentional system is far from perfect not only because of the extreme abundance and complexity of the environment but also because individuals have limited processing resources (Lavie et al., 2004) due to which the attentional system is susceptible to numerous factors within and outside the individual.

The latter explains why the first attentional models have been predominantly concerned with identifying the stage at which attention influences the selection of perceptual information – before or after it has received full processing (Broadbent, 1958; Deutsch & Deutsch, 1963; Treisman, 1969). However, more recent work has suggested that rather than being viewed as a singular process attention is multifaceted, having several loci of selection (Chun & Wolfe, 2005). For example, attention could be deployed over space and time; however, most research has been dedicated to examining the workings of spatial visual attention, predominantly how spatial orienting occurs. Orienting is one of the three aspects[1] of the human attentional system, identified by Posner and Peterson (1990). Orienting has been defined as 'the aligning of attention with a source of sensory input or an internal semantic structure stored in memory' (Posner, 1980, p.4).

Moreover, such an alignment in spatial attention can occur either with the overt motion of the eyes, a process termed *overt attention* or without any change in one's gaze (*covert attention;* Helmholtz, 1866; 1911). Covert attention at a location has been found to facilitate saccades[2] and target identification at that location (Kowler, Anderson, Dosher & Blaser, 1995). Additionally, it seems to precede eye movements and thus is useful at monitoring the environment and guiding eye gaze. Moreover, while eye movements can be directed only to a single location at a time, covert attention can be deployed to more than one location simultaneously (LaBerge & Brown, 1989). Despite that, human and non-human neuropsychological studies have demonstrated that very similar cortical structures subserve both types of orienting (Corbetta et al., 1998; Nobre, Gitelman, Dias &

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[1] The other two being: executive control which monitors selection and resolves conflict; and alerting which is concerned with achieving and maintaining a vigilant state (Fan, McCandliss, Fossella, Flombaum & Posner, 2005; Posner & Peterson, 1990).

[2] Saccades are rapid, ballistic movements of the eyes that abruptly change their point of fixation and can range in amplitude from small (e.g., while reading) to much larger movements (e.g., gazing; Purves et al., 2001).

Mesulam, 2000). For example, the frontal eye field (FEF) which is the main neural correlate of eye movement behaviour has also been found to be active in covert attentional selection (e.g., Thompson, Biscoe & Sato, 2005). Thus, some have suggested that there might be no need for a dissociation between overt and covert attentional orienting processes (e.g., Rizzolatti, Riggio, Dascola & Umiltfi, 1987).

Furthermore, as mentioned above, instead of constructing an accurate representation of the world, the human attentional system interprets the incoming sensory input according to its behavioural relevance to the individual (Treue, 2001). In support, the neural activity of areas, previously considered to be purely sensory, such as the primary visual cortex (V1) have been found to be attention-modulated (e.g., Brefczynski & DeYoe, 1999; Gandhi, Heeger & Boynton, 1999; Silver, Ress & Heeger, 2005). Thus, in the context of spatial attention, the process of mapping the visual input from the retina to the cerebral visual areas (retinotopic activation) relies on how much attention has been deployed in that particular region. Moreover, in terms of behavioural relevance, other two ways in which attention could be oriented are *endogenously*, based on internal information coming from the individual's goals, prior knowledge and assumptions and *exogenously*, based on external information such as the (sudden) appearance of a possibly relevant stimulus (Jonides, 1981). In the first case, the deployment of attentional resources is said to occur in a top-down, voluntary fashion as it is internally guided. An example of the latter would be following a central arrow, pointing at the location where an upcoming target is going to appear. Exogenous orienting, on the other hand, is thought to occur automatically, in a bottom-up manner. Thus, the latter is normally studied in cueing paradigms where a sudden change in the periphery (e.g., a light flash) is found to produce a response time advantage if one needs to subsequently act at that particular area (e.g., Posner & Cohen, 1984). The next subsection in the review has been dedicated to explaining attentional cueing paradigms in more detail.

Finally, the visual attentional system seems to be highly influenced by human features, especially, the other’s eyes (the head area in general; Kuhn & Land, 2006; Langton & Bruce, 2000; Fletcher-Watson, Findlay, Leekam & Benson, 2008) and hands (e.g., Flanagan, Brodeur & Burack, 2015; Hu et al., 2013; Langton & Bruce, 2000). First, lab studies have demonstrated that participants exhibit a preference for these human features since such images easily attract attention, especially when depicting human eyes (Kuhn, Tatler & Cole, 2009; Pelphrey et al., 2002). Furthermore, research has also indicated that the other’s gaze direction orients attention, similarly to other endogenous cues (e.g., Flanagan et al., 2015; Linnell, Caparos, de Fockert & Davidoff, 2013). Thus, participants reflexively turn their look at the direction of where the others’ eyes are pointing, an effect known as gaze cueing (Driver et al., 1999). As gaze cueing has produced vast research interest, there is still an ongoing debate whether others’ eye direction has a special orienting status. Some argue that gaze leads to an indistinguishable cueing effect to non-biological directional cues (arrows; Kuhn & Kingston, 2009) whereas others have identified differences between gaze cueing and cueing from other anatomical organs (tongues; Downing, Dodds & Bray, 2004). However, importantly, even the proponents of the latter account (e.g., Downing et al., 2004) advocate that gaze produces automatic attentional shifts.

1.1.1 The Attentional Cueing Paradigm

As mentioned in the previous section, endogenous and exogenous spatial attention are usually studied in attentional cueing paradigms, the most famous of which has been devised by Posner and colleagues (Posner, Nissen & Ogden, 1978;

Posner, 1980; Posner & Cohen, 1984). In a series of experiments in their seminal paper Posner and Cohen (1984) identified several of the key features of attentional orienting by employing a simple covert orienting paradigm (eye movements were monitored).

In the basic paradigm participants fixate on a centrally presented box displayed along with two peripheral boxes, one to its left and the other – to its right. Then, one of the two peripheral boxes illuminates at random, followed by a delay ranging from 0 to 500 ms and the presentation of a target, which is normally presented at the center (60% of the time) but could also appear in either the left (10%) or the right (10%) box. Additionally, in 20% of the time no target appears (catch trials). Participants are instructed to make a fast response as soon as they detect the target. As targets are most likely to appear at the center of the display, participants' attention is assumed to be guided back to the central box after they have looked at one of the peripheral boxes. In the simpler and most widely used version of the paradigm, however, instead of manipulating target probability, after one of the peripheral cues has been presented, the central box simply illuminates to direct attention to the center of the display (Cohen, 1981).

Posner and Cohen's (1984) results revealed that participants were quicker to respond to the side that was validly cued as compared to the uncued side. Moreover, they performed the same experiment with a central cue in the form of a left or right-pointing arrow which either correctly guided attention to the location of the target (valid cue) or it directed it to the opposite location of where the target was going to appear (invalid cue). As in the exogenous version of the paradigm, participants in the *arrow experiment* were quicker to make a response where the cue correctly predicted the target location (Posner & Cohen, 1984). Furthermore, in the exogenous condition this facilitatory effect was found to be rather short-lived (less than 300 ms). The latter provides evidence that visual spatial orienting occurs before the eyes have had the chance to move to the area of interest (an interval shorter than 300 ms is not long enough for attention to be deployed overtly; Posner, 1980). However, according to Posner and Cohen (1984) the eyes can move to the cued location to improve acuity. Importantly, the RT facilitation did not seem to depend on the probability of the valid trials. For example, even when the cue was valid in only 10% of the time a strong RT facilitatory effect occurred as long as the participants' attention was summoned to the central box after they had observed the peripheral illumination (Cohen, 1981).

Moreover, in the same research Posner and Cohen (1984) unexpectedly identified another property of spatial attentional orienting. When the cue to target delay (stimulus onset asynchronicity; SOA) in their exogenous condition was more than 300 ms, instead of improving target detection, valid cues impeded it, resulting in increased RTs. Posner and Cohen (1984) termed the effect inhibition of return (IOR) and suggested that the source of the effect was the capture of attention by the peripheral cue and the subsequent inhibition to return it to that location, as attention has been removed from it (participants focus their attention back to the center). Thus according to the most popular explanation for IOR, the inhibitory effect occurs at the early stages of perceptual/attentional processing, resulting in increased RTs and an impaired signal detection at that location (Chica & Lupiáñez, 2009; Prime & Ward, 2004). However, neither in Posner and Cohen's (1984) nor in any other early papers (e.g., Rafal, Calabresi, Brennan & Sciolto, 1989) was IOR identified in the endogenous cueing condition even during very long SOAs (1250 ms). Moreover, the effect was found to occur automatically, 'without the need for any deliberate strategy on the part of the subject' (Posner & Cohen, 1984, p.537). Thus, it occurred even without target probability manipulation (Cohen, 1981).

Finally, Posner and Cohen (1984) found that although producing a comparable effect, overt orienting was generally found to increase the magnitude of IOR. Other properties of the IOR effect will be discussed more thoroughly in the next section.

Overall, early findings from attentional cueing paradigms suggested that both central and peripheral cues can improve target detection (Posner, 1980; Posner et al., 1978; Posner & Cohen, 1984; Rafal et al., 1989). Moreover, while RT facilitation and inhibition occur in both covert and overt attentional orienting, their magnitude is larger when the eyes can move to the area of interest (Posner & Cohen, 1984).

1.1.2 Inhibition of Return: Important Properties

Since the discovery of IOR there have been many studies exploring its properties and neural basis. The present section presents a brief summary of some of the key features of the phenomenon while the following subsection outlines what is known about its neural basis.

First, although classically demonstrated to be tagged to spatial locations, IOR has also been found to occur with objects (Abrams & Dobkin, 1994; Tipper, Driver & Weaver, 1991; 1994). Thus, when attention had been previously cued to a moving object, participants inhibited the new location of where the object moved to later (Tipper et al., 1991). Similarly, when a location within one of two stationary objects had been cued, participants were slower to respond to an uncued location within the cued object as compared to an uncued location in the uncued object (Weger, Abrams, Law & Pratt, 2008). Moreover, visual search tasks also suggest that IOR could be object-based. In one such study, for example, participants had to search for a character (Waldo/ the wizard from ‘Where’s Waldo?’) in a complex visual scene (Klein & MacInnes, 1999). Then during search, a probe was presented either in the visual area of participants’ preceding fixation or at a new location, the difference between which revealed an IOR effect. However, the effect disappeared if the visual array was removed when the probe was introduced, suggesting that IOR is tagged to objects (Klein & MacInnes, 1999).

Furthermore, contrary to what had been identified in the early papers on the effect, subsequent research challenged the idea that IOR occurs only with exogenous stimuli and that it could be used as a measure of exogenous orienting (Theeuwes & Godijn, 2002). In fact, recent research has demonstrated IOR with endogenous cues, such as arrows or gaze cues (e.g., Flanagan et al., 2015; Taylor & Klein, 2000; Weger et al., 2008). Thus, for example, Weger and colleagues (2008) reported an object-based IOR with both central arrows and word cues. However, the effect was present only when a sufficient time was allowed for attention to disengage from the cued object[3] (SOA: 1700 ms). Moreover, in their word cue experiment, Weger et al. (2008) encouraged the reorienting of attention to a different location after cueing by instructing participants to follow the motion of a rotating object. It was concluded that the latter might be the reason why IOR had not been identified in previous studies using endogenous cues as the reorienting of attention is vital for the IOR effect to occur.

Finally, there is evidence that the effect is fairly robust and does not depend on the socialness of the central cue or peripheral target (Bayliss & Tipper, 2005; Flanagan et al., 2015). For instance, in a very recent study, children with Autistic Spectrum Disorder (ASD)[4] and typically-developing controls had to detect either a

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[3] Endogenous orienting is more slow-moving as compared to exogenous orienting. Thus, more time is usually needed for attention to disengage from a location/object and to reorient to another when guided endogenously (Theeuwes, Godijn & Pratt, 2004; Wolfe, Alvarez & Horowitz, 2000).

[4] ASD is a neurodevelopmental disorder, characterised by a triad of impairments, among which are a deficit in the social domain, abnormal emotional responses and motor behaviour (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Leslie & Frith, 1985; Frith, 2003).

social (human face) or a non-social target (mixed face) on the basis of a social (a pointing hand) or a non-social cue (arrow) in a variant of Posner and Cohen's paradigm (Flanagan et al., 2015). Despite the fact that ASD individuals have a general difficulty orienting to social stimuli (Dawson et al., 2004), results revealed no difference between the groups and even a tendency for a stronger IOR effect in the ASD group as these children took longer to respond to invalid trials. Moreover, in the long SOA condition (650 ms) ASD children were even quicker to orient to the pointing hand as compared to the TD controls which reveals the robustness of the Posner and Cohen's paradigm in general (Flanagan et al., 2015).

1.1.2.1 Neural Correlates

There is still a debate concerning the precise mechanisms of the effect. As mentioned earlier, followers of the initial account of IOR suggest that the observed slowing down is generated in the early perceptuo-attentional stages, prior to response initiation (Posner & Cohen, 1984; Chica & Lupiáñez, 2009; Prime & Ward, 2004). Alternatively, others have suggested that instead, the peripheral cue produces an automatic activation of an eye movement to the cued location and what is inhibited is this oculomotor movement (Rafal, Calabresi, Brennan & Sciolto, 1989; Taylor & Klein, 1994). Finally, although not without debate, it is generally accepted that IOR affects the attention-perceptual stages of early processing but also has an oculomotor component, so that the magnitude of the effect increases when eye movements are allowed (Kingston & Pratt; 1999; Taylor & Klein, 2000).

Additionally, ERP studies overall advocate a perceptuo-attentional locus of the effect with inhibition occurring only in the pre-motor stages of the IOR task. Thus, the phenomenon is known to be associated with early sensory ERP components, such as P1 and/or N1. First, the occipital P1 is the earliest sensory ERP component peaking at around 100 ms after the onset of a visual stimulus, so a reduction in the signal is interpreted as a sign of inhibition (Luck et al., 1994). However, although a number of studies have reported a reduction in the amplitude of P1 in covert IOR tasks (Prime & Ward, 2004, 2006; van der Lubbe, Vogel, & Postma, 2005; Wascher & Tipper, 2004, Satel et al., 2013), some have found that this does not apply to overt IOR (Satel et al., 2013; Satel, Hilchey, Wang, Reiss & Klein, 2014). Furthermore, the N1 component is usually detected 150–200 ms post-stimulus with a greater peak for validly cued trials, than invalidly cued ones. Thus, IOR ERP studies normally report an enhancement in N1 (a larger peak in signal for valid trials) which is why it is one of the markers of IOR (e.g., McDonald, Ward & Kiehl, 1999; Wascher & Tipper, 2004). Moreover, ERP studies have also examined whether IOR has a motor component by measuring the amplitude of the lateralized readiness potential signal (LRP; Prime & Ward, 2004, 2006). LRP is associated with motor selection and motor preparation. Prime and Ward's (2004, 2006) findings have revealed that while IOR seems to produce a delay in pre-motor behaviour such as motor preparation, it does not have an effect on the LRPs, tagged to the motor response.

Finally, neuroimaging studies on IOR normally present a slightly different picture as compared to ERP studies, as they identify the involvement of motor areas in the effect. Thus, research has revealed that the potential neural correlates of spatial IOR could be found in a dorsal frontoparietal network in the brain which includes the frontal eye field (FEF) and the superior parietal cortex (SPC; Chen,Wei & Zhou, 2006; Lepsien & Pollmann, 2002; Mayer, Seidenberg, Dorflinger & Rao, 2004; Ro, Farne & Chang, 2003). This is not surprising as, as mentioned before the FEF has been implicated in both overt and covert shifting of attention (Corbetta et al., 1998). At the same time the SPC is part of a dorsal frontoparietal system for directing spatial attention or action, known to be activated by spatial attentional tasks only (Corbetta & Shulman, 2002). Moreover, there is evidence that this dorsal frontoparietal network might maintain the inhibitory bias against returning to an already cued location, once attention has been disengaged from the location. For instance, data from a transcranial magnetic stimulation (TMS) study where either the function of the participants' FEF or SPC were disrupted via TMS, two outcomes were found depending on when the stimulation took place (Ro et al., 2003). When TMS was applied so that it followed the presentation of the cue but also appeared shortly before the occurrence of the target (the inhibitory bias had already formed), IOR was no longer present. However, the IOR effect was not disrupted if the stimulation occurred very shortly after the cue (the inhibitory bias had still not formed; Ro et al., 2003). Moreover, several studies have reported an involvement of the the superior colliculus (SC) in the effect (e.g. Posner et al., 1985; Rafal et al., 1989; Sereno, Briand, Amador, & Szapiel, 2006). The SC is a midbrain structure, believed to be involved in the orienting and programming of the eye movements (Schiller, 1977). Consistent with this Sereno et al. (2006) reported the case of a patient with a damaged SC who did not experience IOR. The latter presents evidence that IOR is likely to have an oculomotor component.

Thus, studies looking at the neural basis of the effect have reported evidence for both an attentional and oculomotor component of IOR.

1.1.3 Social Inhibition of Return

However, although predominantly studied in single-participant conditions, a variant of the Posner and Cohen's (1984) paradigm has recently been employed in joint-action settings. First, Welsh et al. (2005) examined what effect would another person have if sat opposite the participant in the standard IOR paradigm. In this study two co-actors sitting opposite each other responded to targets, appearing either at the left or the right location of a flat display located between them. Importantly, in the *within-participant IOR* trials (measuring standard IOR), the target could either occur at the 'same' (repeated) or a different (novel) location, in respect to the co-actor's *own* previous response. However, additionally, the two co-actors also took turns to respond to targets, so that co-actor A responded to either the same or the different location as a function of co-actor B's previous response. The latter was the measure of *between-participant* IOR as it reflects the idea that the IOR effect might transfer between individuals. Moreover, once a response had been made in this task, participants were required to return their hand to a 'home' position located in front of them (See Fig 1.1). Thus, if the two co-actors in the task were named co-actor A and co-actor B, respectively, they completed an 'AABBAABB…' sequence of events, measuring both within- and between-participant IOR. Remarkably, Welsh et al.'s (2005) results revealed both the well-known *within-participant IOR* in which participants were slower to return to a location they had previously responded to, as well as a significant *between-participant IOR.* Thus, co-actors were also slower to execute reaching responses to targets located where the other participant had just responded (Welsh et al., 2005). Therefore, the between-participant IOR effect is measured by the difference in RT (response time; referring to the interval between target onset and target response) when participants act on a location their partner responded to on the previous trial (same location) and RT when acting on a new location, to which the partner did not respond to on a previous trial (different location).

Other authors refer to the effect as Social Inhibition of Return (social IOR; Skarratt, Cole & Kingstone, 2010) which would be the term used in the present thesis. Importantly, another variant of the paradigm measures only the social IOR effect, in which co-actor A and co-actor B simply alternate single responses, resulting in a sequence such as 'ABABAB…' (e.g., Atkinson, Simpson, Skarratt & Cole, 2014; Reid, Wong, Pratt, Morgan & Welsh, 2013; Skarratt et al., 2010). Importantly, this second variant of the paradigm was employed in all experiments, reported in the present thesis.

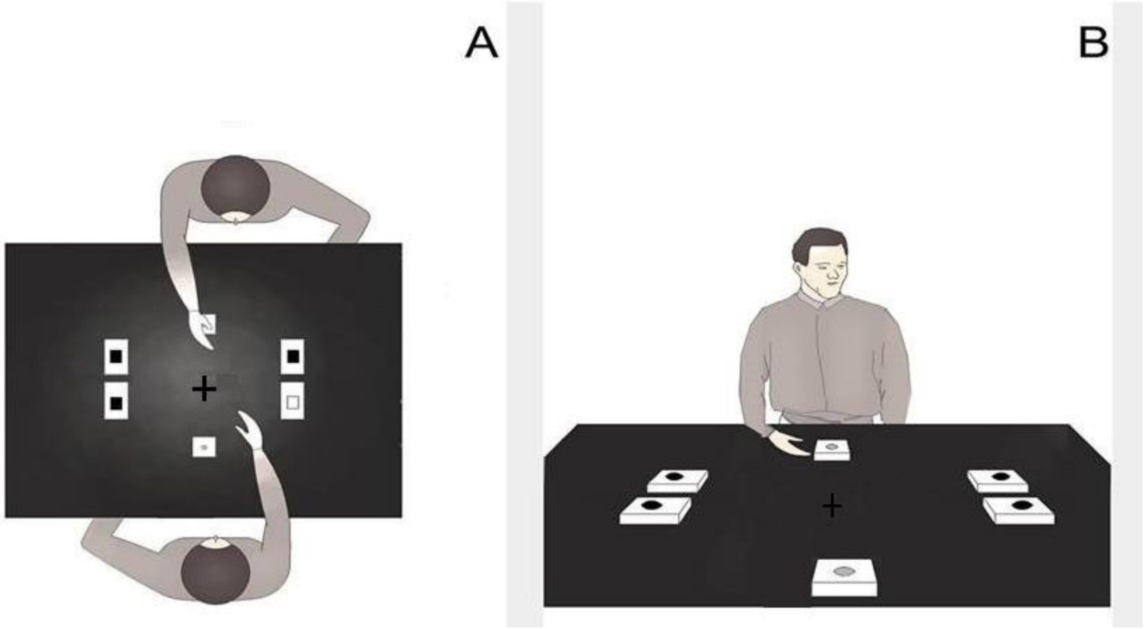

Fig 1.1 An illustration of a standard condition of the social IOR paradigm. Panel A presents a topographical view of the set-up in which one person is reaching to their right where the target has illuminated. Panel B illustrates the co-actors' view of the apparatus.

Two accounts advocate that social IOR relies either partially or fully on inhibitory effects – Welsh et al.'s and Cole et al.'s.

First, Welsh and collaborators explain the social IOR effect as being the result of inhibitory effects combined with action co-representation via the mirror neuron system (Hayes, Hansen & Elliott, 2010; Welsh, et al., 2005; Welsh, Lyons, Weeks, Anson, Chua, et al., 2007; Welsh, McDougall & Weeks, 2009a; Welsh, Ray, Weeks, Dewey, Elliott, 2009b; Welsh, Manzone & McDougall, 2014). Moreover, Welsh et al. submits that the observation of an individual reaching to a location is processed through the action observation (understanding) network of the brain (the mirror neuron system; MNS; Rizzolatti & Craighero, 2004; See Sections 1.2.1 & 1.2.2). The latter leads to the formation of observation-evoked response codes in the observer. Then, in line with the well-established perception-action link (See Section 1.2.1), Welsh et al. suggests that if observing an action and executing it are essentially the same process, then seeing another person acting on a location, would be conceived in the same way as if one performed the action themselves. Thus, back to the social IOR paradigm, when an observer is required to respond to the same location as their co-actor, the representation of the observed action is essentially treated as if the action has been one's own. Then due to the already explained property of the attentional system to inhibit 'old information', participants take longer to respond to the *same location* (i.e., social IOR is observed). In support, consistent with recent findings that the MNS codes for the endpoint goal of an observed action, rather than the action per se (See Section 1.2.2), both Welsh et al. (2007, 2009) and Skarratt et al. (2010) found that social IOR occurred even when only a part of the partner's response was visible. This was interpreted as evidence that the MNS subserves social IOR by inferring the end goal of the action the observer has partially seen. Further, Welsh et al. (2009b) found that social IOR did not occur if individuals had a dysfunctional MNS, like high-functioning ASD participants. Finally, Welsh and colleagues have proposed that social IOR is likely to be a mechanism with an evolutionary significance. By inhibiting attention away from a region already investigated by someone else, individuals optimise their search behaviour. Moreover, Welsh et al. (2007, 2009a, 2009b) suggested that such a mechanism dates back to the hunter-gatherer times of human evolution where using an efficient search strategy to provide one's food and shelter and escape predators was key for one's survival. Taken together, according to Welsh et al. social IOR stems from inhibition of *acting* to a location, already investigated by someone else.

However, an alternative IOR-based account of social IOR has also been recently proposed (Cole, Skarratt, Billing, 2012; Skarratt, Cole & Kuhn, 2012; Atkinson et al., 2014). According to this view, social IOR is an identical effect to IOR. Thus, similar to the peripheral cues in Posner and Cohen's (1984) paradigm, witnessing an attention-capturing event in the periphery, being it the partner's target illumination and/or their reaching response, cues the observer's attention to that location. Then because the SOA is longer than 300 ms, as in classic IOR, participants experience inhibition of return to the previously cued location. Thus, it is possible that instead of inhibiting the representation of an observed action (as proposed by Welsh et al., 2005, 2007, 2009 a, b), co-actors experience social IOR because of an inhibitory effect to the target location, which has just been cued by their partner. In this view, especially in the partial viewing condition, the partner's arm reach/eye gaze serve as a central cue that shifts the observer's attention to the location of their response. As mentioned in Section 1.1.2 there is evidence that classic IOR can be elicited by central cues (e.g., Flanagan et al., 2015; Taylor & Klein, 2000; Weger et al., 2008) and that arm/hand cues shift attention in the same way as pointing arrows do (See end of Section 1.1). Thus, unlike Welsh et al. this account undermines the socialness of the partner and predicts that any sufficiently salient event, appearing at the periphery, being it social or not can produce social IOR. Moreover, this account proposes that the effect is likely to be subserved by perceptuo-attentional and/or oculomotor processes like classic IOR and thus does not predict an involvement of the MNS. In support, a recent behavioural study suggested that social IOR is modulated by the perceptual characteristics of the stimuli (Atkinson et al., 2014). Furthermore, in a series of experiments Cole et al. (2012) had participant pairs respond to the target location either by executing exactly the same actions (e.g. touching the target) or executing very similar actions which differed in terms of their end-point goal (touching the target vs pretending to grip it). Results revealed that social IOR was not modulated by the end-point goal of the action as its size did not differ in the two conditions. To reiterate, according to Cole and colleagues social IOR is an IOR effect that simply occurs in the presence of another person whose actions/target illuminations act as the peripheral cues in Posner and Cohen's (1984) paradigm.

Thus, according to both Welsh et al.'s (2005, 2007, 2009, 2014) and Cole et al.'s (2010; Atkinson et al., 2014) accounts, inhibitory effects give rise to social IOR (although, only partially, according to Welsh et al.). The next section starts by giving a brief overview of joint-action. Then at the end it introduces a variant of the movement congruency effect which very much resembles the described above social IOR procedure and which is often explained with action co-representation.

1.2 Joint Action

The recent years have seen a considerable growth in joint-action research. This trend has been predominantly driven by the intuitive notion that studies of social interaction must represent more adequately the complexity of human interpersonal cognition and action. Moreover, coordination seems to be a universal concept since it is found in both the animate and the inanimate world. For example, some spectacular examples of coordination can be found in nature like the synchronous mass flashing of fireflies (Buck & Buck, 1976, Otte & Smiley, 1977) or the flawless unison between fish in a school, making them look like parts of a single organism (Partridge, 1982). Furthermore, in physics, pendulum clocks, hung side by side begin to synchronise so that their oscillations coincide perfectly, a phenomenon first described as the ‘sympathy of two clocks’ (Pikovsky, Rosenblum & Kurths, 2001).

With respect to humans, joint-action research lies in-between the experimental psychology tradition and the anthropological study of distributed cognition according to which in many respects individuals in the same task environment function as one cognitive unit (Hutchins, 1995). Thus, its perceptual, cognitive and motor properties have been studied by neuroscientists, cognitive and ecological psychologists (Knoblich, Butterfill & Sebanz, 2011). Results have shown that, in general, individuals in joint-action conditions change their behaviour and perform differently as compared to when alone. For instance, the sole belief that one is competing against or collaborating with an unseen other influences one’s gaze rate frequency, as well as their memory for previously presented stimuli (Richardson, Street, Tan, Kirkham, Hoover & Cavanaugh, 2012). Furthermore, the presence of another person has also been found to influence one’s perception of spatial relations (Tversky & Hard, 2009), one’s focus of attention (Böckler, Knoblich, & Sebanz, 2012; Frischen, Loach & Tipper, 2009; Samson, Apperly, Braithwaite, Andrews & Bodley Scott, 2010) and visuospatial skills such as object-mental rotation (Böckler, Knoblich, & Sebanz, 2011). Taken together, these findings suggest that social interaction has profound effects on individuals’ perception and cognition.

Joint-action could be defined as ‘…any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment’ (Sebanz, Bekkering & Knoblich, 2006, p. 70). As this broad definition suggests, it can exist in different forms involving different levels of analyses. According to Knoblich et al. (2011) one can distinguish between emergent and planned joint acts. As its name suggests, emergent coordination is based on the actors' perception and happens spontaneously, driven by motor and perceptual cues that both actors recognise. Examples of such type of joint-action are all instances of 'joint-action for entertainment' where individuals unconsciously synchronise with one another, such as an audience clapping together (Néda, Ravasz, Brechet, Vicsek & Barabási, 2000). Emergent coordination also involves cases of perception-action matching when what is seen is directly matched onto the observer's own motor system, especially when the observer has enough expertise in the action (e.g., a professional dancer watching a dance; Cross, Hamilton & Grafton, 2006). Finally, emergent coordination can also be based on object-affordances (when the two actors have the same repertoire) or on action simulation. Knoblich et al. (2011) distinguishes the latter from coordination, based on a perception-action match, since action simulation can also help the observer infer the outcome of the action (Hamilton, Wolpert & Frith, 2004). Planned coordination, on the other hand, has been defined to occur when 'agents' behavior is driven by representations that specify the desired outcomes of joint action and the agent's own part in achieving these outcomes' (Knoblich et al., 2011, p. 62). Research has shown that when individuals in planned coordination share task representations, they cannot help but form a representation of both their own task and their partner's task even when explicitly instructed to ignore it (Atmaca, Sebanz, Prinz & Knoblich, 2008; Sebanz, Knoblich & Prinz, 2003). The second instance of planned coordination, as defined by Knoblich et al. (2011) is when actors form joint perceptions. Examples of the latter are instances of an agent co-representing the other's perspective (Samson et al., 2010) or trying to infer what the other can perceive when visual information is limited (Shintel & Keysar, 2009).

1.2.1 Action Co-Representation

Such instances of conscious and unconscious synchronization between individuals are commonly explained by ideomotorically-inspired action accounts, advocating an intimate perceptuo-motor link (Greenwald, 1970; Hommel, Müsseler, Aschersleben & Prinz, 2001; James, 1890; Lotze, 1852; Prinz, 1997). One of them is the Theory of Event Coding (TEC; Hommel et al., 2001). In its essence TEC has been postulated on three key assumptions – cognitive representations are *composites* of feature codes; feature codes prime each other based on the *distal* aspects of events and lastly, perception and action are virtually the same (Hommel et al., 2001; Hommel, 2009). First, TEC assumes that the many perceptual and action features of perceived and intended to-be-executed events, respectively, are represented as separate codes in the brain (e.g., colour, direction, response speed), forming a *feature map*. Moreover, in TEC terminology, these cognitive structures are called 'event codes' and represent composites of different features, created via integration. Therefore, in this process, feature codes are constantly compared to each other or confused with one another, based on their level of similarity. Second, it is assumed that the latter priming happens on the basis of goal-directed representations of events (i.e., *distal*-coding level; information that is relevant to the individual; Hommel, 2009). Finally, according to Hommel et al. (2001), 'intentionality renders perception and action-planning inherently similar and functionally equivalent' (p. 904). Thus, irrespective of their role, both stimulus (perception) and response codes (action) are formed and represented in the same medium.

The significant role that this perception-action link plays in joint-action was first proposed by Sebanz, Knoblich and Prinz (2003) as an explanation for the discovery that the classical Simon effect (Simon, 1990) transferred between individuals, a phenomenon they called the 'Social Simon Effect' (SSE). The basic Simon paradigm is a two-choice spatial compatibility task in which a single participant is required to respond to two colours (e.g., blue and green) by pressing one of two buttons, corresponding to the correct colour (one to the left, one to the right). For example, the participant needs to press the left button every time they see a green stimulus, appearing either to the left or right side of the screen. Typical results reveal that RTs are shorter when the response button and the colour-presentation side spatially coincide, even though the spatial features are irrelevant to the task (in fact, the task is to ignore them). In its social variant, two participants, seated side by side, had to operate one of the two buttons in response to one of the two colours (Sebanz et al., 2003). Results indicated that a Simon effect arose again – participants were slower when their target colour appeared on their partner's response side. However, the effect disappeared in the single-participant version, when a single participant operated only one of the buttons (Hommel, 1996). As mentioned above, the basic Simon effect is assumed to occur because of spatial compatibility effects between the spatial stimulus locations and the spatial response locations, either as a result of direct association (e.g., Kornblum, Hasbroucq, & Osman, 1990) or because of a distal overlap between the event codes (e.g., Hommel, Müsseler, Aschersleben, & Prinz, 2001). Since the effect occurs both when a single individual operates the two responses and when these are distributed between two individuals, Sebanz et al. (2003) interpreted the finding of a SSE in their joint-action condition as evidence that participants were co-representing their partner's actions and stimulus-response rules, so that they experienced interference similar to the one in the single-person condition.

Since its proposal, the action co-representation account has gained considerable popularity and has been advocated by several different research groups (Sebanz et al., 2003, 2006; Vesper, Butterfill, Knoblich & Sebanz, 2010; Liepelt, Cramon & Brass, 2008; Brass, Bekkering, Wohlschlager & Prinz, 2000; Tsai & Brass, 2007; Ondobaka, Newman-Norlund, de Lange & Bekkering, 2013; Ondobaka, de Lange, Newman-Norlund, Wiemers & Bekkering, 2012). Thus, the properties of this so called 'direct matching' in the brain (Liepelt et al., 2008; Tsai & Brass, 2007; Tsai, Kuo, Hung & Tzeng, 2008) have been extensively researched. Firstly, research has advocated that action co-representation is automatic, effortless and unintentional (Decety & Jackson, 2004; Liepelt et al., 2008; Sebanz et al., 2006) and that in fact it occurs even when it is more feasible to ignore what the other is doing (Atmaca, et al., 2008; Sebanz, Knoblich, Prinz & Wascher, 2006). In support, there is evidence that the observation of a movement-incongruent action interferes with one's movement execution performance (e.g., Kilner, Paulignan, & Blakemore, 2003; Liepelt et al., 2008). However, action co-representation seems to be biologically tuned and therefore movement kinematics do not seem to be mapped onto the observer's motor system when the observed action is performed by an inanimate agent such as a robot (Kilner et al., 2003), a wooden hand (Tsai & Brass, 2007) or a computer (Tsai et al., 2008). Newer accounts have added to the idea that action co-representation is effortless by proposing that tracking other's beliefs is also an automatic process (van der Wel, Sebanz, & Knoblich, 2014). Finally, the extent to which the observed action is represented has been found to be influenced by higher-order factors such as the co-actors' affect and type of affiliation with their task-partner during the interaction (Kuhbandner, Pekrun & Maier, 2010; Hommel, Colzato & van den Wildenberg, 2009, respectively). Thus, in line with previous findings that positive affect encourages, while negative affect decreases the spread of activation (Gasper & Clore, 2002; Bäuml & Kuhbandner, 2007), positive affect induction has been reported to result in a full-blown SSE, while negative affect – in no SSE (Kuhbandner et al., 2010). Similarly, in line with previous research that liking decreases the self-other distinction (Aron, Aron, Tudor & Nelson, 1991), the SSE has been found to occur only when a positive relationship between the two co-actors existed (Hommel et al., 2009).

1.2.2 Neural Correlates

The suspected neural correlates of action co-representation is a collection of frontoparietal cells, found, more specifically, in the human parietal lobe, the premotor cortex and the caudal part of the inferior frontal gyrus (Jeannerod, Arbib, Rizzolatti & Sakata, 1995; Rizzolatti & Craighero, 2004). This network known as the mirror neuron system (MNS) has been reported to become active both in response to observing an agent perform an action and when an agent executes an action (Gallese, Fadiga, Fogassi & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese & Fogassi, 1996; Umiltà et al., 2001). Unlike the limbic mirror system, involved in the recognition of affective behaviour, the frontoparietal network is believed to be a mechanism for the recognition of voluntary behaviour (Cattaneo & Rizzolatti, 2009). Several studies aimed to shed light on the functional organisation of the mirror mechanism. One of them examined participants' motor activation response while observing either transitive (object-related) or intransitive (non-object related) acts, performed either with the actor's mouth, hand or foot (Buccino et al., 2001). Results revealed that both types of acts activated different parts of the ventral premotor region, so that mouth actions were represented more ventrally, foot movements – more dorsally while manual acts had an intermediate position. Importantly, the identified pattern coincides with the pattern of the classical motor representation of different effectors (Penfield & Rasmussen, 1952). In addition, it was found that transitive actions activated areas of the posterior parietal lobe, too, also in a somatototopic vain (Buccino et al., 2001; Binkofski & Buccino, 2006). Moreover, other research evidence suggested that motor acts in the human parietal lobe are also classified in terms of their behavioural significance so that acts, directed to the self (e.g., grasping) are represented more ventrally while outward-directed acts (e.g., pushing) appear more dorsally (Jastorff, Begliomini, Fabbri-Destro, Rizzolatti & Orban, 2010).Thus, in terms of its functional organisation, the action observation network seems to use different, somatotopically organized frontoparietal circuits not only during action execution but also during action observation.

Moreover, related to the previous point, the MNS has been known to subserve direct action imitation (e.g., passive observation of actions triggered an identical pattern of motor activation in the brain to when these were performed; Fadiga, Fogassi, Pavesi & Rizzolatti, 1995). However, recent evidence has started to suggest that it can also infer and predict action goals. In fact, research has confirmed that actions are often planned in terms of their goals. For example, in a motion-tracking study, Eastough and Edwards (2007) found that participants' end-goal (whether an object of a different mass had to be lifted, reached for or grasped) modulated participants' action kinematics. Going back to mirror neurons, research with macaques showed that the monkey mirror neuron area F5 discharged even when no visual information about the action had been provided (e.g., the monkey inferred the action; Kohler, Keysers, Umilta, Fogassi, Gallese & Rizzolatti, 2002; Umiltà et al., 2001). Moreover, a very recent human study, investigating the effect of conceptual expectations on motor activation, also supported this view (Ondobaka, de Lange, Wittmann, Frith & Bekkering, 2015). Activation during action observation was found only when the object, used by the actor, matched the observer's expectation at a conceptual level. For example, when a rose (but not a pair of headphones) was moved to the nose in the anticipation of smelling. Furthermore, a support for the involvement of the mirror mechanism in goal processing can also be obtained from the Autism Spectrum Disorder (ASD) literature. Recently, several neuropsychological studies have suggested that ASD abnormalities could stem from a dysfunction in their mirror mechanism (Williams, Whiten, Suddendorf & Perrett, 2001; Rizzolatti, Fabbri-Destro & Cattaneo, 2009). In one of these studies, unlike typically-developing children whose MNS was active during the grasping and reaching stages of a grasping-for-eating action, children with ASD showed activation in their mouth-opening muscles only during the last, bringing-to-the-mouth stage (Cattaneo, Fabbri-Destro & Boria, 2007). At the same time, the motor activation in typically-developing children demonstrated intention prediction properties since it was active during the object grasping and reaching stages preceding an eating movement (the action led to the end-goal) but not a placing movement (the action was goal-incongruent). Thus, recent research on the mirror mechanism seems to confirm the importance of action intention understanding for action perception.

1.2.3 Criticism

Despite influential, the action co-representation account has been challenged by alternative approaches, often providing a simpler explanation for the findings of some joint action studies and for those that do not agree with the predictions of the theory, advocated by Sebanz et al. (2003, 2006).

One of these is an account, adopting a more lower-level approach to explain the observed partner-related interference, characteristic of the SSE. For example, Dolk et al. (2011, 2013) submits that instead of stemming from action co-representation, the SSE is likely to result from referential coding effects (Dolk et al., 2011; Dolk, Hommel, Prinz & Liepelt, 2013; Guagnano, Rusconi & Umiltà, 2010). Essentially, this account suggests that participants in the SSE paradigm are simply using the partner as a reference point to which they start associating the respective response (left or right). Thus, the partner does not need to be of a social nature to ensure that the effect occurs, in fact, both the joint and the social Simon effect are predicted to occur with any object or event, salient enough to serve as a reference point. In support, in a series of experiments, where instead of another co-actor, an inanimate object (e.g., a Japanese waving cat, a clock or a metronome) was positioned next to the participant, participants still experienced a SSE-like effect (Dolk et al., 2013). Similarly, the effect occurred even when no online visual or auditory information about the other co-actor was present (Vlainic, Liepelt, Colzato, Prinz & Hommel, 2010) or when a sense of separation between the co-actor's hand and the hand of their partner was induced (Dolk et al., 2011). Moreover, a very recent study (Stenzel et al., 2014) suggested that rather than depending on the co-actor's sense of intentionality (strictly linked to biological partners), the SSE depends on agency[5] (could be applied to both biological and non-biological objects; Pickering, 1995). Clearly, these results do not agree with the action co-representation account, as the SSE does not seem to depend on the availability of a biological co-actor who takes turns with the participant (Dolk et al., 2013; Vlainic et al., 2010), nor it depends on the integration of the other co-actor's perspective, as the effect was found smaller in this condition (Dolk et al., 2011). Still, it should be noted that Dolk et al. (2013) acknowledge that social interaction in this paradigm might contribute to the effect, as the presence of a biological partner has been found to result in a more pronounced SSE.

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[5] whether one could determine the causal source of an action/event

A somewhat related approach to explaining the SSE has been put forward by Liepelt and colleagues (Liepelt, Wenke & Fischer, 2013; Liepelt, Wenke, Fischer & Prinz, 2011; Wenke, Holländer, Atmaca, Liepelt, Baess & Prinz, 2011). They argue that instead of resulting from the co-representation of the other's stimulus-response rules and action plans as proposed by Sebanz and colleagues (2003, 2006), the SSE depends on low level feature integration based on the requirements of the previous trials (Liepelt et al., 2013). Since the effect has only been examined as a function of the match or mismatch between the spatial stimulus attributes and the required response, it has been assumed that the same co-representation processes take place in the social and the standard Simon task, which have been thought to be functionally different from their single-person variant where one participant is in charge of only one response button. However, transitions from trial to trial in the Simon effect contain information about whether the response location has been repeated or not, whether a response to a previous trial was necessary (go trial) or not (nogo trial) and the co-actor's body position (sitting either to the left or right handside; Liepelt et al., 2011). Thus, to examine the contribution of low-level mechanisms to the SSE, Liepelt et al. (2011) compared the social and the single-participant variant of the Simon effect in terms of their trial-to-trial sequential dependencies (i.e., the effect of compatibility, e.g., compatible-compatible vs compatible-incompatible) and go/no-go requirements between two sequential trials). In both conditions, results revealed a Simon-like effect following compatible trials and sequential modulation, which was stronger for trials with a no-go/go transition than for go/go transition. These results were interpreted as indicative of the role that low-level binding (inhibitory effects) plays in the SSE. Moreover, alternatively to co-representing the other's stimulus-response rules, it was concluded that the more pronounced sequential modulation in the social variant of the task and the overall bigger Simon effect after compatible trials, could be due to the presence of another person which transforms the go/no-go distinction into a between-person distinction (mine or your turn) and thus, further increases the inhibitory effects in this condition (Liepelt et al., 2011; 2013).

Finally, the interpersonal coordination dynamics approach has also challenged the 'direct matching' account. Instead of focusing on processes within an individual (i.e., how one processes perception and action), this approach examines how different components are coupled to ensure the coordination of effectors (e.g., arm; leg) coming from two separate individuals (Fine & Amazeen, 2011; Fine, Gibbons & Amazeen, 2013; Richardson, Campbell & Schmidt, 2009). Thus, instead of explaining interpersonal coordination with the idea that co-actors unintentionally and automatically access shared mental models, the vital component for such effects is thought to be the observation of another's limb movements and the emergent motor coordination that follows from it. In support, Fine et al. (2013) demonstrated that their movement congruency effect emerged as a function of spatial congruency (where an effector was relative to the ground). However, it did not depend on anatomical incongruency (where an effector was relative to one's body position) nor on whether different effectors were used which suggests that the 'interference effects in interpersonal coordination might not be the product of embodied simulation interference' (Fine et al., 2013, p.1551). Moreover, research has suggested that *intra*- (within the same individual) and *interpersonal* (within two individuals) coordination seem to have very similar dynamics (Fine & Amazeen, 2011). Thus, similarly to how the motor system ensures *intrapersonal* coordination in a bimanual task when an individual tries to draw two different figures with each hand, the *interpersonal* coordination between two separate effectors (coming from two different co-actors) during unequal kinematic requirements follows similar dynamics (Fine et al., 2013). Thus, contrary to the proponents of the action co-representation account, within this approach the interference observed in incongruent task trials is not indicative of ‘error’. Instead, it represents the attempt of the motor system to stabilize coordination performance which as in this condition can no longer be stabilized, requires compensatory changes to occur, resulting in the observed interference (Fine et al., 2013; Richardson et al., 2009).

1.2.4 The Movement Congruency Effect

As mentioned above, the SSE has been predominantly used to test the action co-representation account and thus has been extensively studied in joint-action research. However, other paradigms based on congruency effects have also recently become an object of interest in joint-action (e.g., Ainley, Brass & Tsakiris, 2014; Brass et al., 2000; Fine et al., 2011, 2013; Liepelt et al., 2008; Ondobaka et al., 2012, 2013; Santiago & Lakens, 2014; van Schie, van Waterschoot & Bekkering, 2008). In the basic procedure of a congruency paradigm, a participant observes a simple action (e.g., a model lifting their index finger) after which depending on the type of condition they are required to either execute a congruent (e.g., lifting their index finger) or an incongruent action (e.g., lifting their middle finger). Typical results indicate that RTs are shorter when the observed and the required actions overlap (congruent condition) and longer when these do not (incongruent condition). Such findings are normally interpreted in line with the action co-representation account and are taken as a measure of one’s ability to inhibit imitation (Brass et al., 2000).

More specifically, congruency tasks can also vary as a function of the overlap between the co-actors’ kinematics on a trial (movement congruency; e.g., a left movement) and whether the two co-actors have the same or a different conceptual goal (goal congruency; e.g., reaching to grab a cup of coffee; Ondobaka et al., 2012, 2013; Pacherie, 2008). Such a task has been employed by Ondobaka et al. (2012, 2013) who used a card-selection paradigm where a participant and a confederate sat opposite each other. Both co-actors alternated responses either to the left or the right handside of a touch screen while the participant either adopted the same conceptual goal as the confederate or not (i.e., reaching for the lower or the higher card). Results indicated that when participants had the same goal, a movement congruency effect occurred.

As mentioned earlier in the Introduction, movement goals are thought to rely on a direct perceptuo-motor mapping between the end-goal location and the observed movement kinematics (e.g., van Schie et al., 2008). Thus, a congruency effect is believed to occur because of automatic mapping of what has been observed to the individual's own movement representations in their MNS (e.g., Buccino et al., 2001; Fadiga et al., 1995). Therefore, in this account, quicker responses to congruent trials are the result of imitation while slower responses to incongruent trials occur due interference (Ondobaka et al., 2012, 2013). However, these results are also consistent with the findings of the social IOR effect (See Section 1.1.2). In other words, as co-actors sit opposite, target location and target handside can never coincide (See Fig 1.1). Thus, instead of saying that one is *quicker* to reach to the *same handside* as their partner, one might simply be *slower* to respond to the *same location* to which their partner has previously responded.

1.3 Thesis Overview

It follows from the above literature review that an identical experimental paradigm has been researched and cited in both the attentional and joint-action literature. However, researchers from the two disciplines have a very different understanding of why the effect is observed, which is also reflected in the two different terms used to refer to it – social IOR and a movement-congruency effect, respectively. There is also an ‘in-between account’ arguing that the phenomenon occurs because of a combination between action co-representation and inhibitory processes (Welsh et al.). Moreover, with a few exceptions, (e.g., Atkinson et al., 2014; Welsh et al., 2014), authors do not normally acknowledge in their research the alternative explanation of the present effect. The current thesis aimed to reconcile this discrepancy in interpretation, by providing a detailed exploration of the causes and properties of the current phenomenon, in light with the predictions of the three theories.

First, Chapter 2 examined the extent to which social IOR could be identified as an attentional effect and more specifically whether it ‘behaves’ as traditional IOR. The magnitude of the effect was tested under a series of perceptuo-temporal manipulations, known to either modulate traditional IOR or to have no effect on it. Thus, Experiment 1 examined the time course of the present effect, Experiment 2 – whether it is modulated by perceptual load and the final Experiment 3 – whether it is affected by trait anxiety. Based on previous research on the characteristics of traditional IOR, it was expected that if social IOR is similar, it should be found in the range between 300 ms and 3000 ms (e.g., Castel, Chasteen, Scialfa & Pratt, 2003; Castel, Pratt, Chasteen & Scialfa, 2005), should occur only when perceptual load is low (e.g., Liu, Fan & Zhou, 2014) and should not be affected by trait anxiety (e.g., Pérez Dueñas, Acosta & Lupiáñez, 2009). Chapter 2, however, did not directly test the impact of ‘the action factor’ on social IOR.

The latter was done in the following Chapter 3. Experiment 4 investigated whether a kinematic mismatch between the observed and the required actions would influence the phenomenon. Experiment 5 looked at whether the observation of a biological action is even required for the effect to occur, or simply having attention shifted to a target location is sufficient. Finally, through a novel modification of the paradigm, Experiment 6 distinguished between the effects of action congruency and target location to evaluate the plausibility of each of the three proposed theories and consequently, the causes of social IOR. Recall that previous joint-action work suggested that action observation leads to automatic activation of motor representations in the observer (Brass et al., 2001; Buccino et al., 2001; Ondobaka et al., 2012; Sebanz et al., 2003, 2005) and that quicker responses to congruent trials in the movement congruency effect are the result of imitation while slower responses to incongruent trials occur due interference (Ondobaka et al., 2012, 2013). Thus, it was hypothesised that if social IOR is indeed based on movement congruency, it should be reduced or abolished during a kinematic mismatch, as well as when the co-actor's action could not be observed. Moreover, a significant effect of action congruency should emerge in the last experiment.

Further, Chapter 4 investigated the degree of socialness of the effect. First, in two different variants, Experiment 7 tested whether the social relationship between the two co-actors would modulate the magnitude of social IOR, as it has been demonstrated for another joint-action effect, the SSE (e.g., Hommel et al., 2009). Based on the findings of Hommel et al. (2009) that a positive relationship between the two co-actors facilitates, while a negative one prevents the integration of the other's task rules and action plans, it was expected that if social IOR is indeed based on representation of action, a greater effect will emerge if participants perform with their romantic partner than with a stranger. Moreover, the effect will be reduced (or even abolished) if the relationship between the two co-actors is negative as compared to a positive one. Finally, in Experiments 8 and 9 participants performed the task without a co-actor to examine whether the presence of another person was even necessary to induce social IOR. In line with the assumption that the observation of actions generates an internal replica in the observer (Buccino et al., 2001; Sebanz et al., 2003, 2005), it was predicted that if indeed based on action co-representation, social IOR should not occur under such conditions.

Finally, Chapter 5 explored whether the effect could spread to higher-order processes and influence a range of free choice decisions, as basic IOR is known to have such an effect (e.g., Posner et al., 1985). In Experiment 10 participants had to make a simple choice – to decide which one of two flashing targets they preferred. Experiment 11 required a more involved decision as participants had to choose between two similar consumer products. In Experiment 12 they decided between two faces, however, here a relative decision was required – to respond to the face that would be considered the most (or least) physically attractive by the majority of people. In the last Experiment 13 each co-actor judged the attractiveness of faces with a confederate, who evenly distributed her responses between the two target locations. Based on the single previous study that found that social IOR could bias simple free choices (Reid et al., 2013), such a bias was expected to occur in Experiment 11. Although the effect of social IOR on more complex choices had not been explored before, it was predicted that if the phenomenon is robust enough, it should influence even these decisions.

The results of nine of the experiments in the present thesis have been published (or are due to be published) in articles in peer-reviewed journals. The list of these follows below. However, for the purposes of the present thesis, all empirical chapters have been fully rewritten to ensure that the experiments in each chapter are thematically organised and that each chapter follows smoothly from the previous one. The author has collected the data for all experiments reported in the thesis.

Doneva, S., Atkinson, M., Skaratt, P. & Cole, G. (resubmitted after a minor revision). Action or attention in social inhibition of return? *Psychological Research.* (Experiment 1, Chapter 2; Experiment 5, Chapter 3; Experiment 7b, Chapter 4).

Cole, G.G., Wright, D., Doneva, S.P. & Skarratt, P.A. (2015). When Your Decisions Are Not (Quite) Your Own: Action Observation Influences Free Choices. *PLoS ONE 10*(5): e0127766. (Experiments 10, 11, 12 & 13, Chapter 5).

Doneva, S.P. & Cole, G.G. (2014). The Role of Attention in a Joint-Action Effect. *PLoS ONE 9*(3): e91336. (Experiment 4, Chapter 3; Experiment 9, Chapter 4).

CHAPTER 2

2.0 SOCIAL IOR AND IOR

The main goal of Chapter 2 was to determine if social IOR and basic IOR share some characteristics in common. Recall from Section 1.1.2.1 in the General Introduction that classic IOR is known to be an attentional effect with an oculomotor component (Kingston & Pratt; 1999; Taylor & Klein, 2000). Moreover, behavioural studies suggested that IOR is rather robust as it occurs both with the classically known peripheral cues (e.g., Posner & Cohen, 1984) but also, as identified in more recent papers (e.g., Weger et al., 2008), with central ones. Additionally, IOR is tagged to both spatial locations and objects (e.g., Tipper et al., 1991) and it does not seem to be modulated by social factors, as the effect is found even in populations, known to demonstrate abnormalities in the social domain, such as ASD individuals (Flanagan et al., 2015; Rinehart, Bradshaw, Moss, Brereton & Tonge, 2008).

Furthermore, several papers have suggested that apart from sharing a similar name with IOR, the social IOR effect bears other resemblance to classic IOR. For example, in a series of correlation analyses, high, significant correlations between the two effects emerged, suggesting that social IOR and IOR are of a similar magnitude (Welsh et al., 2009a). Moreover, importantly, both effects seem to arise in the perceptuo-attentional stages, prior to response initiation. In support, social IOR has been found present only in reaction time (RT) but not in movement time (MT) data (e.g., Skarratt et al., 2010; Welsh et al., 2005; Welsh et al., 2009a). As RT is either reflected in the duration between target onset and 'home' button release (See Fig 2.2 and Section 1.1.3) or it marks the interval between target onset and response completion[6], it always contains a measure of the stimulus

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[6] Depending on the authors, one of the two measures of RT is used, however, in either case RT data includes the premotor attentional component. In the first case it involves the perceptuo-attentional stage only, while in the second – it is a compound of the perceptuo-attentional stage and the response execution stage of the action.

perceptuo-attentional processing. At the same time, MT refers to the final motoric stage of response processing (as it is the duration between the 'home' button release and response completion; see Skarratt et al., 2010). Therefore, Welsh et al.'s (2009a) results were in line with what is already known about classic IOR. Moreover, recently, Atkinson et al. (2014) showed that social IOR was influenced by the perceptual demands of the task and the visual configuration of the targets. Taking these together with the lack of an agreement on the theoretical explanation of what causes the effect (See Section 1.1.3), the present Chapter 2 focused on testing the attentional nature of social IOR by examining how a series of spatio-temporal factors and a particular personality factor (known to influence attentional selection) affect the manifestation of the effect. As the influence of none of the present three factors had been examined in previous research on social IOR, the findings were interpreted in line with what is known about classic IOR and the human visual attentional system, in general. Below is a brief outline of the rationale of each experiment, and what results would be expected if similarly to basic IOR, social IOR has an attentional basis.

First, Experiment 1 assessed the time course of the social IOR effect. Previous studies examining the temporal characteristics of classic IOR have suggested that when the 'traditional' IOR procedure is employed, IOR has a limited time course. Thus, when uninformative, simple cues such as flashing lights are used, the inhibitory effect usually disappears when the cue-target interval (known as the stimulus onset asynchrony; SOA) is beyond 3000 ms (e.g., Castel et al., 2003, 2005; see Samuel & Kat, 2003 for a meta-analysis). As far as the social IOR effect is concerned, up to the author's knowledge there has not been another study specifically examining how long the effect lasts. However, an overview of the literature on social IOR would suggest that the effect is generally considered a short-term one. For example, in an identical paradigm to the one used in the present Experiment 1, Skarratt et al. (2010) tested social IOR only in trials with short SOAs (1200ms – 1654 ms) since their first experiment demonstrated a lack of even classic IOR at a longer SOA (2400 ms). Moreover, other authors have also only tested the effect by using a short SOA design (e.g., 1300ms–1700ms in Atkinson et al., 2014; 1244–1620 ms in Hayes et al., 2010; 1390–1663 ms in Welsh et al., 2005). Considering previous research on social IOR, together with what is expected for standard IOR, where simple stimuli are used, it was hypothesised that if social IOR is indeed an attentional effect, it should disappear when a cue-target interval greater than 3000 ms is employed.

Experiment 2 examined whether social IOR has another property, characteristic of an attentional effect. More specifically, it tested whether it is modulated by perceptual load. Previous research on basic IOR, studying the effect in the context of other classic visual paradigms has suggested that IOR occurs in early visual processing (e.g., Fuentes, 1999; Visser & Barnes, 2009; Wright & Richard, 1996). Thus, consistent with the notion that it is a visual search facilitator, IOR is triggered even by multiple irrelevant events presented at the same spatial location, either in succession (Visser & Barnes, 2009) or simultaneously[7] (Wright & Richard, 1996). However, in these IOR studies, perceptual load was manipulated at the ‘cue’, rather than the ‘target stage’. Predications about how perceptual load at the target stage would influence IOR can be made based on the load theory of selective attention and cognitive control (Lavie, Hirst, de Fockert & Viding, 2004). According to it, perceptual selection is one of the two mechanisms subserving

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[7] The latter suggests that IOR does not stem from an oculomotor inhibition alone, as eye movements can be programmed and executed at only a single location at a time (Eriksen & Yeh, 1985).

selective attention. In brief, when perceptual load increases, attention becomes more focused and individuals are better able to identify targets and ignore distractors because their perceptual capacity is being exhausted (Lavie et al., 2004; Maylor & Lavie, 1998). Thus, consistent with the latter, IOR should extinguish as perceptual load becomes high since participants should be able to identify the target quickly, irrespective of what location has been previously cued. Indeed, a very recent study reported exactly this finding. Liu et al. (2014) combined IOR with a flanker task so that the target letter ('M' or 'N') appeared at one of four previously cued locations (each marked by a squared box; See Fig 2.1). Together with the target, a distractor letter which could either be compatible with the target (e.g., 'M' when the target is 'M' as in the low perceptual load condition on Fig 2.1) or incompatible (e.g., 'M' when the target is 'N' as in the high perceptual condition on Fig 2.1) was displayed in the periphery, either below or above the target. In their low perceptual load condition the target was presented with the other three empty location boxes, each containing a small circle inside. In the high perceptual load condition, however, the target was displayed together with the three boxes, containing a different combination of target and distractor letters (e.g., 'N', 'M', 'N' as in Fig 2.1). Liu et al. (2014) found IOR only in the low perceptual load and that it disappeared in the high perceptual load condition. Thus, it was predicted that if the present social IOR effect is indeed an IOR-like phenomenon, perceptual load should modulate social IOR in a similar fashion.

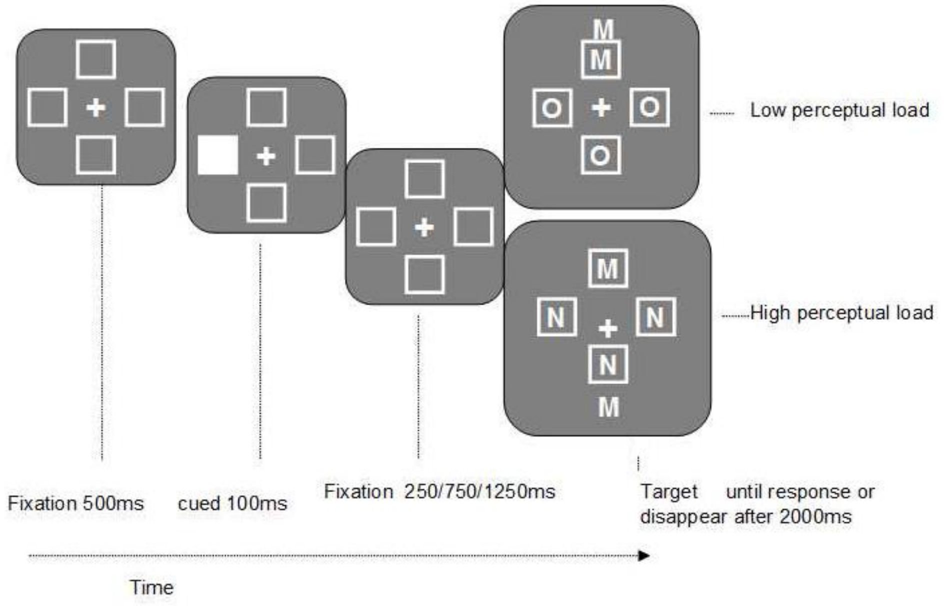

Fig 2.1 An illustration of the IOR procedure in Liu et al. (2014).

Finally, further to Experiment 2, Experiment 3 tested the attentional nature of social IOR by assessing whether the effect is modulated by another factor, known to influence attentional selection – trait anxiety (e.g., Derryberry & Reed, 1998; Eriksen & Hoffman, 1973; Fox, 1993). Trait anxiety is a stable personality characteristic, often described as an increased tendency to experience tension, nervousness and worry in response to perceived stressors. It significantly correlates with state anxiety which is the temporary emotional state of experiencing these feelings (Eysenck, Derakshan, Santos & Calvo, 2007; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983). Eysenck et al. (2007) reported that individuals high in trait anxiety immediately detect threatening information and focus on it even when it needs to be ignored, whereas threatening stimuli do not seem to disrupt the performance of low-trait anxious individuals. Furthermore, trait anxiety is also known to affect the selective processing of non-threatening information, although the precise direction of this effect is less clear. Interestingly, classic IOR is one of the few attentional phenomena that trait anxiety seems to have no effect on. For example, an IOR study using word cues with a different valance (positive, negative or neutral), reported no difference in the magnitude of the effect between the high and low-trait anxious group when stimuli were either neutral (e.g., 'patio') or had a positive valence (e.g., 'optimism' Pérez Dueñas et al., 2009; the full list of words could be found in Pérez Dueñas, Acosta, Megías & Lupiáñez, 2010). However, when the cues were negative ('fright'), only the low-trait anxious group exhibited IOR. Moreover, similar findings have been reported when schematic facial expressions served as cues (Fox, Russo & Dutton, 2002). Fox et al. (2002) found that 'angry' face cues reduced the magnitude of classic IOR in both their high and low-trait anxious group. However, if participants' state anxiety was also high, the angry face abolished the IOR effect in the high-trait anxious group but it did not affect the performance of the low-trait anxious group. Importantly, no such difference was present when attention was cued by the neutral face. The findings of both studies have been interpreted to suggest that IOR is reduced by cues with a negative valence as high-trait anxious individuals focus on 'the threat' and cannot disengage and respond quickly to the uncued IOR locations. Taking into account that neutral stimuli are used in the social IOR paradigm, if social IOR relies on a similar mechanism to classic IOR, a null effect is predicted. Thus, no difference in the magnitude of the effect should occur as a function of trait anxiety.

Taken together, Chapter 2 aimed to assess the extent to which social IOR could be identified as an attentional effect. A series of perceptuo-temporal manipulations, known to either modulate classic IOR or to have no effect on it, was used to determine whether social IOR 'behaves' similarly to IOR. To reiterate, if social IOR is indeed similar to IOR, it was hypothesised that the effect should be relatively short-lasting (not present beyond 3000 ms), should occur only under low perceptual load and its magnitude should not be influenced by trait anxiety.

2.1 Experiment 1

As mentioned in the Introduction, the purpose of Experiment 1 was to examine the time course of social IOR. To do this, the task was performed under four different SOA conditions (1200 ms, 2400 ms, 3600 ms and 4800 ms). Moreover, what had been identified as 'the strictest test of socially-induced IOR' by earlier research on the effect, was used in all experiments in Chapter 2 (Skarratt et al., 2010, p.49). Based on Skarratt et al. (2010) and Welsh et al. (2005, 2007), participants could not see the flashing of the other person's targets, nor their actual response to the target. This was done as these authors have argued that if participants can see each other's targets, then within-person IOR will almost inevitably be induced. Thus, in Experiment 1 physical barriers were used to restrict the participants' view to a central strip of their partners' eyes and hand when it was resting on the 'home' button (See Fig 2.2).

Taking into account previous findings suggesting that traditional IOR has a limited duration of up to 3000 ms after the presentation of the cue (Castel et al., 2003, 2005; Samuel & Kat, 2003), it was hypothesised that if social IOR is a similar effect, it should occur during short SOA conditions but not when the SOA is greater than 3000 ms.

Method

Participants

A volunteer sample of 24 (2 male; 22 female) participants aged between 18 and 22 (*M* = 18.71 years, *SD* = 0.91 years) took part. All were first-year psychology undergraduates at the University of Essex who participated in exchange for course credits. All were right-handed and naïve to the purposes of the study. Ethical approval from the ethics committee of the University of Essex was obtained prior to commencing of all three experiments. All participants gave their informed consent to take part in this research.

Stimuli and Apparatus

The stimuli were displayed on a 19.5-inch LCD touch-screen monitor built flat into a table, raised 740 mm from the floor. Participants sat facing one another and the distance between their chests and their 'home' buttons was approximately 240 mm (See Fig 2.2). All stimuli were presented against a uniform white background (74.6 cd/m^2). The 4 stimulus locations were denoted by 4 black squares which acted as 'placeholders', and remained present for the entire trial duration. Two placeholders (1 to the left, 1 to the right), located at a distance of 160 mm from the black fixation cross and protruding 50 mm to the left and to the right of the screen midline were displayed in front of each participant. The distance between the left and the right placeholder was 320 mm. Each square had an area of 19.6 mm^2. Additionally, the squares were placed within a light-grey area, covering 200 mm^2 of the screen. On each trial, one of the black squares illuminated for 100 ms by turning white (74.6 cd/m^2). Participants made their responses by releasing the 'home' button and touching the square that illuminated. A RM Pentium PC custom software was used for the stimulus generation and the recording of the responses.

Finally, since the experiment was carried out under restricted viewing conditions, two physical barriers were introduced which restricted each participant's view of their partner to a visible gap of 145 mm (see Fig 2.2).

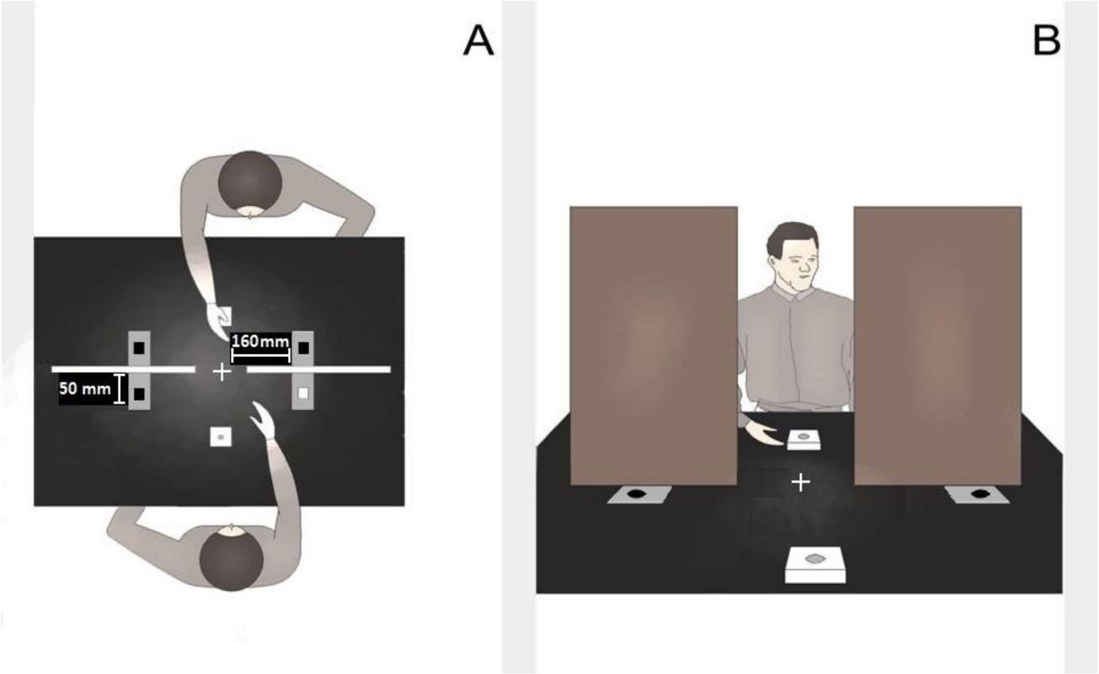

Fig 2.2 A schematic representation of the standard condition in the social IOR paradigm used in Experiments 1, 2 and 3. Panel A presents a topographical view whereas Panel B illustrates the participant's view of the apparatus as the partner's targets are occluded.

Design and Procedure

The experiment had a 2 (target location: same, different) *x* 4 (SOA: 1200 ms, 2400 ms, 3600 ms and 4800 ms) fully within-participants design. A response to a position located on the same side to which the partner had responded on a previous trial is referred to as 'same' whereas a novel location (which had not been responded to by the partner) is referred to as 'different'. The dependent variable in all experiments was the time that elapsed between target presentation and the screen touch (response time, RT).

Participant pairs were tested individually in a quiet cubicle with no external windows. The experimenter verbally explained the instructions after which she demonstrated the procedure. One participant's initial response triggered the target sequence in which each participant pair alternated single responses.

Participants were instructed to keep the home buttons pressed until a response was needed, while at the same time fixating at the cross in the centre of the screen. Then they were required to reach out with their right hand and touch the target location. Although the duration of a trial varied slightly depending on individual differences in response speed, participants took between 500 and 700 ms to complete a response. Thus, the SOA (referring to the interval between target onset of Participant A and target onset of Participant B) was approximately: 1200 ms when the inter-trial interval (ITI) was 350 ms, 2400 ms (ITI: 1550 ms), 3600 ms (ITI: 2750) or 4800 ms (ITI: 3950 ms, See Fig 2.3; Panel A). The four SOA conditions were blocked and their presentation order was counterbalanced. Each block consisted of 209 trials, 104 per participant. This generated a total of 836 trials. The first trial of each block was not analysed since no response preceded it. Participants undertook one practice session consisting of 21 trials which had the same SOA as the first experimental condition they completed. Participants were told to respond as quickly and as accurately as possible.

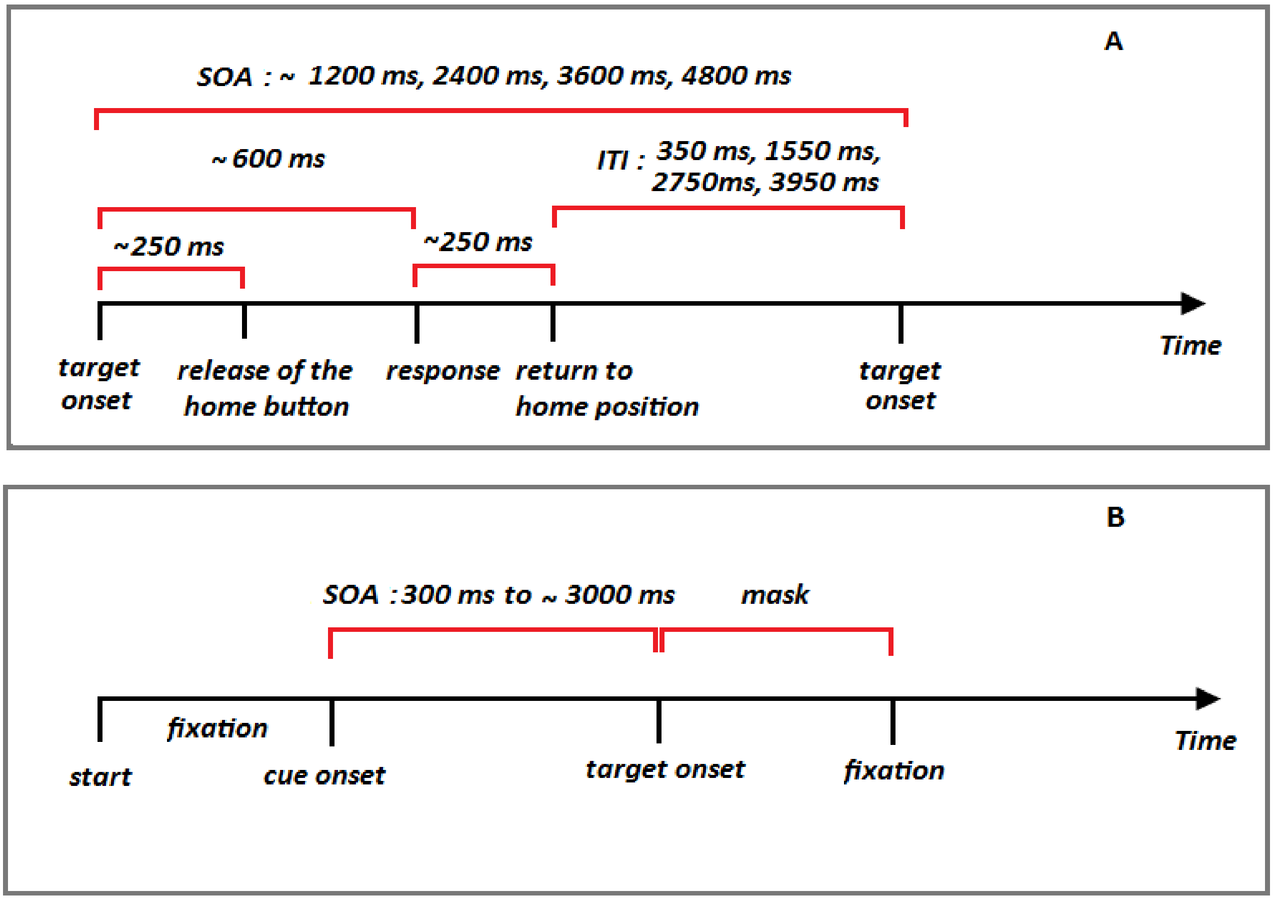

Fig 2.3 Panel A illustrates the procedure in the present social IOR experiment. Panel B presents the procedure used in traditional IOR experiments.

Results and Discussion

Outliers (more than two SDs above or below the mean) were removed from further analysis. Mean RTs (see Fig 2.4) were computed as a function of target location (same, different) and SOA (1200 ms, 2400 ms, 3600 ms and 4800 ms) and were entered into a 2 *x* 4 fully-within participants ANOVA. The main effect of SOA was significant (*F* (3, 69) = 58.17, p < .001, partial eta sq = .717). The main effect of target location was also significant, confirming the presence of social IOR (*F* (1, 23) = 7.91, *p* < .01, partial eta sq = .256). Importantly, the SOA *x* target location interaction was also significant (*F* (3, 69) = 3.26, *p* < .027, partial eta sq = .124) indicating that social IOR was modulated by SOA. Planned comparisons showed that social IOR occurred only when the SOA was 1200 ms (*t* (23) = 2.74, *p* < .012, Bonferroni adjusted alpha = .0125). In all other SOA conditions, the difference between RT to the two location types was nonsignificant (all *p*s > .498).

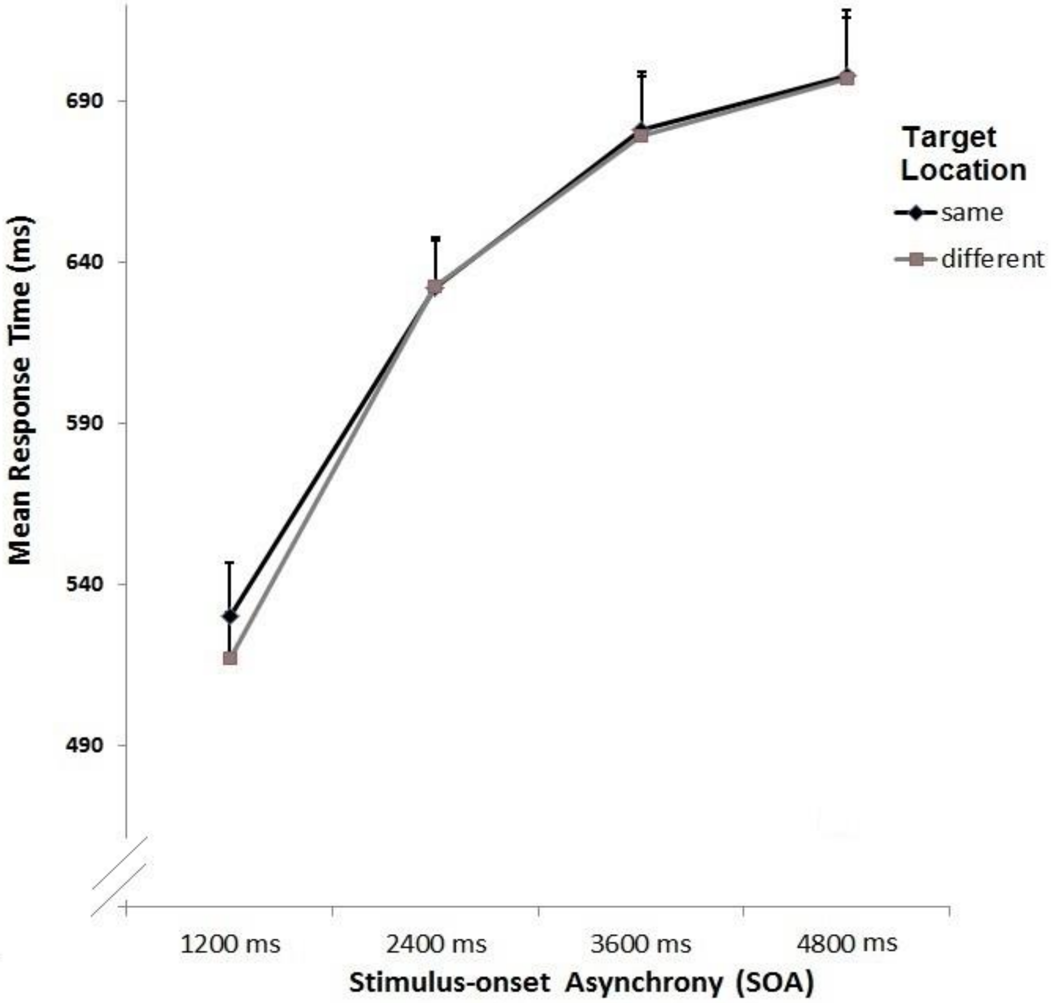

Fig 2.4 Mean RTs as a function of SOA and target location with respect to a partner's target. Error bars represent standard errors of the mean.

Experiment 1 demonstrated that social IOR was modulated by SOA and occurred only during the shortest duration. In other words, social IOR seems to extinguish somewhere between 1200 ms and 2400 ms. This result is consistent with what is known about the temporal duration of within-person IOR when simple stimuli are used and cues are uninformative (e.g., Castel et al., 2003, 2005;

Samuel & Kat, 2003). However, while some IOR studies have demonstrated IOR to last up to 3000 ms, the current social IOR effect was no longer present in the 2400 ms SOA condition. This might have possibly resulted from the present task being performed under restricted viewing conditions. Finally, although no other studies have directly examined the time course of social IOR, the present results support previous studies on the effect where short SOAs are normally employed (Atkinson et al., 2014; Hayes et al., 2010; Skarratt et al., 2010; Welsh et al., 2005).

2.2 Experiment 2

Experiment 2 manipulated the degree of perceptual load in the task. Thus, according to the level of perceptual load, participants were presented with a different number of stimuli at the 'target stage' (See Fig 2.5). Based on Lavie et al.'s (2004) load theory of selective attention and cognitive control and Liu et al.'s (2014) finding that classic IOR disappears during high perceptual load, it was hypothesised that if social IOR is similar to basic IOR, the social IOR effect should disappear or at least be reduced as perceptual load increases.

As in Experiment 1, the task was performed under restricted visual conditions (See Fig 2.2).

Method

Participants

A volunteer sample of 41 (11 male; 30 female) participants aged between 18 and 28 (*M* = 19.91 years, *SD* = 1.80 years) took part in the study. All participants were undergraduates at the University of Essex, were right-handed and were naïve to the purposes of the study. They either received a course credit or £3 for their participation.

Stimuli and Apparatus

The apparatus was as reported in Experiment 1. There were three perceptual load conditions. The stimuli in the low perceptual load were identical to the ones used in Experiment 1 (Fig 2.5, Panel A). In the medium load condition four squares were presented on each side, and in the high load condition there were six squares on each side (See Fig 2.5, Panels B & C). The placeholders in the medium load condition were located 145 mm from the fixation cross and protruded 70 mm to the left and 70 mm to the right of the display midline. The placeholders in the high load condition were also located 145 mm from fixation and protruded 92.5 mm to the left and to the right. They were presented on the same vertical line and were displayed against light-grey background, covering 652.5 mm^2 of the screen in the medium load and 832.5 mm^2 in the high load, respectively. Each placeholder had an area of 19.6 mm^2 and when a target, it flashed by turning white (74.6 cd/m^2). All stimuli were presented against a uniform white background (74.6 cd/m^2). As in Experiment 1, all conditions were performed with physical barriers to prevent targets being seen on a partner's trial.

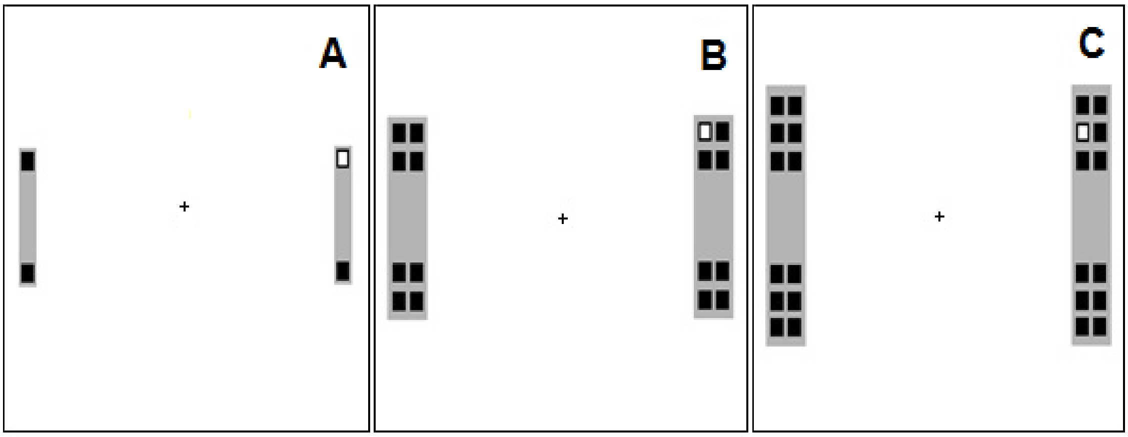

Fig 2.5 An illustration of the stimuli used in the three load conditions of Experiment 2.

Design and Procedure

The experiment had a 2 (target location: same, different) *x* 3 (perceptual load: low, medium, high) fully within-participants design. The procedure was identical to that reported in Experiment 1 with the difference that all trials in all blocks had a SOA of approximately 1200 ms. In the three load conditions, only one target was presented at a time for 100 ms so that when it was the participant's turn, one of the placeholders either to the left or to the right, turned white while the other remained black. The target was equally likely to occur at any of the placeholder locations in the medium and the high perceptual load. The presentation order of the three experimental conditions, blocked according to perceptual load, was counterbalanced. As in Experiment 1, participants first watched a demonstration by the experimenter. This was followed by a practice session consisting of 21 trials where the perceptual load was the same as the first experimental condition they completed. Participants were instructed to respond as quickly and as accurately as possible.

Results and Discussion

Five participants were excluded from further analysis because they failed to fully press the home button when completing a response which resulted in delays in the presentation of subsequent targets. The data of the remaining 36 participants was used after RT outliers (more than two SDs above or below the mean) were removed.

Mean RTs were computed as a function of target location (same, different) and perceptual load condition (low, medium or high) and entered into a 2 *x* 3 fully-within participants ANOVA (See Fig 2.6). The main effect of perceptual load was significant (*F* (2, 70) = 10.88, p < .001, partial eta sq = .237). Planned comparisons revealed that participants were faster in the low load condition as compared to the medium (*t* (35) = 4.43, *p* < .001, Bonferroni adjusted alpha = .0016) and the high (*t* (35) = 2.80, *p* < .008, Bonferroni adjusted alpha = .0016). However, there was no significant difference between the medium and the high perceptual load (*p* > .12). The main effect of target location was not significant (*p* > .06) but there was a significant location *x* load interaction (*F* (2, 70) = 5.42, *p* < .006, partial eta sq = .134) indicating that social IOR was modulated by perceptual load. Follow-up comparisons showed that social IOR occurred only when perceptual load was low (*t* (35) = 4.29, *p* < .001, Bonferroni adjusted alpha = .016). Importantly, the effect disappeared in the medium (*p* > .06, Bonferroni adjusted alpha = .016) and high perceptual load conditions (*p* >.296, Bonferroni adjusted alpha = .016).

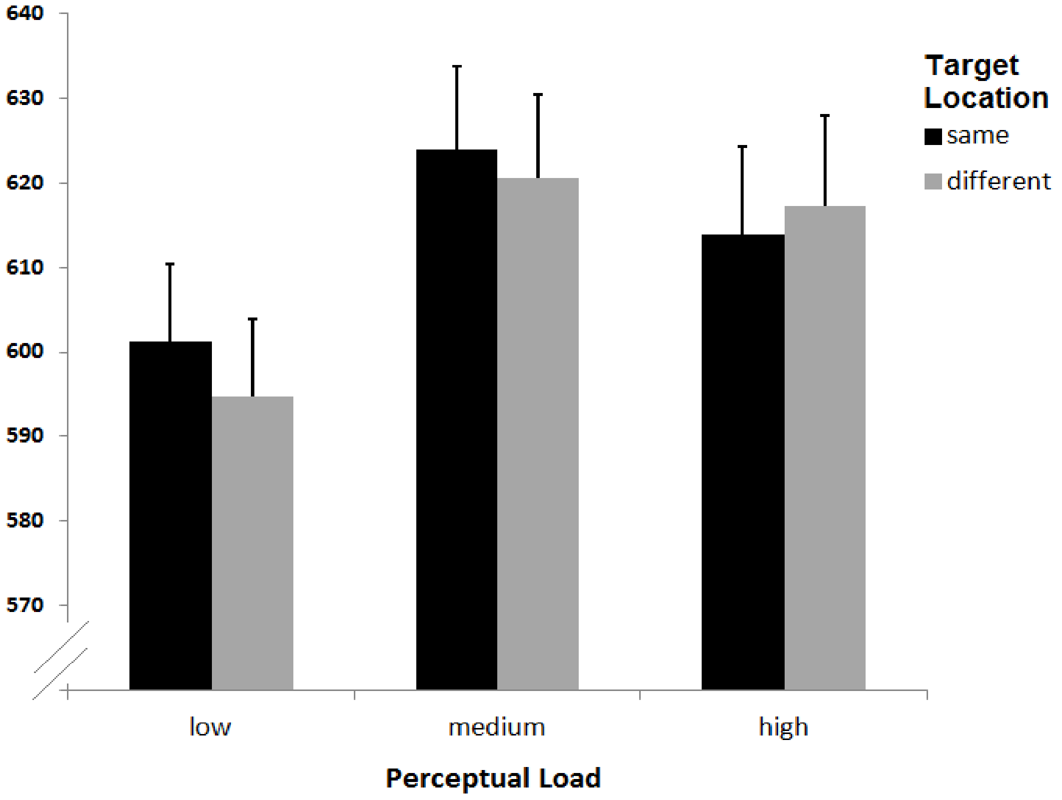

Fig 2.6 Mean RTs to localise targets as a function of perceptual load and target location. Error bars represent standard errors of the mean.

The findings of Experiment 2 demonstrated that social IOR is modulated by perceptual load since the effect occurred only when perceptual load was low. These results are in line with what would be expected for classic IOR (Liu et al., 2014). They could be explained with the load theory of selective attention and cognitive control which proposes that high perceptual load focuses selective attention and reduces distractor interference (Lavie et al., 2004). Thus, what is likely to have happened in Experiment 2 is that when the number of stimuli, presented along with the target increased, participants naturally became more efficient at identifying the flashing target (Lavie et al., 2004). This improved attentional selection ability then in turn, must have overridden the inhibition to the previously cued location, resulting in no RT difference between cued and uncued locations in the medium and high perceptual load.

2.3 Experiment 3

The purpose of Experiment 3 was to examine whether social IOR is modulated by trait anxiety. Recall from the Introduction of Chapter 2 that trait anxiety does not influence classic IOR when the task is performed with neutral stimuli (Fox et al., 2002; Pérez Dueñas et al., 2009). Thus, as the stimuli in the social IOR paradigm do not have any emotional valence, it was hypothesised that if social IOR is based on the same mechanisms that give rise to IOR, trait anxiety should not have any modulating effect on it (i.e., there should be no difference in social IOR between the two groups). Moreover, to assess whether the present experiment was sensitive enough to generate an effect known to be influenced by anxiety, we introduced an additional variable. Therefore, one of the blocks was performed with physical barriers between participants (see Fig 2.2) whereas the other was performed with no barriers. Research has shown that anxiety makes individuals more sensitive to evaluation from others (e.g., Rapee & Heimberg, 1997). At the same time, Eysenck et al.'s (2007) attentional control theory assumes that anxiety impairs cognitive control, resulting in inefficient performance as these individuals often engage in compensatory strategies, such as enhanced effort to achieve standard performance. Thus, in line with the latter it was expected that the high-trait anxious group would generally be slower on the RT task (Eysenck & Calvo, 1992; Eysenck et al., 2007). However, these participants would also be motivated to improve their performance (i.e., by becoming quicker) when their partner could monitor their responses (no barrier condition).

Method

Participants

A volunteer sample of 54 (8 male; 46 female) participants aged between 18 and 30 (*M* = 19.57 years, *SD* = 2.55 years) took part in the study. All participants were first-year psychology undergraduates at the University of Essex who participated in exchange for course credits.

Stimuli and Apparatus

The same stimuli and apparatus were used as those described in Experiment 1. Participants' trait anxiety was measured by Spielberger's State Trait Anxiety Inventory (STAI, Speilberger et al., 1983; state anxiety was also measured for control purposes). STAI has been used extensively in research and has been reported to have good validity and reliability (Elwood, Wolitzky-Taylor, & Olatunji, 2012; Spielberger et al., 1983). Its standard version was administered where state anxiety was assessed by 20 items, evaluating the respondents' feelings at that moment and trait anxiety was assessed by 20 items, evaluating how respondents generally felt. Each participant was given a score from 20 to 80 for each anxiety measure.

Design and Procedure

The experiment had a 2 (target location: same, different) *x* 2 (viewing condition: barrier, no-barrier) *x* 2 (trait anxiety: low, high) mixed design. Participants completed 2 experimental blocks of 209 trials – one with a barrier and one without. The presentation order of these 2 experimental conditions was counterbalanced. As reported previously, before completing the experimental blocks, participants first watched a demonstration by the experimenter. Then they undertook one practice session consisting of 21 trials either with a barrier or without, depending on the first experimental condition completed. Participants were instructed to respond as quickly and as accurately as possible. STAI was always administered after the social IOR task, starting with the state-anxiety questionnaire.

Results and Discussion

Participants' mean state anxiety score was 36.22 (*SD* = 9.32; normative score in college students is 37.62, *SD* = 10.99; Spielberger et al., 1983). Mean trait anxiety was 42.98 (*SD* = 9.87; normative score in college students is 39.35, *SD* = 9.67). As expected trait- and state anxiety significantly correlated ($r = 0.403$, $p < .003$). A median split on participants' trait anxiety scores was performed to classify participants as belonging to either the 'low' or the 'high' trait anxiety group. Outliers were removed from further analysis using the same criterion as described previously. Mean RTs were analysed with a 2 *x* 2 *x* 2 mixed design ANOVA where target location (same, different) and viewing condition (barrier, no-barrier) were entered as within-participants factors, and trait anxiety (low, high) as a between-participants factor. The main effect of target location was significant (*F* (1, 52) = 45.64, *p* < .001, partial eta sq = .467), suggesting that regardless of trait anxiety and viewing condition, participants exhibited social IOR (See Fig 2.7). However, neither the main effect of viewing condition nor trait anxiety reached significance (*p*s > .187) but there was a significant interaction between viewing condition and trait anxiety (*F* (1, 52) = 4.69, *p* < .035, partial eta sq = .083, Fig 2.8). The post-hoc analyses revealed a significant simple effect of viewing condition within the trait anxiety group (*t* (26) = 2.72, *p* < .011, Bonferroni adjusted alpha = .025). Thus, the high-trait anxious individuals were quicker when there was no barrier. No other significant effects were found.

Additionally, in order to generate a greater distinction between the two anxiety groups, the analysis was repeated with the bottom and the top quartiles of the trait anxiety scores (instead of a median split). Again a significant social IOR emerged (*F* (1, 29) = 18.45, *p* < .001, partial eta sq = .389). However, although the same trend in the viewing condition *x* trait anxiety interaction appeared, it did not reach significance (*F* (1, 29) = 0.44, *p* > .51), perhaps due to the smaller sample size (N = 31). Finally, only a significant social IOR was found (*F* (1, 52) = 44.53, *p* < .001, partial eta sq = .461) when state anxiety instead of trait anxiety served as a between-participants factor in the analysis.

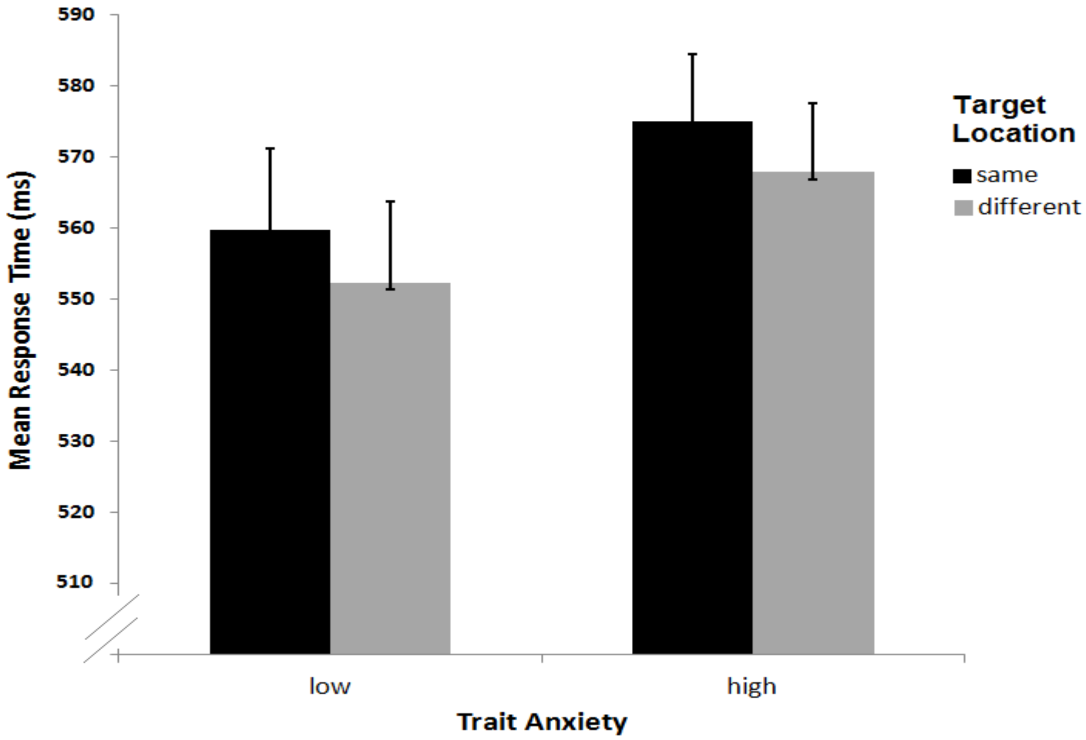

Fig 2.7 Social IOR in the low and the high-trait anxiety group. Error bars represent standard errors of the mean.

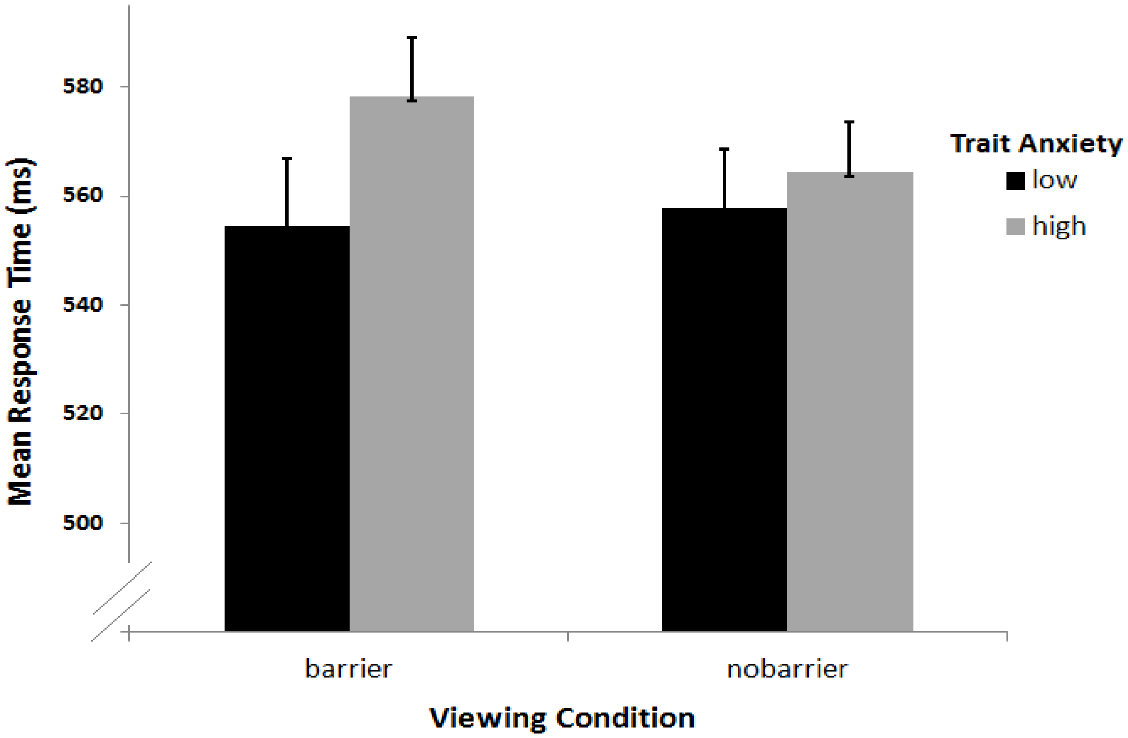

Fig 2.8 Mean RTs of the low and the high-trait anxious individuals to localise targets as a function of viewing condition. Error bars represent standard errors of the mean.

The results of Experiment 3 indicated that social IOR was not modulated by trait anxiety. The present findings are consistent with Fox et al. (2002) and Pérez Dueñas et al. (2009) who also found that trait anxiety did not modulate the magnitude of classic IOR when neutral cues where used. Moreover, although the present findings have been based on a null effect, it seems that the anxiety assessment had been successful as trait anxiety influenced general performance on the task as a function of viewing condition. Thus, the present results showed that trait anxiety impaired performance on the task, resulting in longer latencies for the high-trait anxious group. The latter is in line with previous findings and the attentional control theory suggesting that individuals high in trait anxiety are generally slower on RT tasks as compared to low-trait anxious individuals (Eysenck et al., 2007). Moreover, the finding that the difference in RT between the two groups disappeared when the barrier was removed is in line with previous research showing that high-trait anxious individuals often compensate for their decreased efficiency with increased effort (Eysenck & Calvo, 1992; Eysenck et al., 2007).

2.4 General Discussion

Chapter 2 assessed whether social IOR possessed properties, characteristic of an attentional effect, and more specifically, classic IOR. It was found that social IOR is short-lived; it is modulated by one of the mechanisms of selective attention (perceptual load) and is not influenced by trait anxiety. These findings are in line with an attentional explanation of the effect, according to which social IOR is based on inhibition of return. Provided below is a detailed discussion of the findings of each experiment and an explanation of how these fit with the attentional literature.

First, the observed temporal interval of the effect agrees with what is known about classic IOR. As mentioned in the Introduction, several studies have suggested that classic IOR lasts for up to 3000 ms (e.g., Castel et al., 2003, 2005;

Samuel & Kat, 2003). Moreover, the type of stimuli and procedure in the present Experiment 1 concurred with the conditions under which IOR is normally characterised by this relatively short time-course[8]. In contrast, although several papers have reported that IOR can have a much longer time course, this has been explained as the result of modifications to the original paradigm. For example, when instead of flashing lights, more engaging stimuli, such as human faces were used, IOR was found to last exceptionally longer (up to 13 min; Tipper, Grison & Kessler, 2003). This is probably due to the more engaging stimuli producing a stable memory representation which can be easily reinstated even after a long delay (Tipper et al., 2003). Finally, the result of longer general RTs as a function of SOA is also predicted by the attentional literature. Previous research has established that the longer the SOA in a block, the more difficult it is to estimate when the response signal will occur, resulting in progressively delayed RTs as a function of block SOA (Klemmer, 1956; Rolke and Hofmann, 2007). For instance, Rolke and Hofmann (2007) found that RTs were shorter for blocks with short SOAs (e.g., 800 ms) compared to blocks with long SOAs (e.g., 2000 ms). This probably occurs as the time between the cue and target allows top-down temporal preparation to develop, but as time is prolonged this judgement becomes less accurate.

Moreover, the results of Experiment 2 also agree with what is known about basic IOR. As recently found by Liu et al. (2014), IOR is also present during low perceptual load conditions but disappears under high perceptual load. Moreover, the finding that social IOR was somewhat reduced as perceptual load increased (medium load) and despite non-significant, this tendency was reversed during high

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[8] According to Wilson, Castel and Pratt (2006) these include: simple stimuli such as dots, circles or squares that serve as cues and targets; cues are uninformative and merely observed (not responded to); and the experiment follows the traditional Posner and Cohen (1984) cue-target procedure.

perceptual load (See Fig 2.6) is also consistent with Liu et al. (2014). In their high perceptual load condition, a very similar reversal of IOR was identified. As explained in the Introduction, these results are most likely due to the 'focusing' effect that high perceptual load has on visual selective attention (Lavie et al., 2004). Thus, what is likely to have happened is that the increase in the number of stimuli in the medium and high perceptual load improved attentional selection (leading to more efficient responses and reduced RTs). This, in turn abolished the RT difference between the cued and the uncued location, resulting in a disappearance of the social IOR effect. Additionally, the finding that participants were slower in their general RT to respond to targets in those two conditions (as compared to the low perceptual load) is also in line with the selective attention research. This effect has been widely reported in different attentional paradigms where a target and a distractor are presented and the number of items around the target is varied (e.g., Caparos & Linnell, 2009; de Fockert, Caparos, Linnell & Davidoff, 2011; Macdonald & Lavie, 2008). Finally, evidence from a recent social IOR study also proposed that social IOR was modulated by the perceptual properties of the stimuli, used in the task (e.g., Atkinson et al., 2014). For instance, Atkinson et al. (2014) found that similarly to basic IOR, social IOR was both location- and object-based as the effect disappeared unless the two targets on a particular hand-side had been grouped in an object (such as the grey rectangular shapes in all experiments in the present chapter, See Fig 2.2). Moreover, in a subsequent experiment in the same paper it was found that social IOR disappeared when the perceptual demands of the task increased. Thus, when participants had to discriminate between two targets, instead of performing the usual simple localization response, no social IOR effect occurred.

Lastly, the finding of Experiment 3 that trait anxiety did not modulate the magnitude of the phenomenon also agrees with what would be expected, provided that social IOR is an IOR-like effect. As previously reported for IOR tasks with neutral stimuli (Fox et al., 2002; Pérez Dueñas et al., 2009), Experiment 3 did not identify any difference in social IOR between the present high- and low-trait anxious groups (See Fig 2.7). Moreover, although these findings have been based on a null effect, the poorer performance of the high-trait anxious group (marked by longer general response latencies) as a function of viewing condition was in line with previous findings that anxiety negatively affects RT performance (Eysenck & Calvo, 1992; Eysenck et al., 2007). Additionally, the observed improvement in general response speed is supported by theories conceptualizing cognitive effort as an incentive, usually ‘triggered as a result of the subjects' detection of performance errors or of a declining reward rate’ (Sarter, Gehring & Kozak, 2006, p. 146). Thus, taking into account that anxiety makes individuals more vigilant to threat (Fox et al., 2002; Pérez Dueñas et al., 2009) and especially sensitive to judgement by others (e.g., Rapee & Heimberg, 1997), it is very likely that in the no barrier condition, these participants had a higher incentive to compensate for their slower reaction time with increased effort. This is supported by previous research on anxiety and reading efficiency where high-trait anxious individuals were identified to endorse in compensatory strategies. More specifically, to achieve as good performance as the low-trait anxious group, high-trait anxious individuals either looked back at the previously read text or read the test aloud to improve concentration (e.g., Calvo & Castillo, 1995; Calvo & Eysenck, 1996).

Taken together, the present findings fit best with an IOR account of the effect in which social IOR is based on inhibition to return attention to an area, explored by another individual (Cole et al.). As described in Section 1.1.3 of the General

Introduction, according to Cole et al. social IOR is similar to the effect observed in Posner and Cohen's (1984) classic paradigm. Thus, the partner's arm reach/eye gaze must have served as central cues that shifted the observer's attention to the location of their response. Then, as it happens in the classic IOR paradigm, witnessing an attention-capturing event in the periphery, being it the partner's target illumination and/or their reaching response, cued the observer's attention to that location. Moreover, because of the SOAs being longer than 300 ms, participants experienced inhibition to return attention to the previously cued location and were consequently slower to initiate an action there. Indeed, as described in detail in the above paragraphs, the present findings strongly suggest that the effect of interest possesses a number of properties, characteristic of classic IOR. The only finding that does not completely agree with the IOR literature is that in Experiment 1, social IOR extinguished before 2400 ms. Still, although reported to potentially last for up to 3000 ms, classic IOR has been found to be most stable in the interval between 300 ms and 1600 ms (See Samuel & Kat, 2003 for a meta-analysis). To speculate, another reason why the effect disappeared before 3000 ms might have been the presence of a barrier. This might have reduced the saliency of the central cues which were in fact the partner's eye movements and hand responses. In support, there is evidence that the magnitude of social IOR sometimes increases when partners have a full vision of the paradigm (e.g., Welsh et al., 2007).

However, the present findings do not challenge the other two accounts of the effect – Ondobaka et al.'s (2012, 2013) according to which social IOR is due to movement congruency (See Section 1.2.4) and Welsh et al.'s (2007, 2009, Welsh, Manzone & McDougall, 2014) according to which it is based on action inhibition (Section 1.1.3). This is because the effect of action was not directly manipulated in the present chapter and thus the contribution of action co-representation to the effect cannot be presently determined. Moreover, although the findings of Experiments 2 and 3 concur with what is known about the effect of trait anxiety on classic IOR, it is unclear what influence perceptual load and trait anxiety have on action co-representation, as up to the author's knowledge no such research has been performed up to date. Still, in a broader sense some aspects of the present findings do not concur with Ondobaka et al.'s and Welsh et al.'s accounts. For example, it is unlikely that a system that has adapted to interpret and represent observed actions will be unable to function when the temporal gap between the observed and the required action exceeds 2000 ms (indeed there is evidence that the MNS is involved in delayed imitation which can last for much longer; e.g., Paukner, Ferrari & Suomi, 2011). Moreover, as the two co-actors' actions were kept constant in all experiments and the effect appeared/disappeared as a function of a change in either the temporal or perceptual characteristics of the task, it can be speculated that the observed effect can occur independently of action co-representation. Still, the latter is not enough to disregard Ondobaka et al.'s (2012, 2013) and Welsh et al.'s (2007, 2009, 2014) accounts. Thus, the following Chapter 3 aimed to overcome the limitations of the present chapter by directly testing the contribution of action to the social IOR effect.

Finally, the present results have important theoretical implications for the better understanding of social IOR. First, the present chapter presented three original experiments testing three different characteristics of social IOR, not previously researched. Moreover, by comparing the results to what is already known about classic IOR, the present findings demonstrated that there is ground to propose that social IOR and IOR rely on similar mechanisms and that social IOR might indeed be an attentional effect. To speculate, the present research might help reconcile some results concerning the effect in special populations. For example, Welsh et al. (2009b) reported that ASD individuals do not exhibit social IOR. At the same time, such participants have been found to demonstrate the basic IOR effect (Rinehart et al., 2008). The present research might explain this discrepancy. If the proposed interpretation of the effect is true, social IOR might not occur in this group because the social nature of the cue makes it difficult for the ASD group to orient attention to the partner and their responses[9]. Thus, a situation similar to the medium and the high perceptual load conditions of Experiment 2 might be occurring – a processing preference might be given to the most significant event occurring at the moment. In support, even able ASD individuals show a highly abnormal pattern of visual scanning, such as fixating faces to a much lesser extent than controls, reduced attention to the eye-region and a tendency to focus on non-essential facial parts, like the earlobes (e.g., Dalton, 2005; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Riby & Hancock, 2008).

In sum, the findings of Chapter 2 suggested that social IOR and basic IOR share some similarities in terms of their perceptuo-temporal properties. Three experiments demonstrated that similarly to classic IOR, the present effect has a comparably short time course; it is modulated by perceptual load but not by trait anxiety when the task is performed with neutral stimuli. Although the present findings seem to better fit with an IOR explanation of the effect, they do not, by any means, rule out an alternative explanation of the effect, based on action co-representation. Therefore, in a series of three experiments the following Chapter 3 directly tested the contribution of action co-representation to the social IOR effect.

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[9] ASD individuals are known to exhibit a strong preference for objects to people.

CHAPTER 3

3.0 IS SOCIAL IOR DUE TO ACTION CO-REPRESENTATION?

The dominant paradigm in cognitive research is the testing of individuals on tasks performed in isolation. In the archetypal experiment, a lone individual performs a required task in front of a computerized display, from which the experimenter can examine aspects of the individual's perceptual, attentional, memory, or executive abilities. However, during the past decade a number of researchers have begun to examine how cognition operates when a person acts jointly with another individual. One finding is that the presence of others can influence how attention is selectively allocated across a visual display (Böckler et al., 2012; Frischen et al., 2009; Tversky & Hard, 2009). For example, when participants are asked to respond to a target, whilst ignoring simultaneously appearing distractors, their egocentric frame of reference can shift to an allocentric one if the task is performed jointly with another individual (Frischen et al., 2009).

Joint action work is often placed within the context of theories that link mechanisms representing perception and action, one of which being the theory of event coding (TEC; Hommel et al., 2001). In essence, the TEC suggests that perceived events (perception) and intended to-be-executed events (action) share a common representational domain. As such, irrespective of their role, both stimulus and response codes are formed and represented in the same medium as cognitive structures, called 'event codes'. Event codes are said to prime each other in accordance to an overlap on an abstract distal-coding level, implying these are formed on the basis of goal-directed representations of the events. 'According to TEC, intentionality renders perception and action-planning inherently similar and functionally equivalent' (Hommel et al., 2001, p. 904). Thus, anticipating a perceptual event, perceiving it, planning the event or executing it are assumed to result in a similar activation in the motor system.

The theory has been used as an explanation for one of the most notable joint-action effects, namely the joint Simon effect (or social Simon effect (SSE); Sebanz et al., 2003). In the basic paradigm, co-actors sit adjacent to one another and each has a single target they are required to respond to. One participant responds with their left hand, the other with their right. For example, co-actor A may respond only to the appearance of a blue stimulus by pressing a left key, whereas co-actor B presses a right key whenever a green stimulus is presented. Furthermore, targets can appear either to the left or right hand side of the display. Results indicate that although the position of the targets is irrelevant, co-actors are generally quicker to respond to stimuli appearing on the side associated with their response button (e.g., left key press for a blue stimulus appearing to the left) and are slower whenever their target appears on the partner's side (Sebanz et al., 2003, Hommel et al., 2009). Importantly, this effect is present only when the task is performed jointly with another individual, or alone where the person makes both responses (i.e., Simon & Rudell, 1967), but not when a lone participant responds to just one of the two stimuli (Hommel, 1996). In the terminology of TEC, the standard (lone) Simon effect occurs because agents automatically form binding codes between the relevant stimulus features (i.e., colour) and the irrelevant but corresponding stimulus features (i.e., location). Consequently, when these coincide a facilitation effect, translated into shorter RT, occurs whereas a stimulus-response mismatch results in an interference and longer RT (Hommel et al., 2001; Hommel et al., 2009). Following this logic, Sebanz and colleagues (2003, Sebanz et al., 2006) argued that when acting jointly on a task, co-actors represent each other's stimulus-response maps and therefore experience interference whenever these are violated. This suggests that co-actors represent and integrate each other's perspective (Sebanz et al., 2003, 2006; Sebanz & Knoblich, 2009, Obhi & Sebanz, 2011).

As mentioned in the General Introduction, action co-representation mechanisms have also been invoked to explain the present social IOR effect (Sections 1.1.3 & 1.2.4). To recap, in this paradigm two co-actors sit facing each other and take turns to respond to targets appearing on a flat display located between them. Once a response has been made, the actor is required to return their hand to a resting position in front of them (see Fig 3.1). Typical results reveal that RTs to initiate a response are longer when reaching to the same location as the co-actor's previous response. Or to put it another way, RTs are shorter when reaching to a different location (which involves reaching to two opposite sides of the display; See Fig 3.1). Although several studies have now examined various characteristics and properties of the effect, it is not yet clear why it occurs. Indeed, different authors, have assumed that the effect is due to a particular mechanism. As explained previously, Welsh and colleagues and Skarratt et al. (2010)/Cole et al. refer to it as 'between-person inhibition of return' and 'social inhibition of return (sIOR)' respectively, suggesting that it reflects the visuomotor inhibition that follows an attention-capturing event. By contrast, Ondobaka et al. (2012, 2013) proposed that social IOR was due to congruency of observed and performed action, i.e., imitation.

By investigating the direct effect of action co-representation on social IOR, the present Chapter 3 tested the three explanations that have been posited to explain its basis. These three theories, described below, are referred to as the *action-location* account (Hayes et al., 2010; Welsh et al., 2005, 2007, 2009), the *movement congruency* account (Ondobaka et al., 2012, 2013), and the *attentional shift* hypothesis (Cole et al., 2012; Atkinson et al., 2014). One should note that although fundamentally different from each other, there are similarities amongst the three theories. For instance, both the Welsh et al.'s and Ondobaka et al.'s theories incorporate the action-perception models described earlier in which an observed action is said to be represented both by perceptual mechanisms and action mechanisms. However, in contrast to Welsh et al.'s explanation, the location of response is not important in the Ondobaka et al.'s account. Furthermore, the theories of Welsh et al. and Cole et al. are both concerned with inhibitory mechanisms (i.e., IOR) whereas the Ondobaka et al.'s explanation is not. Although previously described in Section 1.1.3 of the General Introduction, for the purposes of the present chapter, each of the three accounts is again presented below.

First, Welsh and collaborators (and others, e.g., Sebanz & Knoblich, 2009) argued that the effect is caused by the linking of mechanisms underlying action co-representation and inhibition. With respect to the former, Welsh et al. (2007, p.955) suggested 'that between-person IOR results from an understanding of the other person's response'. Furthermore, Welsh et al. (2007) posited the mirror neuron system (MNS, Rizzolatti & Craighero, 2004) as a mediating mechanism. The MNS is often referred to as the action observation system of the brain, known to become active both during action execution and when the same action is observed. As Welsh et al. (2007, p.955) stated, 'We hypothesize that the activation of the mirror neuron system during the observation of the response mimicked the activity associated with the actual response'. The second and complimentary aspect of their account concerns inhibition and specifically IOR. It is now well-established that humans are slower to act upon a stimulus presented at a recently attended location (i.e., Posner & Cohen, 1984). Thus when an observer sees another individual attend to a location, this initiates IOR in the observer. Put simply, Welsh et al.'s account suggests that when co-actor A reaches to location X, co-actor B's perceptual mechanisms ‘perceive’ it as if co-actor B has performed the action themselves, which activates an inhibitory response to that location.

The second account, advocated by Ondobaka et al. (2012, 2013), places the present effect within the context of mechanisms that represent congruency of movement. In addition to inhibiting an action, observing a biological movement can also facilitate the same movement in the observer. For example, participants are quicker to execute a finger (Brass et al., 2001) or an arm movement (Kilner et al., 2003) compatible with the one observed (Kilner et al., 2003, see also Liepelt et al., 2008). With respect to the present phenomenon, Ondobaka et al. argued that when a participant reaches out to, say, their right (because the target appeared on the right) this facilitates a rightward reach in the observer (i.e., co-actor) when she is then required to reach to her right on the next trial. In other words, the action is facilitated when, within an egocentric framework, it is congruent with the one just seen (See Section 1.2.4 for more detail).

Finally, the third explanation argues that the effect occurs solely as a result of mechanisms associated with attentional orienting and resultant IOR (Cole et al., 2012). As explained in detail in Chapter 2, the classic IOR phenomenon is normally studied in paradigms where a peripheral cue is presented to a lone observer, followed by a delay longer than approximately 300 ms and a target that appears with equal probability at either the cued or the uncued location (Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, 1989). Results typically show that participants are slower to respond to cued targets. In other words, after an initial capture of attention by the cue, inhibition follows. Thus, it is possible that instead of representing an observed action social IOR occurs because a co-actor’s arm movement (and/or target onset) shifts the observer’s attention to one side of the display. In effect, the partner’s arm reach serves an identical role to the peripheral cue in Posner and Cohen's classic study (1984); that is, it provides a transient event that draws an observer's attention to a region of space. Furthermore, the fact that the phenomenon is still observed when only the initial portion of the arm movement can be seen (see Welsh et al., 2007 and Skarratt et al., 2010) does not negate the attentional shift hypothesis; occluding the peripheral 'transients' generated by a reaching action renders the initial (seen) movement as a 'central' cue, and classical IOR is now known to be induced with central cues (e.g., Cole, Smith & Atkinson, 2015; Taylor & Klein, 2000; Weger et al., 2008). Indeed, Skarratt et al. (2010) reported that seeing a co-actor's eye gaze only, was sufficient to generate social IOR (Skarratt et al., 2010)[10].

The main aim of the present Chapter 3 was to assess the extent to which action co-representation contributes to the social IOR effect. Thus, Experiment 4 investigated whether the phenomenon is affected if there is a kinematic mismatch between the action that is observed and the one that needs to be performed. Experiment 5 examined the consequences of having attention shifted to a location in the absence of an observed action (i.e., so that no imitation or action co-representation could occur). Finally, Experiment 6 attempted to isolate the effects of action congruency and target location to directly test which of the three accounts of social IOR provides the most plausible explanation of the phenomenon.

Importantly, for consistency, the term 'social IOR', instead of 'movement congruency' was used throughout the chapter to refer to the observed effect. As previously explained, actions to the *'same'* location are always *'movement incongruent'* as in this condition participants need to reach to two different hand-sides of the display (e.g., Co-actor 1 (C1) goes to the right, Co-actor 2 (C2) goes to

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[10] Debate surrounds the degree to which IOR is due to inhibition of attention as opposed to motor processes. However, most authors agree that an initial shift of attention occurs in order to induce IOR.

the left; See Fig 3.1). At the same time, actions to the *'different'* location are always *'movement congruent'* as in this condition participants need to execute movements to the same hand-side of the display (e.g., C1 goes to the right, C2 goes to their right). Furthermore, in contrast with the distinction sometimes made in the joint-action literature between 'action congruency' and 'movement congruency' (Ondobaka et al., 2012, 2013, 2015), these two terms have been *used interchangeably* in this chapter. This is so as action intention was not modulated in any of the present three experiments (i.e., action congruency is usually used to represent action intention (whether the goal of the action differs or not in respect to that of the other co-actor) while movement congruency is used to refer to the exact direction of the movement; Ondobaka et al., 2012, 2013, 2015).

3.1 Experiment 4

The action co-representation account proposes that co-actors in joint-action tasks 'form shared representations of tasks quasi automatically' and that 'the other's task ... [is] … represented in a functionally equivalent way to one's own' (Sebanz et al., 2006, p.72). As mentioned in the Introduction, this is thought to be subserved by the MNS which has been found to be active both during action execution and action observation in humans and monkeys (Rizzolatti & Craighero, 2004). It follows therefore that if the two co-actors use different parts of their body to respond, no movement congruency effect (i.e., social IOR) should be observed because different actions are being performed. In other words, a movement congruency effect should not occur if the observed and the required actions mismatch not only visually but also kinesthetically. Indeed, research on action co-representation suggests that some actions are only simulated when the two co-actors are similar enough (e.g., Avenanti, Sirigu & Aglioti, 2010; Hommel et al., 2009).

Experiment 4 employed the standard social IOR/arm movement congruency paradigm described earlier in which participants reached with their hand/arm to the target location. For consistency, instead of 'movement congruency', the term 'social IOR' was used throughout the chapter to refer to the effect of interest. As previously explained, actions to the *'same'* location were always *'movement incongruent'* as in this condition participants needed to reach to two different hand-sides of the display while actions to the *'different'* location were always *'movement congruent'* as in this condition participants needed to execute movements to the same hand-side of the display (See Fig 3.1). Importantly, in this experiment, on half of the trials, the confederate-co-actor that participants alternated responses with used her hand/arm to make the responses while on the other half she responded with her foot/ leg.

Method

Ethics Statement

Ethical approval from the ethics committee of the University of Essex was obtained prior to commencement of all experiments. All participants gave their written informed consent to take part in this research.

Participants

A volunteer sample of 21 (9 male; 12 female) participants aged between 20 and 45 (*M* = 25.38 years, *SD* = 7.05 years) took part. All of them were students at the University of Essex who participated in exchange for £4. All were right-handed and were naïve to the purposes of the study.

Stimuli and Apparatus

The stimuli were displayed on a 19.5-inch LCD touch-screen monitor built flat into a table, raised 74 cm from the floor. They were presented against a uniform white background (74.6 cd/m^2). The two co-actors sat facing one another such that the distance between their chests and their 'home buttons' was approximately 160 mm (See Fig 3.1). In the foot condition, the confederate sat on a chair raised 58 cm from the floor, whereas participants in all conditions and the confederate in the hand condition were seated at a height of approximately 44 cm. The four stimulus locations were denoted by 4 black squares (19.6 mm^2 each) which acted as 'placeholders', and remained present for the entire trial duration. Two placeholders (1 to the left, 1 to the right), located at a distance of 160 mm from the black fixation cross and protruding 50 mm to the left and to the right of the screen midline were displayed in front of each participant. The distance between the left and the right placeholder was 320 mm. The squares were placed within a light-grey area, covering 200 mm^2 of the screen. On each trial, one of them illuminated by turning white (74.6 cd/m^2). Participants made their responses by releasing the 'home' button and touching the square that had illuminated. A RM Pentium PC custom software was used for the stimulus generation and the recording of the responses.

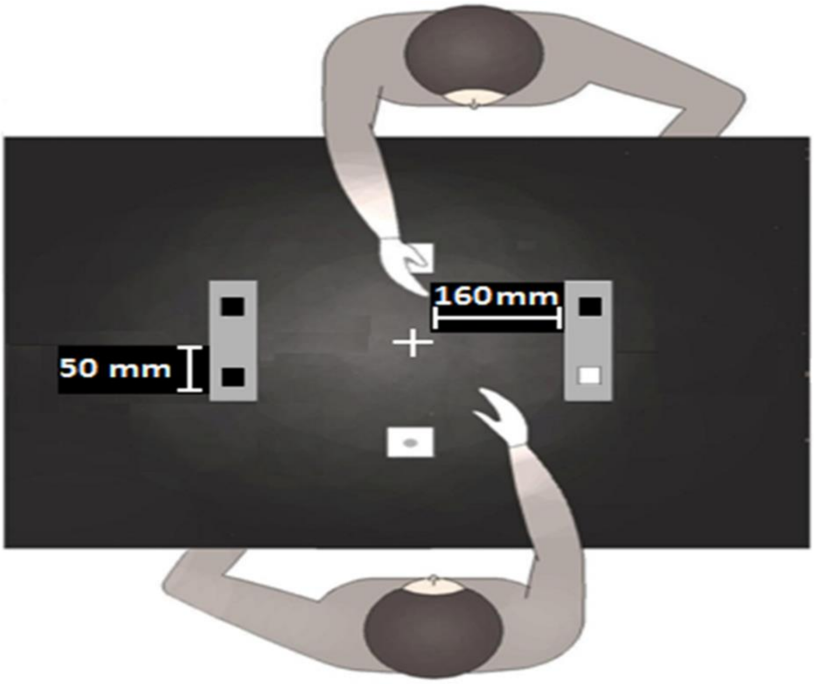

Fig 3.1 An illustration of the standard condition of the social IOR/movement congruency paradigm used in Experiment 4. In the figure shown, one of the co-actors is reaching to their right where the target has illuminated.

Design and Procedure

The experiment employed a 2 (target location: same, different) *x* 2 (effector: hand, foot) fully within-participants design. The dependent variable in all three experiments in this chapter was the time that elapsed between the target presentation and the target (i.e., screen) being touched (RT).

All participants were tested individually and performed the task with the same confederate who was also the author. The confederate always sat in the same position relative to the workspace (See Fig 3.1). She verbally explained the instructions after which she performed a short demonstration of the procedure, consisting of a practice session of 21 trials. The confederate's initial response triggered the target sequence in which co-actors alternated single responses. They were instructed to keep the home buttons pressed until a response was needed whilst at the same time fixating the cross in the centre of the screen. Then participants were required to reach out with their right hand and touch the target location, which illuminated for 100 ms. All trials had an inter-trial interval of 350 ms and a stimulus onset asynchrony (SOA) of approximately 1200 ms. Participants performed two experimental blocks of 209 trials (i.e., 104 per participant plus the first trial which was not analysed since no response preceded it). They always used their right hand to make the responses. However, in one of the blocks the confederate responded with her right hand whereas in the other – with her right foot (the block order was counterbalanced across participants). Regardless of which limb was used by the confederate, both the confederate and participant had a full view of each other and each other's targets and responses (See Fig 3.1). Participants were instructed to respond as quickly and as accurately as possible.

Results and Discussion

RT outliers (more than two SDs above or below the mean) were removed prior to the formal analyses. Mean RTs were computed as a function of target location (same, different) and effector (hand, foot) and entered into a 2 *x* 2 fully-within participants ANOVA (See Fig 3.2). The main effect of effector was significant (*F* (1, 20) = 30.92, p < .001, partial eta sq = .607). Thus, overall, participants were slower when the confederate responded with her foot as compared to the standard hand condition. The main effect of target location was also significant (*F* (1, 20) = 17.75, p < .001, partial eta sq = .470), suggesting that social IOR was observed. Finally, there was no reliable target location *x* effector interaction (*F* (1, 20) = 3.89, *p* > .06, partial eta sq = .163). However, to test whether social IOR was present in both conditions, follow-up comparisons were carried out. These analyses confirmed that participants exhibited the effect in both the hand (*t* (1, 20) = 4.94, p < .001, Bonferroni adjusted alpha = .025) and the foot (*t* (1, 20) = 2.54, p < .02, Bonferroni adjusted alpha = .025) condition. No difference in within-participants' variability in RT across conditions was found (*F*s (1, 20) > 0.57, *p*s > .307). Additionally, significant positive correlations emerged between the participants' and the confederate's responses in all four social IOR-effector combinations (different location, hands: *r* (19) = .53, *p*< .013; same location, hands: *r* (19) = .46, *p*< .035; different location, feet: *r* (19) = .54, *p*< .011; same location, feet: *r* (19) = .61, *p*< .003).

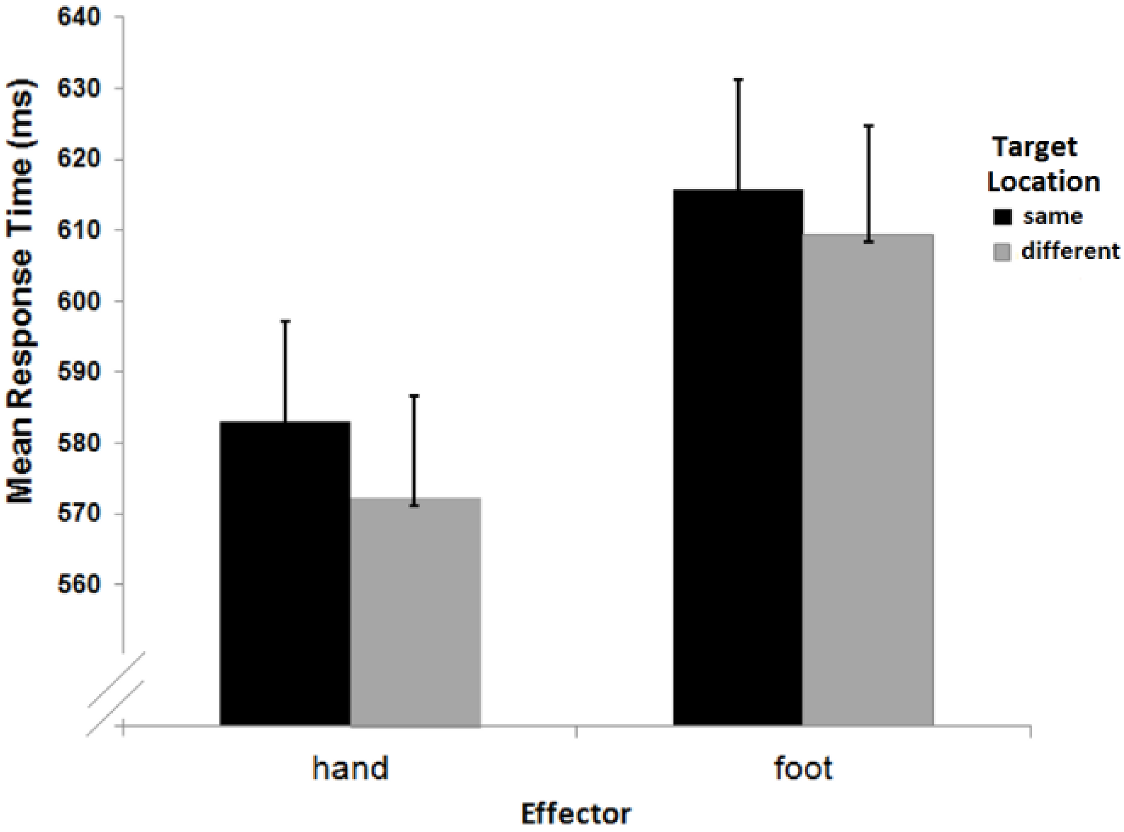

Fig 3.2 Mean RTs to localise targets as a function of effector and social IOR/movement congruency in Experiment 4. Error bars represent standard errors of the mean.

First, the results of Experiment 4 are consistent with the general finding of previous work employing the same movement congruency/social IOR paradigm – participants were slower to repeat the location their confederate-co-actor responded to on a previous trial (e.g., Cole et al., 2012; Ondobaka et al., 2012;

Welsh et al., 2005). However, this effect occurred even when participants used a different effector to that used by their partner. This finding is not in line with the action co-representation account according to which action observation leads to automatic activation of motor representations in the observer (Brass et al., 2001; Buccino et al., 2001; Ondobaka et al., 2012; Sebanz et al., 2003, 2005). This taken together with research showing that the human ventral premotor cortex is somatotopically organised (i.e., different sectors become active during the observation of hand and foot movements, e.g., Buccino et al., 2001) challenges the explanation advocated by Ondobaka et al. (2012, 2013, 2015) that the observed effect is due to movement/action congruency.

Finally, the significant main effect of effector can be accounted for by the fact that the confederate was slower in the foot condition and this affected the participants' overall response tempo. Moreover, the significant relationships between participants' and confederate's responses reveal that participants, at some level, must have been taking into account their task-partner and their actions. In support, observing biological movements carried out by another individual has been reported to bias one's perception of timing (Kaneko & Murakami, 2009; Watanabe, 2008). For example, Kaneko and Murakami (2009) found that the speed of a stimulus was a significant predictor of how participants perceived observed motion so that the apparent duration proportionally increased with the speed logarithm.

3.2 Experiment 5

Experiment 5 further tested whether a direct match between the observed and the performed actions is needed for the present social IOR effect to occur. Recall from the Introduction that Welsh et al.'s account posits that co-actors inhibit actions via the MNS, whilst Ondobaka et al. suggests that the effect is due to congruency of actions. Thus, action co-representation is central to both of these theories. By contrast, Cole et al. (2012) proposes that actions are epiphenomenal: in this context, they merely happen to shift attention.

It follows therefore, that if the actions performed by a co-actor are different to that of the participant, and furthermore, cannot be seen by the participant, then no imitation or action co-representation should occur. Therefore in one block of trials in the present Experiment 5, the participant made a reaching response to a target (i.e., performed the standard task) whilst their confederate-co-actor operated a physical arrow that merely pointed to the target rather than reach to it*.* Moreover, *all actions* in these trials performed by the confederate-co-actor were occluded by a barrier (the 'non-visible' condition). In a second block, both co-actors performed the standard task in which they both reached out to the target.

Critically therefore, in the non-visible condition participant's attention could be shifted to a target location without the co-actor having made a reaching response to it. The action accounts of Welsh et al. and Ondobaka et al. predict that social IOR should be reduced, if not abolished, when actions cannot be seen. The Cole et al.'s account by contrast predicts that the effect should occur because the arrow and/or targets act as an attentional cue.

Method

Participants

A volunteer sample of 24 (6 male; 18 female) participants aged between 18 and 25 took part in the study. They received a course credit for their participation. All were undergraduates at the University of Essex, right-handed and naïve to the purposes of the study.

Stimuli and Apparatus

Stimuli were presented on a 22″ LCD monitor built into a table positioned between the two co-actors and had a Keytec touch-screen placed over it. The participants sat across the table so that they were facing one another and the distance between their chests and their ‘home buttons’ was approximately 240 mm. A black square measuring 10 mm in diameter (0.3 cd/m^2 measured on-screen) was presented in the centre of the display against a uniform white background (67.3 cd/m^2) and acted as a fixation point. Two other squares of the same size and luminance were presented to the left and right of the display area (see Fig 3.3). The target was the rapid onset then offset (i.e., a flash) of one of these squares. Participants made a response by moving their hand from the home button and touching the target square. One co-actor served as the naïve participant whilst the other was a confederate (the author). On half of the trials a barrier was located such that it occluded all hand/arm movements made by the confederate co-actor. A wooden arrow was located at the base of this barrier operated by the co-actor. An RM Pentium PC running custom software controlled the stimulus generation and recording of responses.

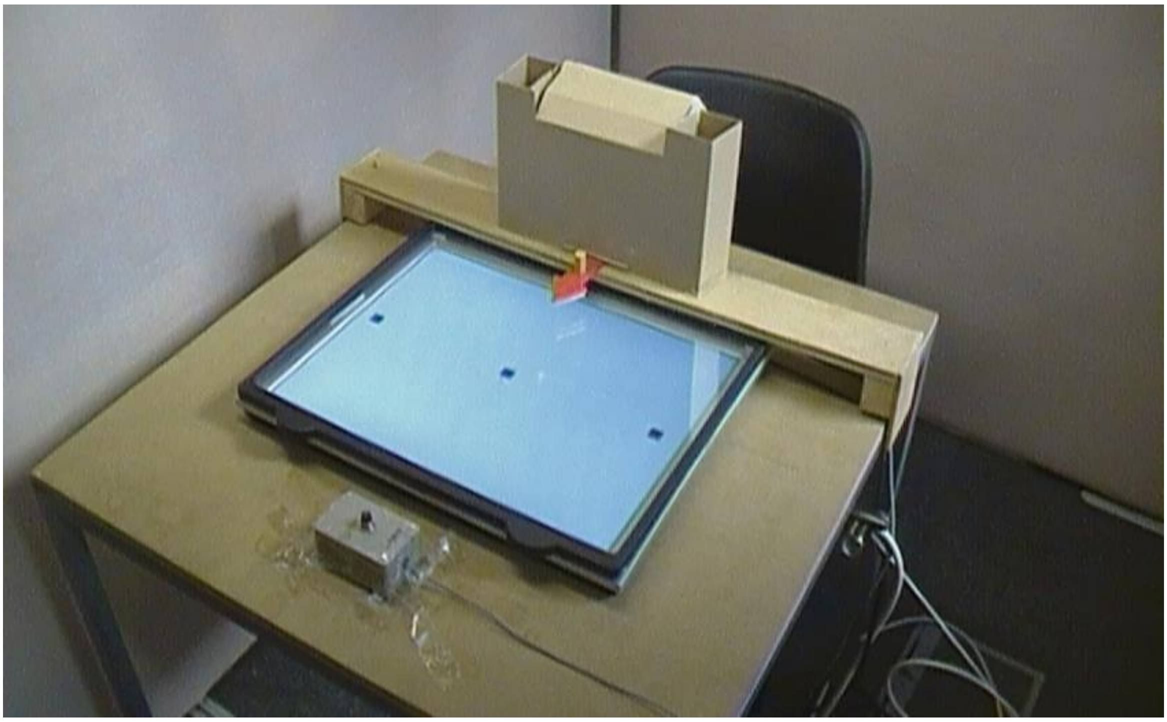

Fig 3.3 The equipment used in Experiment 5. The confederate co-actor operated one end of the wooden arrow. No actions could be seen by the participant.

Design and Procedure

We employed a 2 (target location: same, different) x 2 (visibility: visible, non-visible) fully within-participants design. The visibility factor referred to how visible was the co-actor’s action. Either could participants see the co-actor’s action or it was fully occluded (See Fig 3.3).

As before, participants’ task was to alternate responses with the confederate-co-actor. The confederate always started first, after which it was the participant’s turn. When their target appeared, they simply reached out and touched it and then returned their hand to the ‘home’ button located in front of them. The target flashed for 100 msec. Three hundred and fifty ms elapsed between response completion and the next target occurring. Participants were asked to fixate the centre until they were required to make their response, during which they were instructed to fixate the target. They were also told that they should respond as quickly and as accurately as possible. Furthermore, they were instructed to ignore their partner's responses.

In the 'visible' condition both the confederate-co-actor and the participant performed the same task. This was identical to the 'hand' condition, described in Experiment 4. In the 'non-visible' condition by contrast, the confederate operated a wooden arrow behind a barrier, not allowing any visibility of her actions. Thus, once a target appeared either to the left or the right on the confederate's turn, she moved the arrow to the corresponding end of the apparatus to point at the target location. The confederate then returned the arrow to the mid position immediately after. The arrow also remained fixated on the central point for the entire duration of the trial. A custom program generated a random sequence for the presentation of the targets where no target appeared on the same side more than four times in succession. The target location factor was presented randomly within block whilst the visibility factor was blocked. Two blocks of trials were presented, each comprising 209 trials (104 participant trials together with 105 co-actor trials).

Results and Discussion

Outliers (more than two SDs above or below the mean) were removed from further analysis and accounted for 4.1% of responses. Fig 3.4 illustrates the mean RTs for the four conditions. An ANOVA with target location (same, different) and visibility (visible, non-visible) as within participant factors revealed significant main effects of target location, $F(1, 23) = 86.3$, $p < 0.001$, partial eta sq = .79, and visibility, $F(1, 23) = 17.7$, $p < 0.001$, partial eta sq =.44. The interaction was not, however, significant, $F(1, 23) = 1.57$, $p > .22$. Post-hoc analyses showed that the target location effect (i.e., social IOR) was present in both the visible and non-visible conditions, $t(23) = 7.8$, $p < 0.001$, and $t(23) = 8.0$, $p < 0.001$, respectively.

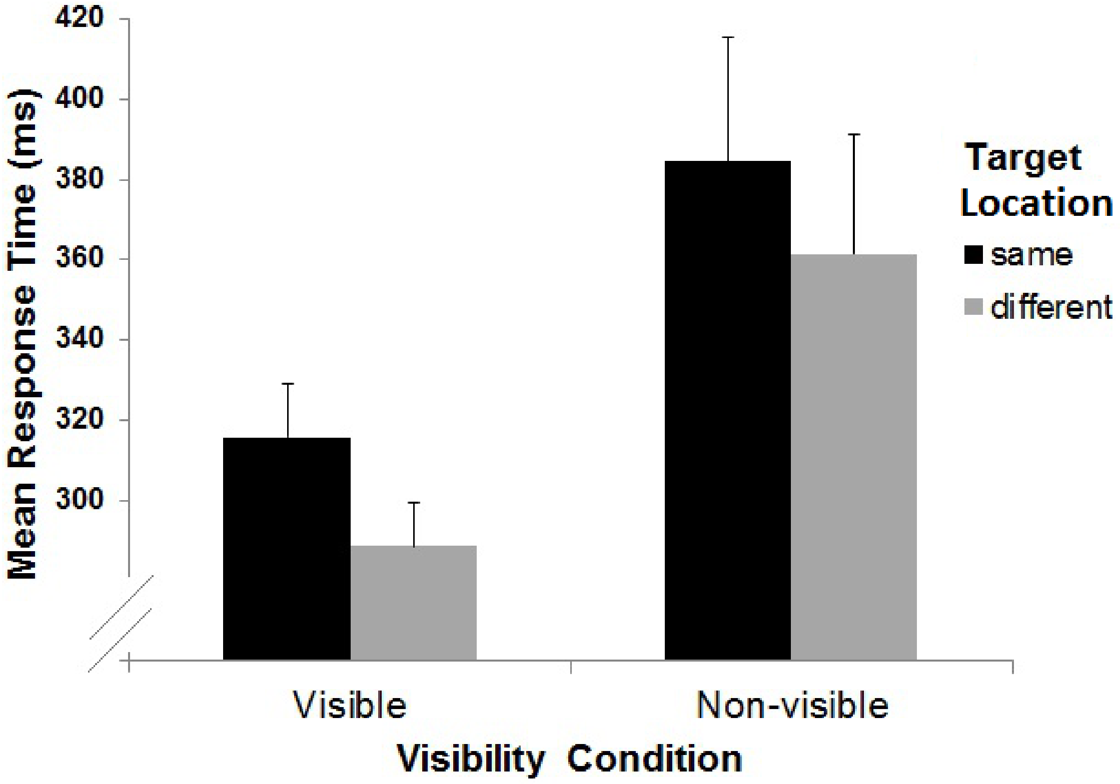

Fig 3.4 Mean RTs for Experiment 5 as a function of visibility condition and target location. Error bars represent standard errors of the mean.

The first notable aspect of the results of Experiment 5 is that participants were slower to initiate a response to the same target location that their co-actor had just reached to (in the visible condition). This replicates the basic social IOR findings of Welsh et al. (2005; 2007) and Skarratt et al. (2010). Important, however, was the observation that the effect also occurred in the non-visible condition in which no co-actor movements could be seen (and were different) but attentional cues were presented. Furthermore, the size of the effect was approximately the same in both visibility conditions. Overall, these data show that observing actions is not necessary for the effect to occur.

These findings together with those of Experiment 4 challenge the notion that the basic phenomenon is due to mechanisms that represent actions. Rather, it seems that as long as attention is shifted to a particular target location, inhibition of return occurs in the observer, thus generating the observed effect.

3.3 Experiment 6

Experiments 4 and 5 suggested that a direct match between the observed and the required-to-perform actions was not needed for the effect to occur. However, these experiments do not completely rule out action co-representation as a subserving mechanism of the effect. For example, although in the foot and the non-visible condition, the observed and the required actions did not match kinematically, participants might have co-represented the partner's action intention, instead (e.g., Wilson & Knoblich, 2005). For instance, to move to the right hand-side as opposed to how exactly the response was performed.

The aim of the present Experiment 6, therefore, was to directly evaluate the contribution of the 'action' factor to the effect. Thus, Experiment 6 also tested which of the three theories outlined in the Introduction accounts best for the basis of social IOR. It should be noted that in the standard social IOR paradigm the effects of target location and movement congruency (action type) are confounded (Atkinson et al., 2014; Cole et al., 2012; Hayes et al., 2010; Ondobaka et al., 2012; Skarratt et al., 2010; Skarratt et al., 2012; Welsh et al., 2005, 2007, 2009b, etc.). This is because target location and action type can never coincide when co-actors sit opposite. For example, when co-actors both move to the same target location, this always indicates that one of them has executed a leftward movement, whereas the other – a rightward one (See Fig 3.1). Thus, it follows that results are consistent with both Cole et al.'s and Welsh et al.'s IOR accounts and Ondobaka et al.'s action co-representation account.

In the author’s view, the only way to effectively isolate the effects of target location and movement/action type is to modify the paradigm so that participants sit offset, instead of opposite each other (See Fig 3.5). This would create two critical conditions that cannot be examined in the standard paradigm – testing the social IOR effect when the two co-actors either perform same or different actions. It should be noted that the present paradigm is unique in terms of distinguishing between these two effects. Even in the single previous research aiming to study these in isolation, co-actors sat next to each other, implying that opposite actions were executed towards the shared target in the middle, as well as to the two outer targets (Welsh et al., 2009; compare the two conditions, represented in Fig 3.5 with a scenario where co-actors sit next to each other, sharing the middle target).

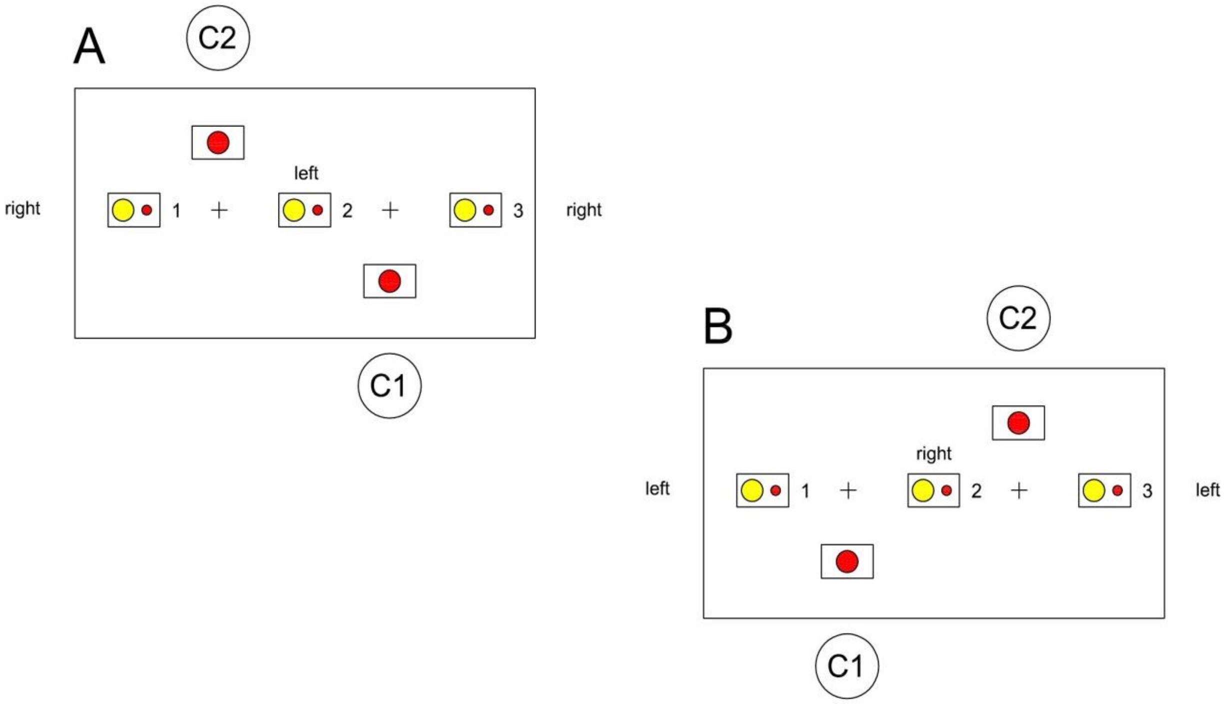

Fig 3.5 An illustration of the social IOR paradigm used in Experiment 6. Block 1 (A), Block 2 (B). Block 3 has not been illustrated as it involved participants sitting opposite each other as in the standard procedure. C1 refers to Co-Actor 1, while C2 - to Co-Actor 2.

Fig 3.6 illustrates what is predicted by each of the three competing theories of the effect. According to Welsh's *action-location* account there should be a significant main social IOR effect, as well as a significant main effect of action type with longer RTs in the movement congruent condition (Panel A). Welsh et al. (2009a) reported the latter in a very similar modification of the social IOR paradigm, where, however, participants sat side by side. Second, Cole et al.'s *attentional shift* hypothesis predicts a significant social IOR effect but no effect of action type (thus the two lines, representing action type should coincide; Panel B). Finally, Ondobaka et al.'s *movement congruency* account predicts no significant main effect of social IOR but only a significant movement congruency effect (Panel C).

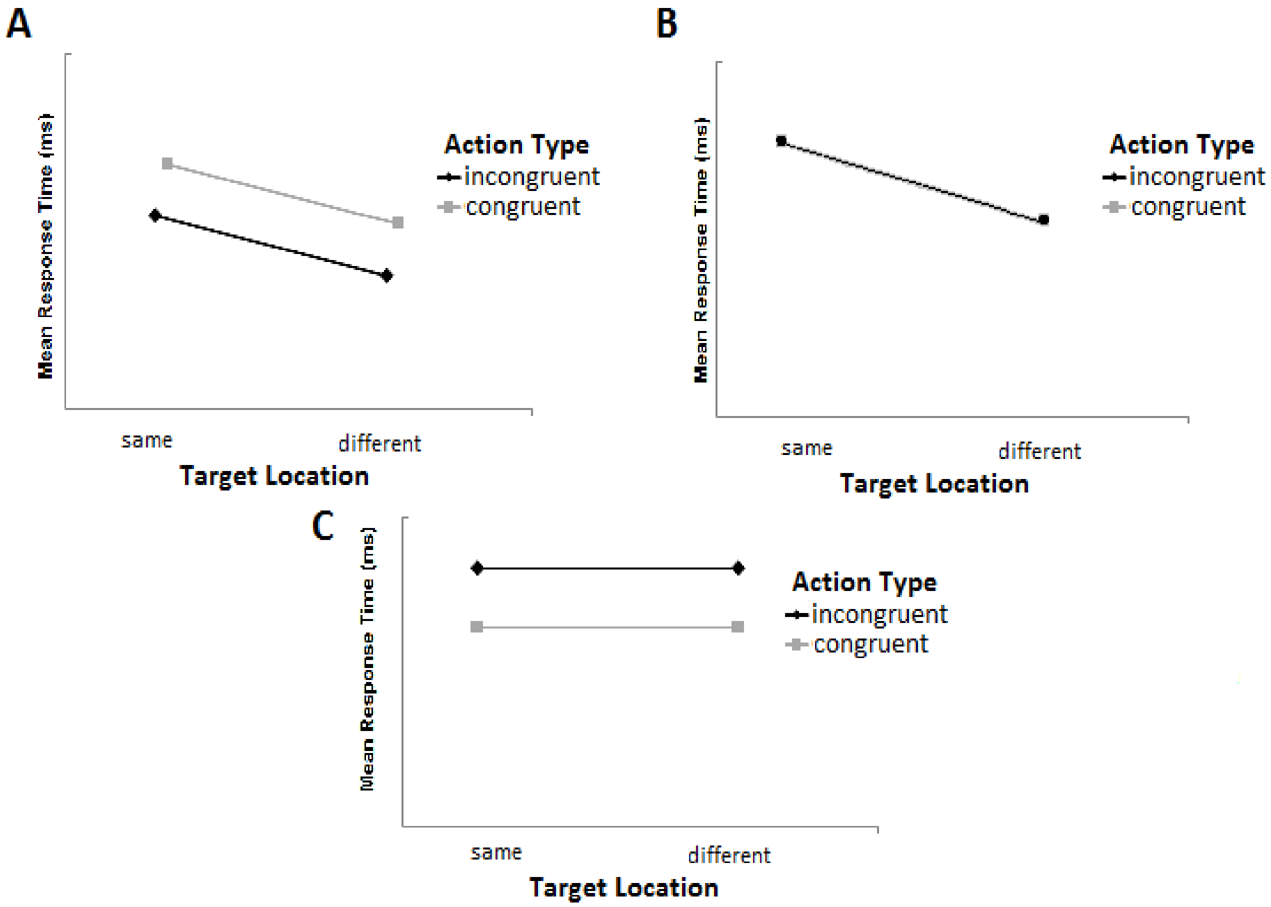

Fig 3.6 The predictions of the three accounts of social IOR. (A) Welsh et al., (2007, 2009); (B) Cole et al. (2012) and (C) Ondobaka et al. (2012).

Method

Participants

A volunteer sample of 24 (9 male; 15 female) participants aged between 18 and 28 (*M* = 20.25 years, *SD* = 2.40 years) took part in the study. All participants were undergraduates at the University of Essex, were right-handed and naïve to the purposes of the study. They either received a course credit or £4 for their participation.

Stimuli and Apparatus

The stimuli consisted of three plastic boxes, positioned centrally in a row at a distance of 500 mm between them (See Fig 3.5). Two white 20 mm x 20 mm fixation crosses (one for each participant) were located in between the boxes. Each box contained a response button and a light-emitting diode (LED). These served as a target and response button for each participant. Moreover, additional 2 boxes, equipped with a response button only, were placed at a distance of approximately 240 mm from the participants' chests (Fig 3.5). These served as 'home buttons' for the two co-actors. The distance between the centre of the home position and each of the two target boxes was 320 mm. All boxes (100mmx100mmx10mm) were placed on the wooden top of a table with dimensions (1400mm (L) x 70mm (W) x 65mm (H)). PsycoPy software (Peirce, 2009; version 1.80.04) was used for the stimulus generation and the recording of the responses.

Design

The experiment had a 2 (target location: same, different) *x* 2 (action type: same, different) fully within-participants design. Table 1 presents all the possible conditions, generated by the three experimental blocks. 'Same target location' referred to a condition where both co-actors moved to the same physical box on two consecutive trials. In contrast, 'same action type' referred to a condition where both co-actors executed the same movement (i.e., both making a leftward movement) on two consecutive trials within an egocentric framework.

Moreover, recall that one of the accounts (Cole et al.'s) advocated that social IOR is similar to classic IOR. There is also evidence that inhibition in classic IOR can spread to hemifield side, instead of being tight to the exact physical location (e.g., Tassinari, Aglioti, Chelazzi, Marzi & Berlucchi, 1987; Tassinari, Aglioti, Chelazzi, Peru & Berlucchi, 1994; Berlucchi, Tassinari, Marzi & Di Stefano, 1989). Thus, to test whether social IOR could also spread within the cued hemifield or it is strictly location-based, a condition was created (different action/different location condition) where on half of the trials the cue[11] and target[12] appeared in the same hemifield and on the other half – in different hemifields (See Table 1 and Fig 3.5). Still in all other conditions (same action/same location; same action/different location; different action/same location), location and hemifield coincided. Thus, when location was 'same' the cue and target emerged in the same location and hemifield but when location was 'different', cue and target occurred in different locations and different hemifields (See Fig 3.5 and Table 1).

Procedure

Two participants sat offset, so that there were two target locations and a home position in front of each participant. In Block 1 the pair was seated in such a way that the shared location in the middle was on their left and in Block 2 it was on their right (See Fig 3.5). In Block 3 participants sat opposite as in the basic social IOR paradigm (See Fig 3.1).The experimenter verbally explained the instructions after which she demonstrated the procedure.

One participant's initial response triggered the target sequence in which each participant pair alternated single responses. Participants were instructed to keep the home buttons pressed until a response was needed while at the same time fixating at the cross opposite them. Then depending on whose turn it was, one of the two LEDs in front of them illuminated for 100 ms after which they were required to make a response by reaching out and pressing the response button next to the LED that flashed. Once they had completed their turn, participants returned their

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[11] In line with Cole et al. 'the cue' in the present paradigm refers to the response of the other participant that the co-actor passively observed on a previous trial.

[12] In line with Cole et al., 'the target' in the present paradigm refers to the participant's flashing LED when it is their turn to act.

hand on the home button. The SOA was approximately 1300 ms with an inter-trial interval (ITI) of 350 ms. Each block consisted of 209 trials, 104 per participant. This generated a total of 627 trials. The first trial of each block was not included in the analysis since no response preceded it. Participants undertook one practice session consisting of 21 trials which was identical to the experimental condition they were about to complete. All participants had a full view of the other co-actor and their responses.

Table 1 All experimental conditions in Blocks 1, 2 & 3 of Experiment 6. The trial conditions where the cue and target appeared in the same hemifield side have been printed in bold.

	Block 1		Block 2		Block 3	
	Target location		**Target location**		**Target location**	
Action Type	Same	Different	Same	Different	Same	Different
Same	**C1[a](left),C2[b](left)** **C2(left),C1(left)**	C1(right),C2(right) C2(right),C1(right)	**C1(right),C2(right)** **C2(right),C1(right)**	C1(left),C2(left) C2(left),C1(left)	___	C1(right),C2(right) C1(left),C2(left) C2(left),C1(left) C2(right),C1(right)
Different	___	C1(left),C2(right) **C1(right),C2(left)** C2(left),C1(right) **C2(right),C1(left)**	___	**C1(left),C2(right)** C1(right),C2(left) **C2(left),C1(right)** C2(right),C1(left)	**C1(left),C2(right)** **C1(right),C2(left)** **C2(left),C1(right)** **C2(right),C1(left)**	___

The conditions where cue and target appear on the same hemifield within an egocentric perspective have been printed in bold.
(a) Co-actor 1
(b) Co-actor 2

Results and Discussion

Outliers (more than two SDs above or below the mean) were removed from further analysis. Since Block 1 and Block 2 generated identical conditions, the data from the following conditions (same action/same location; same action/different location; different action/different location) represented the average of these two blocks. Furthermore, the data from the different action/same location condition was taken from Block 3 since this condition was only present in this experimental block (See Table 1).

Mean RTs were computed as a function of target location (same, different) and action type (same, different) and were entered into a 2 *x* 2 fully-within participants ANOVA (See Fig 3.7). The main effect of target location was significant (F (1, 23) = 29.36, *p* < .001, partial eta sq = .561), confirming the presence of a social IOR effect. However, there was no significant main effect of action type (p > .62). Importantly, the target location *x* action type interaction was significant (F (1, 23) = 15.04, p > .001, partial eta sq = .395). Planned comparisons indicated that social IOR occurred only when co-actors executed the same actions (t (23) = 8.57, p < .001, Bonferroni adjusted alpha = .025). Although, the social IOR effect was not statistically significant when they made different actions (*p* > .46), descriptive statistics indicated that RTs were still longer when co-actors moved to the same location (*M* = 968.55; *SD* = 84.61) as compared to the different one (*M* = 959.93; *SD* = 64.88). Pearson’s correlation tests confirmed that RTs between the three experimental blocks were comparable (all *ps* < .001). Of a particular importance was the comparison between the same action/same location condition and the different action/same location condition since in both participants responded to the same physical location but these were also generated by different set-ups of the paradigm. The analysis revealed that RTs in these two conditions were highly correlated (*r* (23) = .73, *p*< .001).

Importantly, to test whether the observed interaction was the result of social IOR spreading to hemifields, instead of being tight to the physical locations, an additional analysis was performed. The RTs of every participant in the different action/different location condition were separated as a function of hemifield (same, different). Thus, for example, when in Block 1, C1 went to the *right* and C2 – to the *left*, both responses occurred in C2's left hemifield (same hemifield). However, in contrast, if in Block 1, C1 went to the *left* and C2 – to their *right*, then as it could be seen from Fig 3.5, the cue occurred in C2's left hemifield, however, C2 responded to a target in their right hemifield (different hemifields). Thus, this data from Blocks 1 and 2 was collapsed together and submitted into a paired samples t test. The analysis yielded a highly significant effect of hemifield (t (23) = 4.00, p < .001, Cohen's d =. 42, (95% confidence interval of the difference: lower = 14.4, upper = 45.3), indicating that in the different action/different location condition co-actors made significantly slower responses when cue and target appeared on the same hemifield side (M = 981.01; SD = 71.96) as compared to the different one (M = 951.15; SD = 70.27).

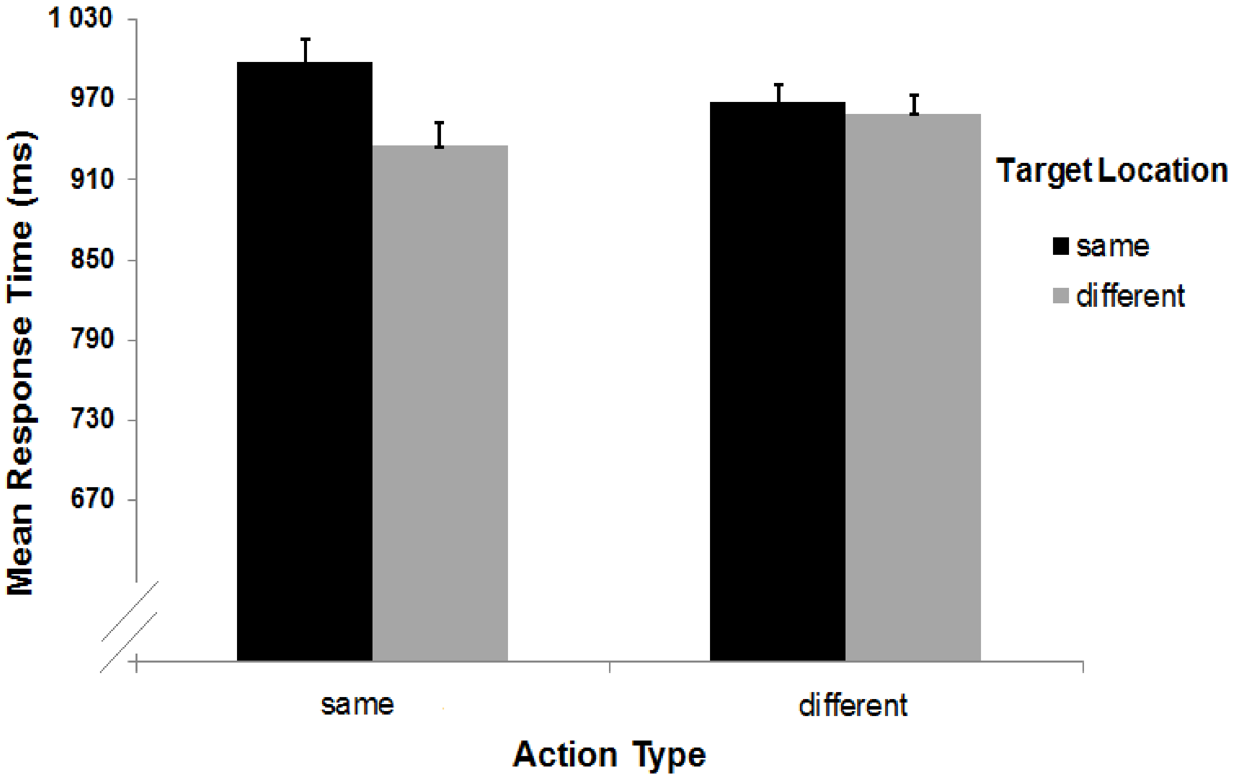

Fig 3.7 Mean RTs as a function of target location and action type in Experiment 6. Error bars represent standard errors of the mean.

Experiment 6 examined the contribution of action co-representation to the effect and which of the three accounts stated in the Introduction provided the most plausible explanation of the phenomenon. This was done by disentangling the effects of target location and action congruency on the effect. On first glance, the present findings did not go in the exact direction, predicted by any of the three accounts (compare Fig 3.6 and Fig 3.7). However, a second look at the data suggests that these are mostly consistent with Cole et al.'s attentional shift hypothesis according to which social IOR is an attentional effect, similar to classic IOR. The general finding of Experiment 6 was that a significant social IOR effect emerged in the paradigm but no significant main effect of action congruency was present. This fits well with the predications of both the action-location account (Welsh et al.) and the attentional shift hypothesis (Cole et al.) and goes against

Ondobaka et al. who argues that the effect relies on action congruency. Still, the finding that social IOR occurred only in the ‘same action’ condition but not when co-actors executed different actions, suggested that action congruency might modulate the magnitude of the present effect. However, the additional analysis examining the effect of hemifield side challenges the latter by suggesting that the observed interaction was likely to be driven by hemifield side being mixed in the different action/different location condition. The found effect of hemifield suggested that participants in social IOR might be in fact inhibiting the whole hemifield in which a cue appeared, instead of the exact physical location, which fits best with Cole et al.’s theory. Furthermore, even if one ignores this latter analysis, the present results are still not in line with Welsh et al.’s account that social IOR is due to the formation of observation-evoked response codes as the suspected modulation of the effect as a consequence of action type did not go in the direction, reported by Welsh et al. (2009a).

All in all, taking into account the findings of Experiments 4 and 5, the present results seem to challenge the notion that social IOR is based on action congruency and are mostly consistent with Cole et al.’s attentional shift hypothesis.

3.4 General Discussion

As outlined in detail in the General Introduction, the general findings of the social IOR paradigm fit three alternative explanations. Recall that the slower responses to the ‘same’ location, characteristic of the effect could either stem from movement congruency effects (Ondobaka et al.), from an IOR-like inhibition (Cole et al.) or from a mixture of the two (Welsh et al.). Following the findings of Chapter 2 which demonstrated that social IOR and classic IOR share a number of similarities, the present Chapter 3 aimed to test the contribution of action co-representation to the social IOR effect. Thus, Chapter 3 not only assessed which of the three theories provides the most accurate explanation of the effect but also, it indirectly evaluated which of the two terms (i.e., a movement congruency effect or social IOR) most appropriately describes the observed phenomenon and as a consequence should be used in the following chapters. First, Experiment 4 demonstrated that the effect occurred even when the observed and the required-to-perform actions were executed with different effectors. Further, Experiment 5 showed that RTs to the same location were still longer (i.e., social IOR occurred) even when the co-actor's actual action was fully occluded from view and was different from the one that the participant had to execute. Importantly, however, social IOR was observed when a participant's attention was directed to the target location via an attentional cue. Finally, the notion that the type of action that co-actors execute in the paradigm does not play any role in the effect, was supported by Experiment 6 where after disentangling the effects of action type and location type, only a significant social IOR effect was observed but no movement congruency effect emerged.

Overall these findings do not support an account of the phenomenon based on action co-representation and thus they do not fit with the two theories advocating that social IOR is either solely (e.g., Ondobaka et al.) or partially based on the formation of observation-evoked response codes (e.g., Welsh et al.). Indeed, there is evidence that action observation automatically generates an internal replica of that action in the observer's motor system and that the movement of different effectors, such as hands and feet activate different regions of the human ventral premotor cortex (e.g., Binkofski & Buccino, 2006; Buccino et al., 2001). Moreover, a movement congruency effect is believed to occur because of automatic mapping of what has been observed to the individual's own movement representations in their MNS (e.g., Fadiga et al., 1995). Therefore, action co-representation should have been prevented when the observed and the required actions differed kinematically (Experiment 4) or when no action was observed (Experiment 5), so that no representation of a motoric movement could have been formed and integrated into the observer's motor system. Moreover, the findings of Experiments 4 and 5 are in line with previous work on the SSE suggesting that the effect might not be based on action co-representation. For example, Dolk et al. (2011) found that 'emphasizing the difference between the two actions – or the related effectors – leads to a more pronounced SSE' (p. 4), as opposed to when the integration of these two is facilitated (which should result in a bigger SSE if the effect indeed depends on co-representation of actions). Furthermore, the findings of the present Experiment 6 demonstrated even more categorically that social IOR might not rely on the co-representation (or imitation) of action. Thus, when the contribution of target location and action type were examined separately, action congruency was not found to have any effect on participants' general RTs. In addition, the identified interaction between social IOR and movement congruency was not expected by either Welsh et al.'s or Ondobaka et al.'s accounts and therefore is unsupported by previous work. For instance, based on Welsh et al. (2009a), the action-location hypothesis predicts that co-actors should have in fact been *slower to repeat* the same action (e.g., 'participants took longer to initiate a movement when that movement was in the same direction as the recently observed response than when the recently observed response was in a different direction'; Welsh et al., 2009, p.67). Moreover, the observed interaction was not predicted by the movement congruency account either, as according to it co-actors should have only been *quicker* to imitate an action, identical to the one observed ('participants were faster in the movement-congruent trials than in the movement-incongruent trials';

Ondobaka et al., 2012, p.33). Thus, it seems more plausible that the observed interaction was driven by the hemifield side of the cue and target being mixed in the different action/different location condition (See Table 1 and Experiment 6).

Rather, the present findings suggest that the effect is due to IOR induced by an attentional shift. Specifically, when a co-actor reaches to a particular area on the screen, this shifts an observer's attention there (Cole et al.'s attentional shift hypothesis). Attention is then shifted away from this 'cued' position to where the co-actor returns their hand. Visuomotor inhibition (i.e., IOR) is subsequently generated in the observer for the processing of stimuli that appear at the target location. In effect, an observed response acts in the same manner as any other visual cue that shifts attention and elicits IOR. Thus, according to Cole et al. the role of action is no different than any other sufficiently salient event in the paradigm as it only serves to shift the observer's attention. Moreover, the findings of Experiment 6 suggested that the triggered visuomotor inhibition might even spread to the inhibited hemifield, instead of being tagged to the particular target location. This interpretation is in line with the literature on classic IOR demonstrating that the effect could transfer to different locations within the inhibited hemifield (e.g., Tassinari et al., 1987, 1994; Berlucchi et al., 1989; however, see Abrams & Pratt, 1996; Tipper, Weaver & Watson, 1996; Wright & Richard, 1996). The latter proposition, however, needs to be further researched. Additionally, the present findings are supported by other published work. For example, Skarratt et al. (2010) suggested that even very limited information about where the other co-actor was going to respond, was sufficient to generate the effect. More recently, Atkinson et al. (2014) found that the observation of the partner's reaching was not necessary to produce social IOR and the effect occurred even when participants observed their co-actor merely pointing to the target location (i.e., no reaching was performed). Thus, these suggest that social IOR is more similar to an attentional effect and more specifically, to classic IOR.

The present work has theoretical implications as it also raises the possibility that previous work has underestimated the role that attentional orienting plays in joint action phenomena. This issue has thus far received little consideration. Indeed, it is common for action observation and joint action studies to make no reference to attentional orienting, or ‘attention’ at all, (e.g., Atmaca et al., 2008; Braun, Ortega, & Wolpert, 2011; Paulus & Moore, 2007; Vesper, van der Wel, Knoblich, & Sebanz, 2011), including articles that review the field (e.g., Galantucci & Sebanz, 2009). One exception was reported by Dolk et al. (2013). They showed that the SSE could occur even in the absence of a partner as long as a sufficiently salient event shifts attention to where the partner would normally respond. Although this shift is believed to initiate a different process to the one proposed for the present paradigm, i.e., a spatial coding of event features as opposed to IOR, attentional orienting is also central to Dolk et al.’s explanation. Indeed, Dolk, Hommel, Colzato, Schütz-Bosbach, Prinz and Liepelt (2014) have gone on to suggest that ‘neither the integration of another person nor the integration of another person’s action into one’s own action, task, or body representation is necessary for the [Joint Simon Effect] to occur’ (p.5). This is however, not to say that models advocating shared action representations exclude attentional processes initiated by an action performed by another individual. Nor do attentional models rule out the possibility that attentional attraction leads to co-representation. For instance, attention, along with perception and intention, is very much part of the TEC (Hommel et al., 2001). The issue however is whether action co-representation is required at all for some joint action effects. It does appear that it is not necessary for two such effects to occur, i.e., the SSE and social IOR. Still, it should be noted that the latter does not by any means suggest that attention plays a role in, and/or explains all action observation effects.

In sum, in a series of experiments Chapter 3 tested the contribution of action co-representation to the present effect. The results of Experiments 4 and 5 suggested that social IOR is a robust phenomenon, not influenced by the extent to which the observed and the required actions matched. Thus, the magnitude of the effect stayed unchanged regardless of the type of response effectors used; whether the partner’s action was visible or whether it was identical to the one that had to be executed. Finally, Experiment 6 further supported the notion that action co-representation does not seem to induce the present effect. These findings are best placed within Cole et al.’s attentional shift hypothesis according to which, similarly to IOR, social IOR occurs as a consequence of the co-actors’ attention being shifted by a sufficiently salient event in the paradigm. Still, to further assess the robustness of the present effect and to more confidently rule out the action co-representation account as an explanation of the phenomenon, one should also test the socialness of the effect as the extent to which co-actors integrate the other’s perspective in other joint-action effects has been known to vary depending on social factors. Thus, the following Chapter 4 explored how the presence or absence of a biological co-actor influenced the magnitude of the social IOR effect.

CHAPTER 4

4.0 HOW SOCIAL IS SOCIAL IOR?

As outlined in detail in Section 1.2 of the General Introduction, joint-action work has indicated that performing a task with another biological co-actor uniquely influences one’s performance on the task (e.g., Atmaca et al., 2008; Atmaca, Sebanz, & Knoblich, 2011; Liepelt, Stenzel & Lappe, 2012; Sebanz et al., 2003, 2006; Sebanz, Knoblich & Prinz, 2005, etc.) and that only human movement kinematics are discrete enough to be mapped onto the observer’s motor system (e.g., Kilner et al., 2003; Tsai & Brass, 2007; Tsai et al., 2008; Wilson & Knoblich, 2005).

Furthermore, according to many action co-representation proponents (e.g., Atmaca et al., 2011; Tsai et al., 2008; Richardson et al., 2012), even simply *believing* that another individual is also participating in the task, is sufficient to induce task co-representation (i.e., participants are likely to represent and integrate the other’s action plans even though there is no visible co-actor present). For instance, in one such study a single co-actor participated in a SSE paradigm while they either believed that they were performing the task with the computer or with another biological co-actor, placed in a different room (Tsai et al., 2008). However, in both cases, the partner’s responses were randomly generated by the computer program. Still, both neuropsychological and behavioural data revealed that when participants believed that a biological co-actor was operating the responses, this modulated their action planning, resulting in a significant SSE. Moreover, Tsai et al. (2008) concluded that ‘the co-representation of human action may be an evolved biologically tuned default of the human motor system’ (p. 2015) and that ‘the lack of compatibility with inanimate co-actors may result in failure to submit their motor behavior to mapping from our experiential motor repertoire, as reflected in brain activity’ (p. 2023). Thus, according to the action co-representation account, joint-action effects are inherently social. As a consequence, these should not occur if no biological movement is present nor has the observed action been perceived as stemming from the intentionality of another’s actions (Kilner et al., 2003; Tsai & Brass, 2007; Tsai et al., 2008; Wilson & Knoblich, 2005). Finally, the extent to which co-actors integrate and represent each other’s actions seems to be sensitive to social factors, such as the co-actors’ affect and type of affiliation during the interaction (e.g., Kuhbandner et al., 2010; Hommel et al., 2009).

At the same time recent findings into the *socialness* of joint-action effects have emerged to suggest that the SSE might in fact not be as ‘social’ in nature as predicted by the action co-representation account. Indeed, it is difficult to reconcile how the effect emerges even when no online visual or auditory feedback about the partner has been made available (e.g., Vlainic et al., 2010). Furthermore, Dolk and colleagues showed that no partner was required for a SSE-like effect to occur (i.e., Dolk et al., 2011, 2013). In a modified version of the task, involving the rubber hand illusion (Botvinick & Cohen, 1998), Dolk et al. (2011) demonstrated that the SSE increased when there was a greater difference between the actions of the two co-actors. However, the opposite would be expected if automatic action co-representation was driving the phenomenon, as suggested by Sebanz et al. (2003, 2005). In addition, the SSE was found even when the partner was not actively involved in the task and most importantly – when there was no partner at all, only the stroking device, used for the rubber hand illusion, was in operation. In a follow-up paper, Dolk and collaborators (2013) again demonstrated that the presence of a social co-actor might not in fact be necessary for the effect to occur. In a series of experiments, a SSE was still observed when different attention-capturing events replaced the co-actor. For instance, in one experiment participants performed the task alongside objects which possessed no biological features, such as a clock or a metronome. Dolk et al. (2011, 2013) explained the results with a more bottom-up approach, known as the referential coding account (Hommel, 1993). According to it, as stimuli are spatially coded in reference to other events that are either voluntarily attended to or salient enough to attract attention, the alternative response location in the SSE condition is likely to have been coded in reference to the person, *but also* any salient object or event that occurs there.

This line of research leaves open the possibility that other joint-action effects might also be less social than previously thought. As explained in detail in the previous chapters, the present social IOR task is identical to the joint-action paradigm, employed by Ondobaka et al. (2012) who explains the effect with movement congruency. Although the findings of Chapters 1 and 2 have already suggested that the effect of interest is more likely to stem from bottom-up processes, rather than motor facilitation/interference, as submitted by Ondobaka et al. (2012), examining its socialness will provide further support for one of the accounts. Thus, if the observed effect does not stem from action co-representation, it is possible that it still occurs irrespective of whether a co-actor performs the task with a biological partner or simply another salient event shifts the co-actor's focus. This is in fact the prediction of the attentional shift hypothesis (Cole et al.) which is one of the accounts aiming to explain the phenomenon. As outlined in detail in Chapter 3, according to this account, social IOR is subserved by a perceptuo-attentional inhibition to return one's attentional focus and/or respond to an area in the visual scene to which another individual has previously responded to. However, as Cole et al. have proposed that the effect is similar to IOR, social IOR is still expected to occur even if another event (as long as it is salient enough) replaces the biological co-actor. Indeed, a previous study that has examined the latter in an identical paradigm found a significant effect when participants alternated responses with an animated co-actor, although Skarratt et al. (2010) gave a different interpretation of the found effect[13].

The aim of Chapter 4 was to investigate the socialness of the present effect by assessing how the partner's presence and behaviour impact its magnitude. For this purpose, the standard social IOR/movement-congruency paradigm, commonly employed in research was used (e.g., Atkinson et al., 2014; Cole et al., 2012; Hayes et al., 2010; Ondobaka et al., 2012; Reid et al., 2013; Skarratt et al., 2010; Welsh et al., 2005, 2007, 2009b). As explained previously, in the basic procedure, two participants sit opposite each other across a table (that incorporates a flat touch screen monitor) and take turns to reach out and touch one of two targets that appear on either the left or right hand side of the workspace (as shown on Fig 4.1). As mentioned in the General Introduction (Section 1.2.4) and Chapters 1 and 2, typically RTs are longer when participants have to *repeat the location* that their partner went to on a previous trial as compared to responding to a novel location. These findings, however, also concur with the movement-congruency explanation, according to which RTs are actually *longer* when a participant's target position requires them to make *the same reaching action* as the one their co-actor just performed. Thus, for instance, if Participant A reaches to their right, Participant B will be slower to reach to their own left (See Chapter 3 for more detail on the three competing accounts of the effect). Importantly, for the purposes of clarity, the observed effect was referred to as *a social IOR effect* throughout the chapter. A total of three experiments evaluated the importance of a biological co-actor to the effect. First, in two variants, Experiment 7 tested whether the valence of the relationship between the two co-actors modulated the magnitude of the social IOR

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[13] As participants had a full view of the animated co-actor, Skarratt et al. (2010) interpreted the findings as indicative of *classic IOR only* (that latter interpretation has been discussed in detail in the General Discussion section).

effect. Finally, Experiments 8 and 9 tested its socialness by examining whether the presence of another person was even necessary to induce it.

4.1 Experiment 7

Experiment 7 examined whether the effect is modulated by higher level mechanisms that represent relations between co-actors. As discussed in the Introduction, SSE research has suggested that higher-order factors such as the personal relationship between the two co-actors have been found to affect the extent to which each represents the other's task rules. For instance, Hommel et al. (2009) found that a SSE was present only when there was a positive relationship between the two partners and disappeared when participants were partnered with a negative confederate. Furthermore, a similar study indicated that the SSE was also influenced by one's mood (Kuhbandner et al., 2010) such that it was present when a positive mood had been induced in participants but disappeared if the task followed negative affect induction. Indeed, early social psychology research has indicated that individuals are less likely to integrate the perspective and ideas of a person they dislike (Heider, 1958) and that liking another person decreases the self-other distinction (Aron et al., 1991). Experiment 7 aimed to test whether the present effect is also sensitive to social factors. First, in Experiment 7a, social IOR was compared between participants who either completed the task with their romantic partner or with a stranger. Second, based on Hommel et al. (2009), participants in Experiment 7b alternated responses with a co-actor who either acted in a positive or a negative manner towards them.

Experiment 7a

In Experiment 7a half of the participants performed the task with their romantic partner whilst the other half did so with a stranger.

Method

Ethics Statement

Ethical approval from the ethics committee of the University of Essex was obtained prior to commencement of all experiments. All participants gave their written informed consent to take part in this research.

Participants

A volunteer sample of 24 (12 male; 12 female) participants aged between 18 and 32 (*M* = 21.46 years, *SD* = 2.87 years) took part in the study. All participants were undergraduates at the University of Essex who participated in exchange for £3.

Stimuli and Apparatus

The stimuli in Experiment 7a and 7b were identical. These were displayed on a 19.5-inch LCD touch-screen monitor built flat into a table, raised 74 cm from the floor. They were presented against a uniform white background (74.6 cd/m^2). The two participants sat facing one another such that the distance between their chests and their 'home buttons' was approximately 160 mm (See Fig 4.1). The four stimulus locations were denoted by 4 black squares (19.6 mm^2 each) which acted as placeholders, and remained present for the entire trial duration. Two placeholders (1 to the left, 1 to the right), located at a distance of 160 mm from the black fixation cross and protruding 50 mm to the left and to the right of the screen midline were displayed in front of each participant. The distance between the left and the right placeholder was 320 mm. The squares were placed within a light-grey area, covering 200 mm^2 of the screen. On each trial, one of them illuminated by turning white (74.6 cd/m^2). Participants made their responses by releasing the 'home' button and touching the square that had illuminated. A RM

Pentium PC custom software was used for the stimulus generation and the recording of the responses.

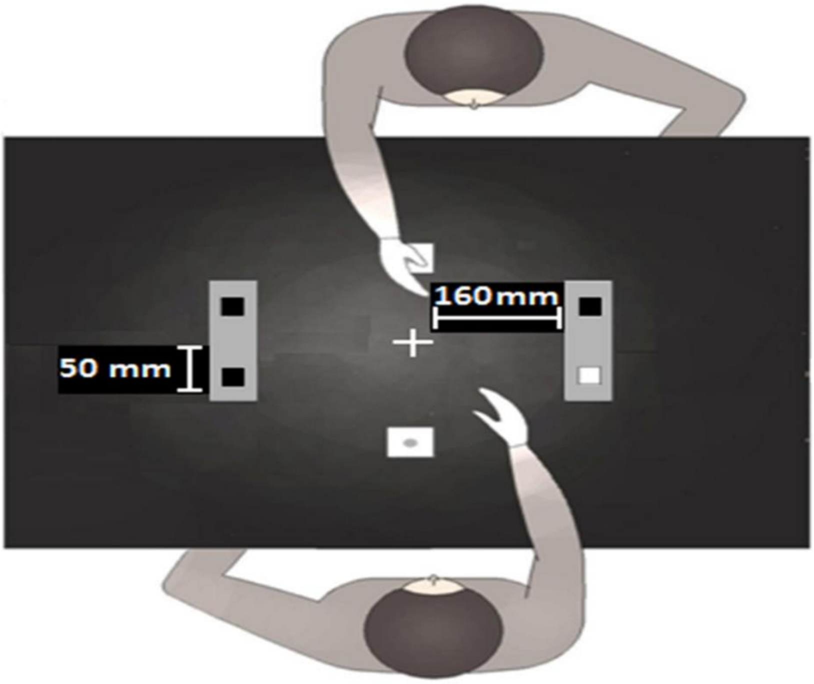

Fig 4.1 An illustration of the standard condition in the social IOR/movement congruency paradigm used in Experiments 7, 8 and 9. Each person takes turns to reach out and touch one of two targets presented on the left or right. In the figure shown, one person is reaching to their right where the target has illuminated.

Design

The experiment had a 2 (target location: same, different) *x* 2 (partner: romantic partner, stranger) mixed participants design. The dependent variable in all experiments was the time that elapsed between target presentation and the screen touch (response time, RT).

Procedure

The standard social IOR/movement congruency procedure, described previously was followed. As explained earlier in this experiment, half of the participants carried out the task with their romantic partner, while the other half performed with a stranger as in the standard procedure. All participant pairs were tested individually in a quiet cubicle with no external windows.

One participant's initial response triggered the target sequence in which each participant pair alternated single responses. Participants were instructed to keep the home buttons pressed until a response was needed, while at the same time fixating at the cross in the centre of the screen. Then they were required to reach out with their right hand and touch the target location which illuminated for 100 ms. All trials had an inter-trial interval of 350 ms and a stimulus onset asynchrony (SOA) of approximately 1200 ms. Participants performed two experimental blocks of 209 trials (i.e., 104 per participant plus the first trial which was not analysed since no response preceded it). They always used their right hand to make the responses. The first trial of each block was not analysed since no response preceded it. Participants undertook one practice session consisting of 21 trials which had the same SOA as the first experimental condition they completed. They were told to respond as quickly and as accurately as possible. The task was completed under full viewing conditions so that participants could fully see their partner's flashing targets and reaching responses.

Results and Discussion

Outliers (more than two SDs above or below the mean) were removed from further analysis. The data was entered into a 2 *x* 2 mixed ANOVA with target location (same, different) as a within-participants factor and partner type (romantic, stranger) as a between-participants factor (See Fig 4.2). The main effect of target location was significant (*F* (1, 22) = 37.23, *p* < .001, partial eta sq = .629), confirming the presence of social IOR. Additionally, there was a significant main effect of partner type (*F* (1, 22) = 14.54, *p* < .001, partial eta sq = .398), such that participants performing the task with a romantic partner were faster compared to those performing with a stranger. Although the partner type *x* target location interaction did not reach statistical significance (*p*s > .273), follow-up analysis of the simple effect of social IOR at each level of partner type were carried out for maximum transparency. These indicated a significant social IOR effect both when participants alternated responses with their romantic partner (*t* (11) = 5.63, *p* < .001, Bonferroni adjusted alpha = .025) and when with a stranger (*t* (11) = 4.03, *p* < .002, Bonferroni adjusted alpha = .025).

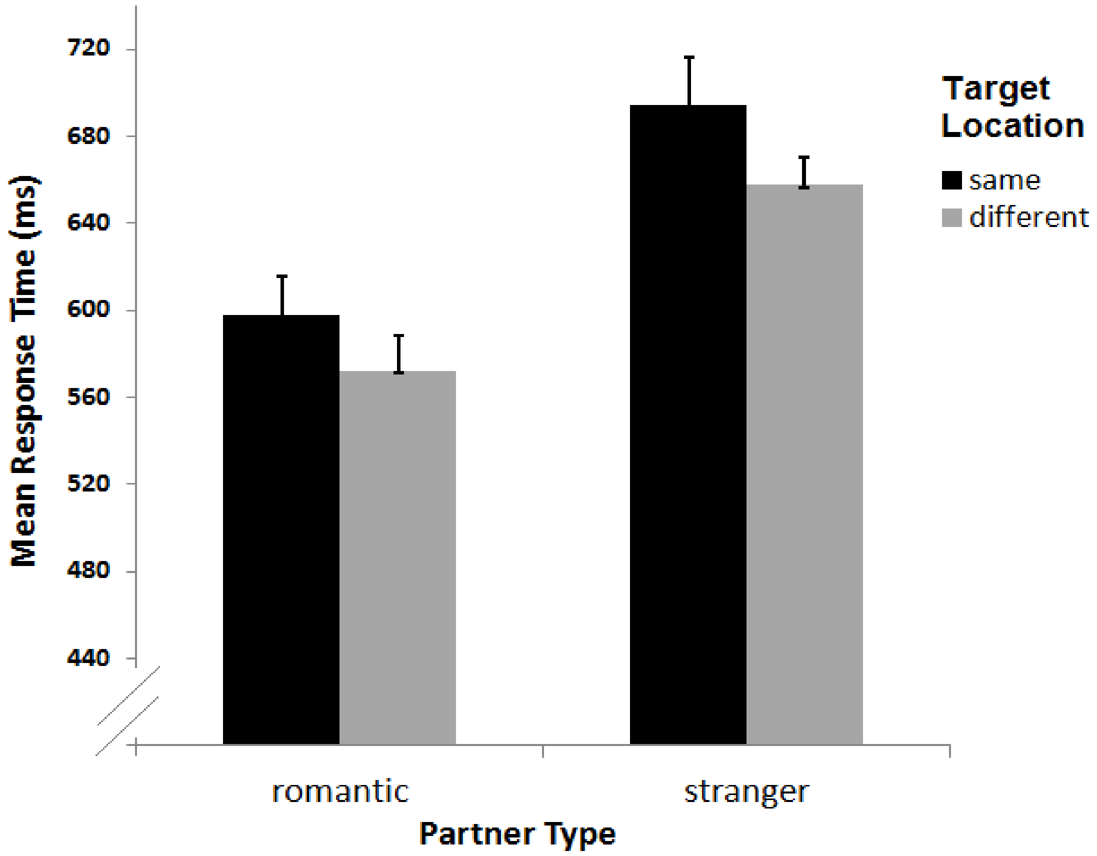

Fig 4.2 Mean RTs to localise targets as a function of partner type and target location. Error bars represent standard errors of the mean.

The results of Experiment 7a revealed that social IOR emerged in both conditions, suggesting that the presence of a romantic partner made no difference to the effect. These results are in line with the findings of the present Chapters 2 and 3, demonstrating once again the robustness of the effect. Moreover, these indicate that the present phenomenon does not seem to be influenced by higher-order factors such as the social affiliation between the two co-actors. This in turn suggests that the present effect is probably not subserved by shared task co-representations like other joint-action effects have been reported to be (e.g., Hommel et al., 2009).

At the same time, the present experiment revealed that partner type affected participants' general RT performance – those paired with their romantic partner were significantly quicker than those performing with a stranger. To speculate, this significant main effect could be due to the fact that participants acting with their romantic partner experienced an elevated positive affect during the task. This is likely to have been the case not only because they felt more comfortable with the partner but also because their romantic partner was more likely to engage in a behaviour, known to induce positive emotion (e.g., smiling; Kraut & Johnston, 1979, giving supportive comments; Lambert et al., 2013; etc.) as compared to a stranger. Positive affect, in turn is known to trigger an increased release of dopamine in the brain which beneficially affects a number of cognitive functions (e.g., Ashby, Isen & Turken, 1999). Thus, people generally perform better when in a positive mood.

Experiment 7b

Experiment 7b aimed to further test how the valence of the relationship between the two co-actors influences the social IOR effect. Taking into account that participants in the standard procedure are usually strangers, Experiment 7b aimed to provide a more robust measure of whether the affiliation between the two partners modulates the effect. This study was a direct replication of Hommel et al.

(2009)[14] in which half of the participants were involved in a positive relationship with their co-actor during the task, while the other half – in a negative relationship. Moreover, to evaluate whether type of viewing condition makes any difference to the social IOR effect, this second experiment was performed under partial viewing conditions (a physical barrier was placed between the two co-actors), as recommended by earlier research (e.g., Skarratt et al., 2010; Welsh et al., 2007).

Method

Participants

A volunteer sample of 24 (9 male; 15 female) participants aged between 18 and 28 (*M* = 20.38 years, *SD* = 3.87 years) took part in the study. All participants were undergraduates at the University of Essex who participated in exchange for £3.

Design and Procedure

The experiment had a 2 (target location: same, different) *x* 2 (partner: positive, negative) mixed participants design. Participants completed 2 blocks of 209 trials. All other aspects were as described previously. Based on Hommel et al. (2009), half of the participants were confronted with an exceptionally nice confederate (positive condition) whereas the other half with a more distant and critical one (negative condition)[15]. The author acted as the confederate in both valence conditions. This began at the start of the experimental session, with the 'positive' confederate greeting the participant and initiating a friendly conversation, and smiling throughout the experiment. At the same points in the negative

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[14] With the only difference that performance on the social IOR effect, instead of the SSE was tested.

[15] There is clearly an inherent difficulty in manipulating and operationalising (i.e., acting out) what is essentially a personality variable. We therefore based this aspect of our procedure on Hommel et al. (2009) who partly manipulated positive/negative interaction via a number of set phrases.

condition, the confederate was more distant, indifferent yet still polite. She also greeted the participant, yet did not smile at them, or initiate an informal conversation before the start of the experiment. Regardless of confederate type, a set of fixed phrases were used as feedback to the participant during the experiment. The confederate gave feedback to the participant on only two occasions – once they had completed the practice session and after the first experimental block. The wording of the phrases used in the positive and negative condition was very similar and the feedback was delivered only while the confederate was looking at the participant's data. Thus, in the positive condition after the practice block, the confederate used the phrases: 'You were very quick' and 'You didn't make any mistakes' and confirmed this after the first experimental block by saying: 'You were again very quick' and 'You didn't make any mistakes'. By contrast, in the negative condition the confederate used: 'I'm afraid you were not quick enough' and 'You made several mistakes' and confirmed this with the statements: 'You were still not very quick' and 'You again made some mistakes' after the end of the first experimental block. Although it was not expected that the negative condition would cause emotional discomfort in participants, their emotional reactions were monitored, so that the experiment could be stopped immediately if any signs of significant distress were noticed.

Based on Hommel et al. (2009), participants' subjective feelings of happiness, anxiety, nervousness, irritation and insecurity were informally assessed. Participants were also orally debriefed. A physical barrier was placed between the two co-actors, allowing only a central strip of their partners' eyes and hand when it was resting on the 'home' button (See the Method sections of the experiments in Chapter 2).

Results and Discussion

As previously described, outliers (2SDs) were removed. The data were entered into a 2 *x* 2 mixed ANOVA with target location (same, different) as a within-participants factor and partner type (positive, negative) as a between-participants factor (See Fig 4.2). The main effect of target location was significant, (*F* (1, 22) = 5.28, *p* < .031, partial eta sq = .19), confirming the presence of social IOR. However, neither the effect of partner, nor the partner x target location interaction were significant (*ps* > 0.74). Still, to be more stringent, planned follow-up comparisons were performed to examine whether social IOR emerged in the two partner conditions. Interestingly, these revealed a significant effect in the negative partner condition (*t* (11) = 2.74, *p* < .02, Bonferroni adjusted alpha = .025) but not in the positive partner condition (*t* (11) = 0.41, *p* < .687, Bonferroni adjusted alpha = .025).

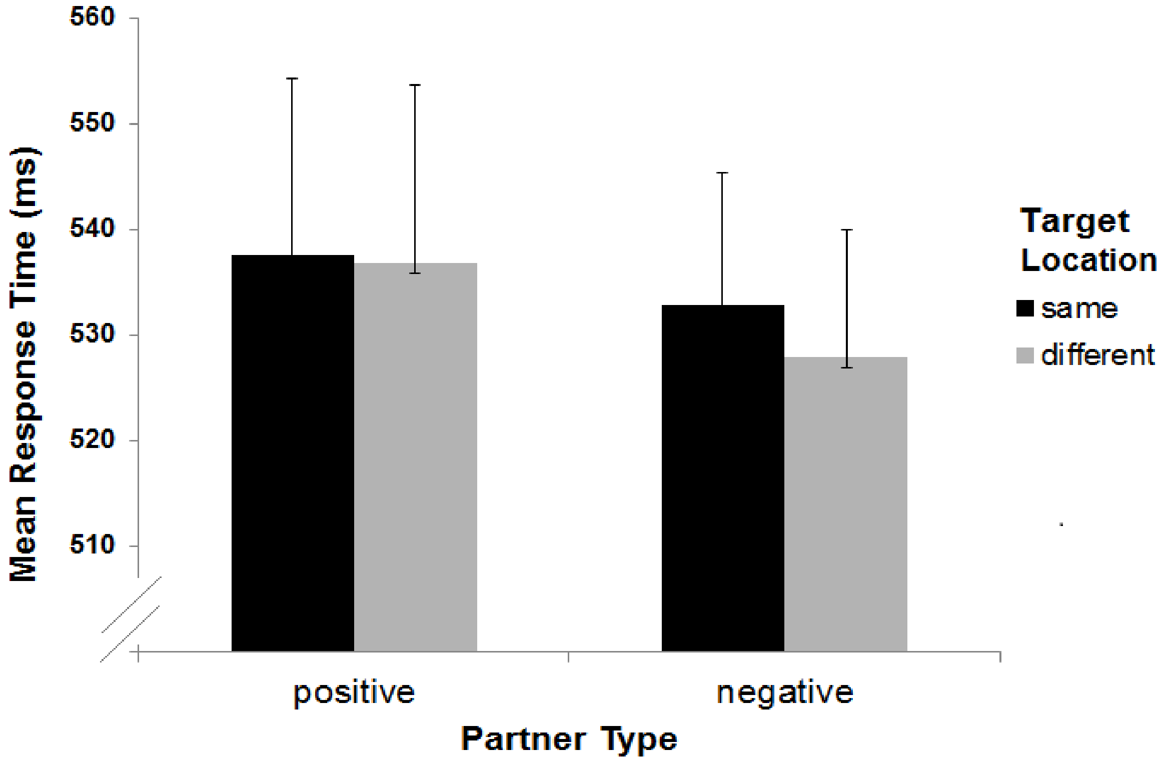

Fig 4.3 Mean RTs to localise targets as a function of partner type and target location. Error bars represent standard errors of the mean.

The results of Experiment 7b replicated those of Experiment 7a by revealing that social IOR occurred irrespective of co-actor condition (i.e., a significant main social IOR effect emerged). Indeed, statistically, the effect was comparable in both partner conditions as the target location by partner type interaction did not reach significance. However, even a more conservative interpretation of the results (i.e., exploring the simple main effects) yields the opposite of what would be expected if action co-representation subserved the present effect – social IOR should have emerged in the positive, rather than the negative partner condition, as individuals are known to normally integrate the perspective of people they like (Heider, 1958; Hommel et al., 2009). Thus, these findings suggest that unlike the SSE, social IOR is not influenced by higher-order factors such as the social affiliation between the two co-actors or the participant's affect during the task.

Finally, in Experiment 7b type of partner did not significantly affect participants' general response speed as in Experiment 7a. However, this might be due to both the positive and the negative condition producing comparable effects on general RT performance *through different routes*. Thus, while participants in the positive partner condition performed well because they presumably experienced increased levels of positive affect (Andersen & Chen, 2002), those in the negative condition probably wanted to improve their performance as they were receiving negative feedback ('participants took the speed-related comments of the confederate to heart', Hommel et al., 2009, p.797). In support, the tendency in general RTs was similar to that reported by Hommel et al. (2009) who found that individuals in the negative condition responded more quickly. Finally, we consider the present partner type manipulation successful since virtually all participants in the negative condition reported feelings of irritation in the post-experimental interviews. In contrast, participants in the positive condition reported feelings of happiness, security and satisfaction.

4.2 Experiment 8

The results of Experiment 7 suggested that the valence of the relationship between the two co-actors does not modulate social IOR. To assess whether the presence of a co-actor is even necessary for the effect to occur, Experiment 8 directly tested the socialness of the present social IOR/movement congruency effect by incorporating a condition where participants performed the task, alone, with no co-actor present, as in Dolk et al. (2013).

Method

Participants

A volunteer sample of 26 (9 male; 17 female) participants aged between 19 and 35 (*M* = 22.16 years, *SD* = 3.91 years) took part in the study. All were undergraduates at the University of Essex, were right-handed, and naïve to the purposes of the study. They received £4 for their participation.

Stimuli and Apparatus

The apparatus and stimuli were identical to the ones used in Experiments 7a and 7b.

Design and Procedure

The design was a 2 *x* 2 fully within-participants design. The two factors that were manipulated were target location (same, different) and co-actor's presence (present, absent).

The procedure in the co-actor-present condition was identical to one of the standard social IOR procedure where two naïve participants were tested simultaneously (as in the stranger condition of Experiment 7a). In the co-actor-absent condition, however, only one of the participants was tested at a time, while the other was waiting with the experimenter. The participant's initial response triggered the target sequence in which the participant reached out and touched the target location, as in the co-actor-present condition; however, on the partner's trial they only saw a target illumination for 100 ms, appearing either in the left or the right response location. Each participant took part in two experimental blocks, i.e., the co-actor-present and absent conditions (209 trials in a block, 104 per person plus the first trial which was not analysed). The presentation order of the two blocks was counterbalanced. Similarly to Experiment 7a, participants had a full view of their partner and targets. Participants first watched a demonstration by the experimenter and completed a 21-trial practice session. They were instructed to respond as quickly and as accurately as possible.

Results and Discussion

As before, RT outliers (more than two SDs above or below the mean) were removed prior to the analyses. Mean RTs were computed as a function of target location (same, different) and partner (present, absent) and entered into a 2 *x* 2 fully-within participants ANOVA (See Fig 4.4). The main effect of co-actor was significant (*F* (1, 25) = 7.89, p < .01, partial eta sq = .240). Thus, RTs were shorter when the participant performed with a co-actor than when they were responding alone. The main effect of social IOR was also significant (*F* (1, 25) = 14.70, p < .001, partial eta sq = .370). Finally, the interaction between target location and partner just missed statistical significance (*F* (1, 25) = 3.91, p < .059, partial eta sq = .135). Still, to be more stringent, planned follow-up comparisons were performed to examine whether the effect was present in both partner conditions. These revealed a significant effect in the co-actor-present condition (*t* (25) = 5.24, *p* < .001, Bonferroni adjusted alpha = .025) but not in the co-actor-absent one (*t* (25) = 1.53, *p* < .138, Bonferroni adjusted alpha = .025). Finally, there was a significant positive correlation between participants' performance when acting alone and when with a partner (*r* (24) = .60, *p* < .001).

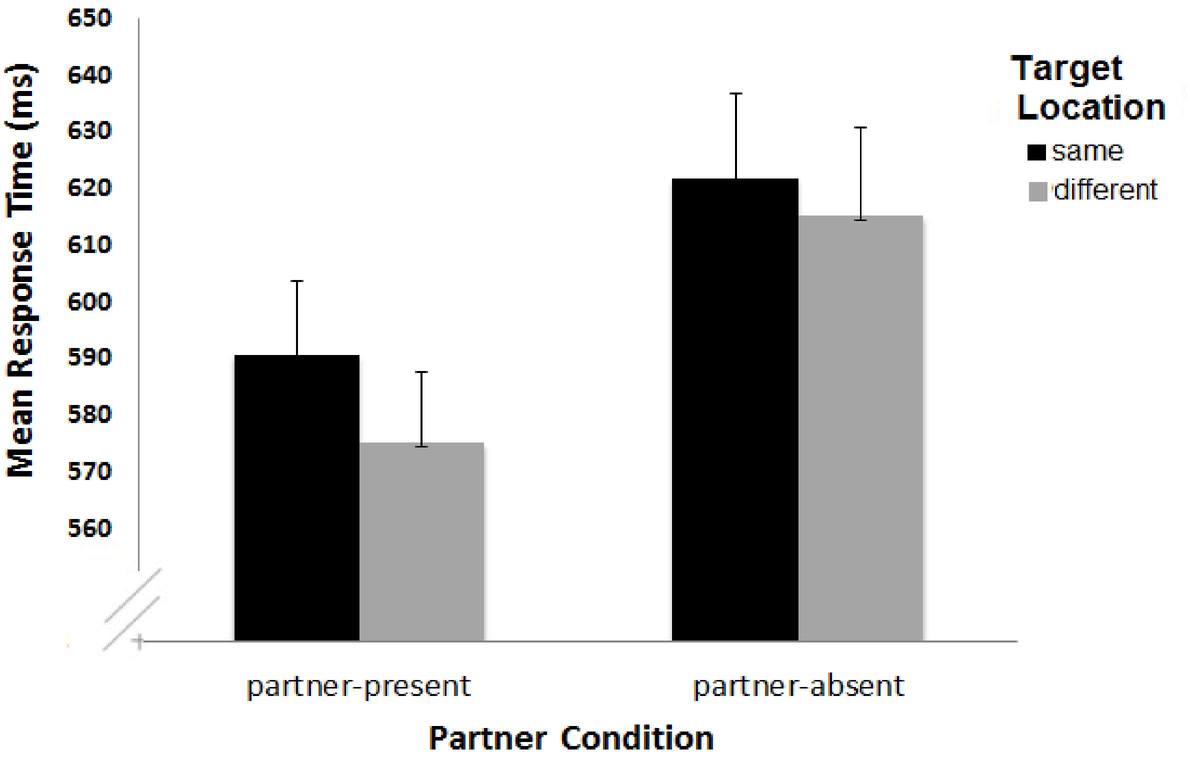

Fig 4.4 Mean RTs to localise targets as a function of partner and target location in Experiment 8. Error bars represent standard errors of the mean.

The main findings of Experiment 8 are consistent with previous studies on the social IOR/the movement congruency effect as they indicated that co-actors were significantly quicker to initiate an action to the different location (i.e., initiating a movement congruent action). Moreover, the significant main effect of partner condition on participants' general RT is in line with previous work suggesting that observing a biological movement biases one's timing of movement execution (e.g., Kaneko & Murakami, 2009; Watanabe, 2008). Furthermore, the partner by social IOR interaction just missed statistical significance, meaning that statistically there was no difference in social IOR between the partner-present and the partner-absent condition. However, for maximum transparency, further analyses were carried out which revealed that the effect disappeared in the partner-absent condition.

There are two possible explanations for the latter. One is that an internal replica of the action could not have been generated in the observer’s motor system because there was no biological action present (Buccino et al., 2001; Sebanz et al., 2003, 2005). However, alternatively, the target illuminations in Experiment 8 might have not been salient enough to attract attention and induce social IOR in the partner-absent condition. In support, a recent selective attention study showed that ‘the probability of a planned saccade being inhibited increases logarithmically with the size of the distractor’ and that the effect is larger when distractors appear at a different hand-side from an egocentric perspective (Buonocore & McIntosh, 2012, p.32). In sum, strictly speaking, in the present Experiment 8 no social IOR effect emerged in response to the sole observation of target illuminations in the absence of a partner.

Therefore, in Experiment 9 more salient attention-capturing transients were introduced in the partner-absent condition.

4.3 Experiment 9

The purpose of Experiment 9 was similar to that of Experiment 8 since it also assessed the socialness of the effect. However, this time a more abrupt attention-capturing event was presented to test whether attentional capture was sufficient to induce the present effect. Thus, in Experiment 9, where the partner would normally respond, attention-capturing cues, mimicking a hand movement, moved across the display to the target (see Fig 4.5).

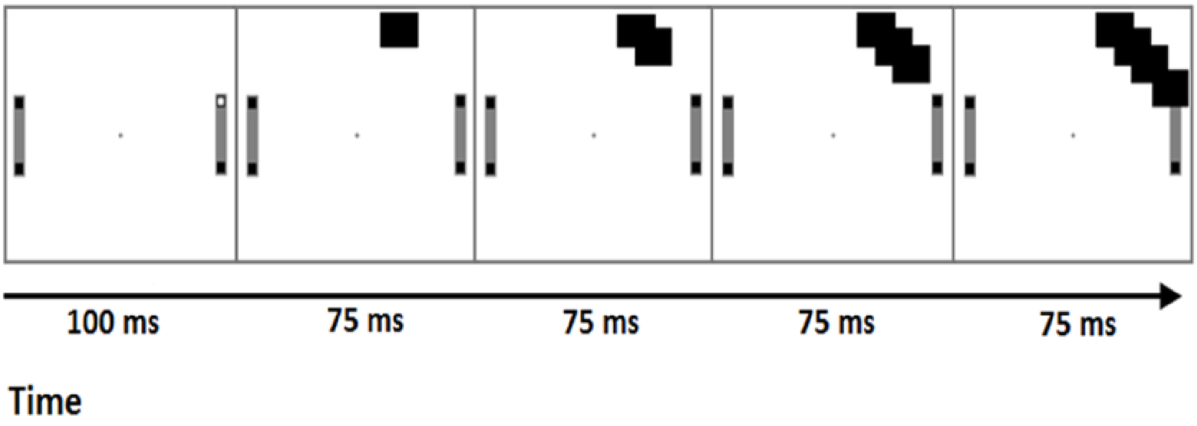

Fig 4.5 Trial sequence in Experiment 9.

Method

Participants

A volunteer sample of 20 (7 male; 13 female) participants aged between 19 and 32 (*M* = 22.50 years, *SD* = 3.17 years) took part in the study. All were undergraduates at the University of Essex, were right-handed, and naïve to the purposes of the study. They received £4 for their participation.

Stimuli and Apparatus

The apparatus was as reported previously. The black rectangular transients in the partner-absent condition had an area of 270 mm^2. They were either displayed 40 mm to the left or 40 mm to the right of the screen midline, depending on which target location had illuminated on the partner's side of the table.

Design and Procedure

The experiment employed a 2 *x* 2 fully within-participants design. As in Experiment 8 the two factors manipulated were the presence of a partner (present, absent) and target location (same, different). A 'same location' of response in the partner-absent condition referred to a situation in which, the participant acted on a location to which the attention-capturing cues had also just 'moved', while a 'different location' was a condition where the participant responded to the opposite location to which the attention-capturing cues moved on a previous trial.

The procedure of the partner-present condition was identical to the one of the partner-present condition in Experiment 8. Similarly, in the partner-absent condition, only one of the participants in a pair was tested at a time, while the other was waiting with the experimenter. However, rather than only observing the partner's target illuminations as in Experiment 8, participants in this condition also saw a sequence of 4 black rectangular transients moving towards and covering the target (See Fig 4.5). The first transient was displayed 100 ms after one of the target locations had illuminated. Every new transient appeared for 75 ms and then once the fourth transient reached and covered the target location, they began disappearing at 75 ms-intervals following a backward sequence. As in Experiment 8, each participant took part in two experimental blocks, i.e., the partner-present and absent conditions (209 trials in a block, 104 per person plus the first trial which was not analysed). They always had a full view of their partner/rectangular transients, their targets and their responses. Participants first watched a demonstration by the experimenter and completed a 21-trial practice session. They were instructed to respond as quickly and as accurately as possible.

Results and Discussion

Any RT outliers (more than two SDs above or below the mean) were removed prior to the analyses. As in Experiment 8, mean RTs were computed as a function of target location (same, different) and partner condition (present, absent) and entered into a 2 *x* 2 fully-within participants ANOVA (See Fig 4.6). The main effect of partner was significant (*F* (1, 19) = 5.65, p < .03, partial eta sq = .229). Thus, RTs were shorter when the participant performed with a co-actor than when they were responding alone. The main effect of target location was also significant (*F* (1, 19) = 36.44, p < .001, partial eta sq = .657) confirming the presence of social IOR. Finally, there was a significant target location *x* partner interaction (*F* (1, 19) = 7.89, p < .01, partial eta sq = .293). Planned follow-up comparisons revealed that this time the social IOR effect was present in both the co-actor-present (*t* (19) = 4.66, *p* < .001, Bonferroni adjusted alpha = .025) and the co-actor-absent conditions (*t* (19) = 4.67, *p* < .001, Bonferroni adjusted alpha = .025). Thus, essentially the interaction was driven by the significant difference in making a response to the same location when alone and when with a partner (*t* (19) = 3.00, *p* < .007, Bonferroni adjusted alpha = .025; See Fig 4.6). There was no such difference between the two partner conditions when targets appeared in different locations (*p* > .115). Additionally, there was no significant difference in within-participants' variability in RT as a function of condition (*F*s (1, 19) > 0.03, *p*s > .722). Moreover, although this analysis also revealed a significant target location by partner interaction (*F* (1, 19) = 10.29, p < .005, partial eta sq = .351), none of the simple main effects was significant.

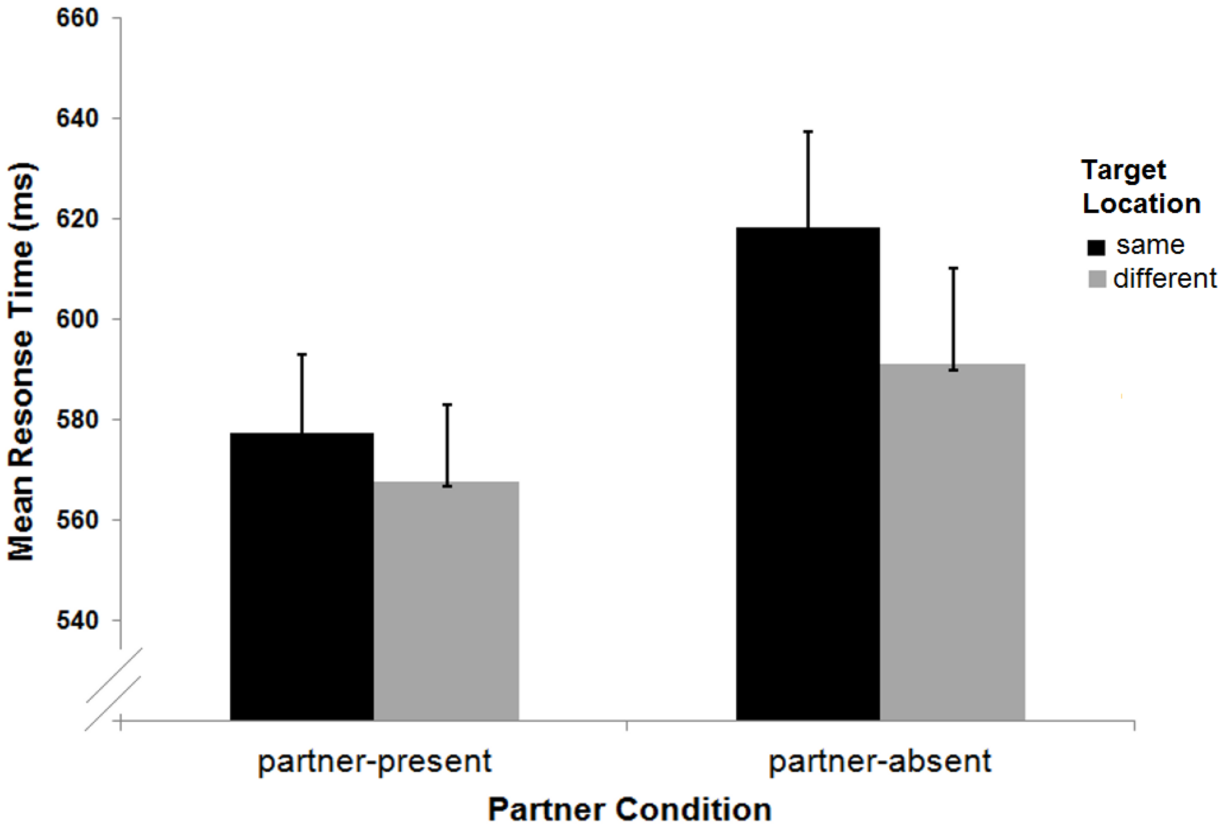

Fig 4.6 Mean RTs to localise targets as a function of target location and partner condition in Experiment 9. Error bars represent standard errors of the mean.

The results of Experiment 9 confirmed the presence of social IOR even in the absence of a biological partner. The only difference with the previous Experiment 8 was the introduction of more salient attention-capturing transients which resulted in a significant social IOR effect even in the partner-absent condition. Thus, it seems that these transients had a similar effect to the arm/hand movement in the standard social IOR procedure. Presumably, their abrupt onset induced visuomotor inhibition (in participants) to the target location where the transients have occurred (Cole et al.). Indeed, it has been previously reported that transients of a bigger size as well as stimuli with abrupt visual onsets capture attention more easily (e.g., Buonocore & McIntosh, 2012 and Cole & Kuhn, 2009; Cole & Kuhn, 2010; Ruz & Lupianez, 2002 and Yantis & Jonides, 1984, respectively). Finally, the partner condition influenced general RT speed in a similar fashion as reported in Experiment 8.

Taking together the present findings with those of Experiment 8, there are grounds to assume that the present effect is fairly robust and can occur in the complete absence of a biological partner, as long as a salient event such as abruptly moving exogenous cues has been introduced in the paradigm.

4.4 General Discussion

Recent body of work has started to challenge the socialness of some joint-action effects. For example, as mentioned in the Introduction, Dolk et al. (2011, 2013) showed that the SSE can be generated with no partner present. Chapter 4 aimed to assess the impact and importance of a biological partner in the social IOR paradigm, which has also been used to test a variant of the movement congruency effect. First, the two versions of Experiment 7 indicated that a significant effect emerged, irrespective of the relationship between the two co-actors, regardless of whether the task was performed under full or partial viewing conditions. Moreover, although the findings of Experiment 8 were ambiguous, Experiment 9 confirmed the notion that the presence of a biological partner is not necessary for the effect to emerge. Taken together, the present results suggest that the effect of interest is not likely to be social in nature. Moreover, these fit well with what was found in the previous two chapters as the present findings also suggest that the phenomenon is more likely to stem from inhibition of return processes, rather than from direct matching between the observed and the required actions.

These findings clearly do not support an explanation of the present phenomenon based on action co-representation as previous research has suggested that social factors modulate joint-action effects in a top-down manner. Thus, for example, in contrast to what was found in Experiment 7, the congruency effect has been reported to increase when participants have been primed with pro-social cues (Leighton, Bird, Orsini & Heyes, 2010) and that on the other hand, behavioural mimicry enhances the affiliation and rapport between co-actors (e.g., Lakin & Chartrand, 2003). Furthermore, under different experimental settings, both Hommel et al. (2009) and Iani et al. (2011)[16] demonstrated that the SSE was sensitive to the relationship between the two task-partners as the effect was abolished when there was a negative interdependence between them. Finally, some have even reported that when two individuals share a task, the joint-action effect disappears when the visual access to the other's stimuli has been disrupted (Böckler et al., 2012, Experiment 3). The latter is clearly in a stark contrast to what was found in the present Experiments 8 and 9 where the effect of interest occurred even in the absence of a biological co-actor.

In this line, the present findings can be placed within the context of other work challenging the notion that action co-representation, via the observer's motor system, drives joint-action phenomena. For instance, Vlainic et al. (2010) showed that neither visual nor auditory information about the partner's actions was required for the SSE to occur while Dolk et al. (2011, 2013) obtained the effect even in the absence of a biological partner. Moreover, directly relevant to the present study, in a recent motor priming paradigm, Liepelt and Brass (2010) found that when participants observed either a human or wooden hand executing an action, a significant congruency effect occurred in both the animate and the inanimate agent conditions[17]. Consequently, newer theories, challenging the action co-representation account have started to emerge. For example, advocates of the

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[16] Iani, Anelli, Nicoletti, Arcuri and Rubichi (2011).

[17] Liepelt and Brass (2010) reported a significant SSE in both conditions, even though it was of a smaller magnitude in the wooden hand condition.

referential coding account have recently argued that the perception of the other's *agency* (identifying the causal source of an action), rather than *intentionality* (the attribution of agency) drives joint action (Stenzel et al., 2014). Thus, as long as the causal source of the action has been identified (being it a biological co-actor, an event or an object), a joint-action effect should occur. Furthermore, another alternative theory to the action co-representation account is the Coordination Dynamics Approach. According to it, the vital component for such effects is the emergent interpersonal motor coordination rather than the mental simulation of the observed action (Fine & Amazeen, 2011; Fine et al., 2013; Richardson et al., 2009; Romero, Coey, Schmidt & Richardson, 2012). Moreover, when considering the interference in movement congruency paradigms, the proponents of this account suggest that rather than being indicative of 'error' the motor system represents the necessary compensatory changes to ensure coordination across unequal kinematic requirements (Richardson et al., 2009). In support, Fine et al. (2013) manipulated the spatial congruence between the participant and the confederate (i.e., whether they made horizontal or vertical movements) and the anatomical congruence (i.e., whether they were facing one another or the confederate was rotated at 90^o). The results showed that *anatomical incongruence* did not create interference, suggesting that coordinating actions with the actor did not depend on the simulation of postural-based motor representations.

Therefore, rather than action co-representation, the results of the present Chapter 4 seem to better fit with the alternative, social IOR explanation of the effect (Cole et al., 2012). As explained in the previous chapters, according to this *attentional shift hypothesis*, a partner's reaching action shifts the observer's attention to the location of the response. Then, when the partner returns their hand, the observer's attention is shifted back to the centre of the display.

Consequently, when a target appears at the responded-to location, participants inhibit the stimulus and/or response to that position. In line with this account, the personal relationship between the two co-actors should not influence the effect, as found in Experiments 7a and 7b. Moreover, this 'social IOR' account predicts that any transient event that shifts the observer's attention will generate visuomotor inhibition at that location, including for instance, flashing transients as in the current Experiments 8 and 9. Along the same lines, the visual transients in Experiment 9 are likely to have attracted the observer's attention more easily than the ones in Experiment 8 because of their size and abrupt motion (Buonocore & McIntosh, 2012 and Cole & Kuhn, 2009; Cole & Kuhn, 2010; Ruz & Lupianez, 2002 and Yantis & Jonides, 1984). Thus, although moving transients replaced the biological partner in Experiment 9, what may be important is the introduction of an event that is salient enough to produce an attentional shift to that location. This explains why the effect occurs even when the partner's targets and final part of the response (i.e., arm reach) are occluded from view – the actor's hand movement and gaze shift are enough to direct the observer's attention to that direction (Skarratt et al., 2010; Welsh et al., 2007).

However, still, not all aspects of the present findings agree with previous social IOR research. For example, one of the first papers on social IOR examined the socialness of the effect by either making participants alternate responses with a real or an animated co-actor (Skarratt et al., 2010). It was found that when performing with a biological partner, the effect occurred both during the full and the restricted viewing conditions. However, social IOR only emerged during unrestricted viewing conditions (i.e., no barrier present) when participants performed the task with an animated partner. Importantly, although these results fit with the ones reported in the present Experiments 8 and 9 (as no barrier was employed in these present studies, either), Skarratt et al.'s (2010) interpretation differs from the present as they concluded that the observed effect was *classic IOR*, rather than *social IOR* (i.e., 'only IOR was observed', p.50). This proposition was based on the idea that when participants could fully see their partner's target flash and arm movement, this inevitably generated IOR as IOR is activated in a response to sensory stimulation. Thus, Skarratt et al. (2010) submitted that 'IOR is not usually obtained […] under impoverished viewing conditions' and 'the strictest test of socially-induced IOR, then, would be its emergence in a task performed in conjunction with a real, rather than animated, partner and under impoverished viewing conditions' (p. 49). However, this early interpretation of the effect excludes any necessity to test its socialness, as it intrinsically assumes that social IOR is social and that it is triggered by different factors as compared to basic IOR. Moreover, it seems that the mentioned above 'strictest test' of social IOR is simply based on one of the possible explanations of why the effect occurs but does not necessarily represent a robust measure of social IOR. Indeed, Skarratt et al.'s (2010) interpretation simply seems to be more in line with the action-location hypothesis submitted by Welsh et al. than Cole et al.'s attentional shift hypothesis (e.g., 'any resulting inhibition must instead be generated through inference of a real person's response behaviour', Skarratt et al., 2010; See Chapter 3 for more detail on both theories). However, as explained in detail in the previous chapters, later work has challenged this early explanation of the effect involving the MNS (e.g., Cole et al., 2012; See Chapter 3 for more detail). As a consequence, in all recent papers the effect emerging in the social IOR paradigm (where the RT of one co-actor is examined as a function of the responses made by another co-actor/event) under *full viewing* conditions is interpreted as *indicative of social IOR* (e.g., Atkinson et al., 2014; Cole et al., 2012; Reid et al., 2013; Welsh et al., 2014). Finally, Skarratt et al. (2010)'s proposition that 'IOR is not usually obtained […] under impoverished viewing conditions' has been challenged in a very similar set-up to the one used in the present Experiment 9. For instance, instead of a co-actor, in their last experiment, Welsh et al. (2007) introduced a moving rectangle, mimicking hand movements while at the same time restricting participants' vision and even preventing auditory cues as white noise masked any response-related noise. In discrepancy with Skarratt et al.'s (2010) proposition about classic IOR, despite the lack of any visual or auditory cues, a significant *within-participants IOR* effect emerged. Thus, in unison with Cole et al.'s attentional shift hypothesis and the most recent work on social IOR, it seems that a more accurate measure of the social IOR effect is the difference in RT of co-actor A as a function of whether they repeated or not the location of co-actor B, regardless of viewing condition.

In sum, Chapter 4 demonstrated that the effect in the present paradigm is not modulated by the valence of the relationship between the two co-actors and it can occur even in the absence of a biological co-actor. While in some previous research it has been interpreted as stemming from action co-representation (Ondobaka et al., 2012), the present findings indicated that although the results fit with the general findings of what would be expected from a movement congruency effect, the current phenomenon does not rely on the socialness of the co-actor. Indeed, naming the phenomenon, emerging from the present paradigm as a 'movement-congruency effect' (Ondobaka et al., 2012) appears to be a mislabel since the results seem to better fit with the attentional shift hypothesis, referring to it as 'social IOR'. Thus, as before, the observed effect will continue to be named 'social IOR' in the following Chapter 5.

CHAPTER 5

5.0 DECISION MAKING AND SOCIAL IOR

The previous three empirical chapters have revealed that social IOR is most likely to result from inhibitory processes to return attention to a previously cued location (triggered either by an event or a biological partner); its properties are more consistent with basic IOR than an effect, stemming from action co-representation; and it does not seem to be as 'social' as its name suggests. Thus, it could be concluded that the effect 'behaves' more like an attentional phenomenon rather than a joint-action effect.

As explained in the General Introduction, the abundance and complexity of the environment tax highly the human visual attentional system. Moreover, because of the individuals' limited processing resources (Lavie et al., 2004) the selection and interpretation of information are not only imperfect but also often constructed in accordance to its behavioural relevance to the individual, rather than reflecting an accurate representation of the world (Treue, 2001). This is apparent from participants' subsequent behaviour after the presentation of stimuli in standard visual attention paradigms where a forced choice is required (e.g., press either the left or the right button).

However, recently the latter has also been discovered for paradigms where participants freely choose how to respond (e.g., Kiesel, 2006; Klapp & Hinkley, 2002; Schlaghecken & Eimer, 2000; Wilson & Pratt, 2007). One such example are priming paradigms where participants' decisions are shown to be greatly influenced by the presentation of a stimulus (i.e., 'a prime') that is still at the subliminal or preconscious stages of processing[18] (Dehaene, Changeux, Naccache, Sackur & Sergent, 2006). For example, in their last experiment Klapp and Hinkley (2002)

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[18] Subliminal (attended) and preconscious processing both occur prior to conscious perceptual processing. It has been suggested that priming takes place in those two stages. According to Dehaene et al. (2006) these differ in neural activation between one another and as compared to conscious processing.

demonstrated that the direction of a masked prime ('<' or '>') presented prior to an ambiguous target (< >) predetermined the participants' response on 60.5% of the trials. As the used prime-target SOAs were above 100 ms, the well-known negative compatibility effect (NCE)[19], found in forced-choice priming, occurred with participants being quicker to respond to stimuli incongruent with the prime. Moreover, facilitation from congruent primes has also been demonstrated in a free choice priming task. For example, Kiesel et al. (2006) found that when shorter SOAs than 100ms were used, participants were more likely to make a response, congruent with the direction of the prime. Furthermore, these responses were also faster than those to non-primed stimuli.

As explained in the General Introduction, according to the two social IOR accounts of the present effect, social IOR is subserved by similar mechanisms to basic IOR (See Sections 1.1.2 & 1.1.3). Thus, the observed inhibitory effect is thought to be triggered either by the saliency of the partner's location per se (Cole et al., 2012; Skarratt et al., 2011, 2012) or the partner's action towards that location, which is interpreted as if one performed the action themselves (Welsh et al., 2005, 2007, 2009, 2014). There is evidence that similarly to priming, IOR is another attentional effect which influences free choice decisions. For example, some early IOR studies examined the preferred direction to which participants freely moved their head or eyes, following the presentation of a peripheral cue. They found that participants' head orientation/eye gaze were directed more often than chance towards the uncued side than the cued one (Clohessy, Posner, Rothbart & Vecera, 1991; Posner et al., 1985, respectively). Moreover, Wilson and Pratt (2007) have more recently demonstrated that basic IOR can also bias participants'

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[19] NCE occurs when responses are faster after incongruent primes than after congruent primes (this is when the prime-target SOA is greater than 100 ms). In contrast, facilitation from congruent primes (i.e., a positive compatibility effect; PCE) usually occurs at shorter prime-target SOAs (Kiesel et al., 2006; Schlaghecken & Eimer, 2000).

response selection. In this task participants freely chose whether to press a right or a left button after hearing a tone. However, in this ‘choice task’ a peripheral cue appearing either 200ms or 800ms before the tone was presented. Results revealed that participants tended to avoid selecting the button that corresponded to the previously cued location at the long SOA and were more likely to choose the cued location at the short SOA (Wilson & Pratt, 2007). Such results are consistent with the notion that IOR is a visual search facilitator as it biases attention away from previously examined locations and directs it, instead, to new areas in the visual scene (Klein & MacInnes, 1999). Thus, it is interesting to examine whether social IOR has also evolved to maximise search behaviour (as proposed by Welsh et al.) by directing individuals to novel locations even when they freely select their response.

The present Chapter 5 examined whether social IOR could influence free choice. Up to date, there has been only a single study examining the latter (Reid et al., 2013). This study employed the standard social IOR paradigm (as described in Section 1.1.3; See Fig 1.1 or Fig 4.1 in Chapter 4) where participants freely chose whether to respond to the right or the left target location after hearing a ‘go’ tone. Consistent with the social IOR effect in forced-choice studies, the results revealed a significant social IOR bias, so that participants generally avoided the location to which their task-partner had previously responded (Reid et al., 2013). The present investigation aimed to expand this study by testing both whether social IOR could influence simple decisions such as choosing between two target locations and whether it could bias more complex judgements that one makes about a stimulus. All experiments in Chapter 5 incorporated the standard social IOR procedure in which two individuals sitting opposite one another alternated responses to stimuli appearing either to the left or the right of the screen. In Experiment 10 participants were asked to freely select and reach to either of two occupant squares. In Experiment 11 they had to make a decision about which of the two consumer products they preferred and indicate their choice by reaching to the product. In Experiment 12 they were presented with pairs of human faces and asked to decide which of the two would be considered the most (or least) physically attractive by the majority of people. In the last Experiment 13 each participant judged the attractiveness of human faces with a confederate. Thus, over the course of these experiments, participants were required to make a range of free choice decisions, varying from simple ('select a location') to more complex ('which face is more/less attractive?'). In each case, participants were instructed that the presence of their partner, as well as the choices they make, should have no bearing on their own task.

5.1 Experiment 10

Method

Ethics Statement

All four experiments reported in the present chapter have been approved by the Ethics Committee of the University of Essex. All participants gave their written informed consent to take part in this research.

Participants

16 participants (10 females) aged between 18 and 25 took part in exchange for course credits.

Stimuli and Apparatus

The stimuli were displayed on a 22-inch flat touch-screen monitor mounted on a table, raised 740 mm from the floor. Participants sat with their chest approximately 240 mm from a 'home' button positioned directly in front of them.

The stimulus positions were denoted by squares (14 mm along each side) located 310 mm from each other. The squares were black (0.4 cd/m^2) and acted as 'placeholders' in that they were present for the entire duration of a condition block. They illuminated briefly (100 ms) by turning white (76.2 cd/m^2), thus rendering them invisible momentarily. The fixation cross was a black cross, presented in the middle of the screen. All stimuli appeared on a uniform white background (76.2 cd/m^2). Participants made their responses by releasing a home button and touching one of the two squares. A RM Pentium PC custom software was used for the stimulus generation and the recording of the responses.

Design and Procedure

Participants used their right hand to hold the home button and make responses. The first response of Participant A activated the stimulus sequence after which the two participants alternated single responses for the duration of the experiment. Thus, a response on one trial by, say, Participant A also acted as the inducing stimulus for the next trial of Participant B. Each response was prompted by a cue, marked by the simultaneous illumination of both stimulus squares. Upon seeing this, participants had to decide to which of the two positions to make a response. They were told that while the speed of decision was not important they should aim to respond within a 'second or so' of the cue. This was stated to discourage participants from taking time to think over their decision. Once a response was completed, 350 ms elapsed until the next target occurred. They were also asked to fixate centrally at all times until they were required to make their response, during which they were instructed to fixate the response position. Furthermore, participants were told that they could ignore their partner's response since it was not relevant to their decision. Participants always had a full vision of the apparatus and their co-actor. They completed two blocks, each consisting of

209 trials. Data from the first trial was always omitted as no response preceded it. Thus, in total, data from 208 trials was used for each participant. The experiment measured the proportion of responses each participant made to the same location as their partner's previous response compared to chance level (50%).

Results and Discussion

Each participant's response was coded as being the 'same' or 'different' in relation to their partner's previous response. On occasions when a response was too light to be registered by the touchscreen (and its location could not be established) the response was omitted from the analysis along with the next response of the other participant. Approximately 13% of data were omitted this way. The percentage of the remaining same responses was then compared to chance level. Results showed that overall, participants responded to the same location on 40.6% (SD = 7.41) of trials compared to 59.3% made to the different location (see Fig 5.1 for all 'same' responses in Experiment 10). Each person's percentage score was entered into a one-sample t-test with 50 being the test value. This analysis showed that participants were less likely to respond to the same location than chance would allow, t(15) = 5.1, p < 0.001, Cohen's d = 1.3, (95% confidence interval: lower = 37.0%, upper = 44.2%). Additionally, although participants were informed that response speed was not important, RTs were also analysed. Results showed that the effect reported above did not manifest in terms of shorter RTs to reach to a different location; same RT = 537 (SD = 178), different RT = 552 (SD = 195), t(15) =. 88, p >. 39, Cohen's d =. 08. Finally, the within-person IOR effect was also analysed (whether participants avoided their own previous response location). Results revealed that such basic IOR effect was present: same location = 41.7%; SD = 10.6, t (15) = 3.1, p <. 01, Cohen's d =. 78.

Finally, one further analysis was conducted to examine whether a response strategy or bias might account for the effect (i.e., a general tendency to respond to one location more than the other). For this test, the data of participants who had not performed the task together was randomly paired. Thus, for instance, the response from Participant number 4 on trial number 156 was followed by the response from Participant number 15 on trial number 157. This was then followed by the response from Participant number 4 on trial number 158, and so on. Results showed that responses to the same position did not differ from chance, 50.5% (SD = 6.6), t(15) =. 27, p > 0.79, Cohen's d = 0.08. Overall, these data show that participants tended to choose a location different from the one their partner chose on a previous trial and this decision is not likely to be due to a response bias or strategy.

5.2 Experiment 11

The decisions participants had to make in Experiment 10 were tied to the two spatial locations. Moreover, in the previous experiment the task did not differ much from the basic Social IOR paradigm; it was also fairly simple and required little deliberation. Thus, Experiment 11 examined whether social IOR would have an effect on more complex decisions, hence, whether the partner's choice of location could influence one's preference for consumer products. Thus, where normally the two squares would occur, images of two similar consumer products were presented.

Method

All aspects of the method were as reported previously with the following exceptions. 26 new and naive participants (16 females) aged between 18 and 27 took part in exchange for £6. 52 pairs of familiar everyday products were generated. Examples included clothing, watches, furniture, music and gardening equipment, kettles, cars, cycles, and kitchen appliances. The pairs were randomly selected from the same category, e.g., two watches, two kettles, etc., and presented on screen in the locations occupied by the two square cues in Experiment 10. That is, each was centred 155 mm to the left or right of a centrally positioned cross. The images of the products were all scaled to fit within an imaginary square measuring approximately 65 mm along each side, and were presented in their natural colours.

The trial types were presented in a random order with the stipulation that the same pair could not occur on the following trial. Thus participants were never presented with the same two items that their co-actor had just made a judgement on. Participants were instructed to 'scan both products and decide which of the two they prefer'. In a second block of trials participants were asked to decide which of the two was least preferred. The presentation order of the two blocks was counterbalanced. Each participant was presented with the same pairs of products four times over the course of the experiment, twice when judging which was the most preferred, and twice when judging which was the least preferred. As previously, participants had a full vision of the apparatus and their co-actor. They were also told to firmly press the touchscreen in an attempt to ensure all touch responses were recorded. As in the previous experiment, there were 209 trials in each block generating 418 trials for the entire experiment from which 416 were analysed (See the Method section of Experiment 10).

Results and Discussion

Of all responses only 2 were not registered by the touch-screen. As with Experiment 10 we compared the proportion of responses made to the same location as a partner's previous response with the chance value of 50%. Results showed that, overall, participants responded to the same location on 47.6% (SD = 4.1) of the trials (see Fig 5.1 for all 'same' responses in Experiment 11). A one-sample t-test revealed this to represent significantly fewer responses than chance would allow, t(25) = 3.0, p <. 006, Cohen's d =. 58, (95% confidence interval: lower = 46.0%, upper = 49.2%). A further analysis revealed that there was no difference in this effect as a consequence of making a preferred or non-preferred decision (preferred = 47.2%, non-preferred = 48.0%), t(25) =. 54, p >. 59, Cohen's d = 0.14. Furthermore, similarly to Experiment 10, the decision effect did not manifest in terms of RT; same RT = 1323 (SD = 238), different RT = 1305 (SD = 251); t(25) = 1.4, p >. 17, Cohen's d =. 07. However, no within-person IOR effect was present in this experiment: same location = 50.6%; SD = 7.7, t(25) =. 43, p >. 67, Cohen's d =. 08.

As in Experiment 10, data from different combinations of participants was randomly paired together to test response bias. Again, responses to the same position did not differ from chance, 50.4% (SD = 6.6), t(25) =. 45, p > 0.66, Cohen's d = 0.1. Overall, these data show that, in addition to the simple location choices that were measured in the previous experiment, social IOR can also influence more complex subjective choices; namely, preference for consumer products.

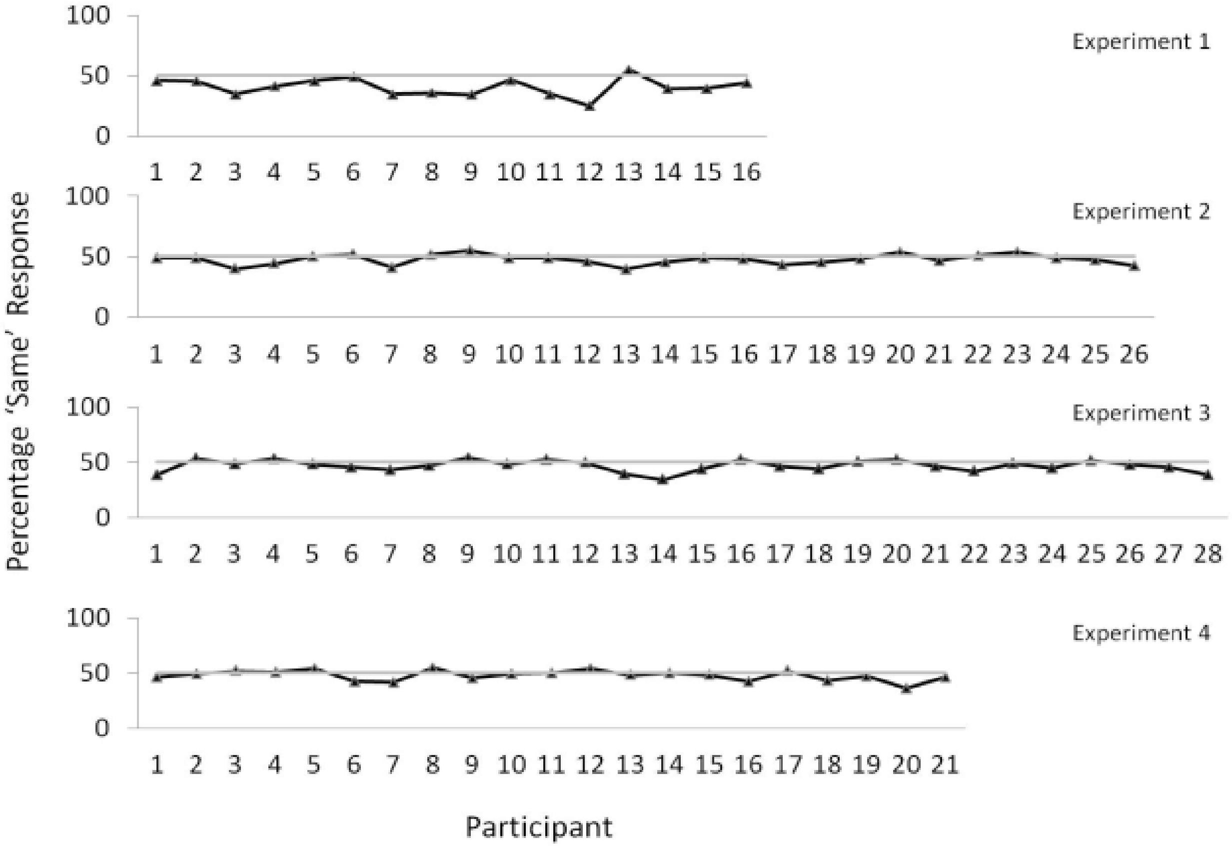

Fig 5.1 Percentage of 'same' responses for each participant in all four experiments.

5.3 Experiment 12

Experiments 9 and 10 represented two kinds of free choice decisions that ranged from simple ('select a location') to more considered ('select your most/least preferred product'). Both types of decision were therefore based on personal preference. In Experiment 12 we explored the generality of this effect by examining whether seeing a response could influence a relative judgement[20] concerning physical attractiveness. Using the same paradigm, participants were presented with pairs of faces and asked to decide which of the two would be considered the most (or least) physically attractive by the majority of people. As before, they indicated their decision with a reaching response.

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[20] A judgement based on the participant's comparison of the stimulus to an internal psychological standard or referent.

Method

All aspects of the method were as reported in Experiment 11 with the following exceptions: 16 of the 28 participants, aged between 21 and 26 years were female, and none had taken part in Experiments 9 or 10. The stimuli were colour photographs of male or female faces taken from a library of images held at the University of Essex. The images were cropped to show the face with only a minimal amount of hair. Half the faces were male and half female but the pairs always comprised faces of the same sex. Prior to the experiment, an observer who was naive to the rationale and aims of the experiment was asked to sort the faces into pairs that were of similar attractiveness until 52 face pairs were generated. Thus, each participant was presented with the same pairs of faces four times over the course of the experiment, twice when judging which was the most attractive, and twice when judging which was the least attractive. Participants were asked to 'scan both faces and decide which one they thought most people would consider more physically attractive'. In a second block participants were asked to decide which of the two they thought would be considered as less attractive. Participants always had a full vision of the apparatus and their co-actor.

Results and Discussion

All reaching responses were registered by the touch-screen. Again, we compared the proportion of responses to the same location as a partner's previous response with the chance value of 50%. This analysis showed that participants responded to the same location on 46.6% (SD = 5.1) of trials (see Fig 5.1 for all 'same' responses in Experiment 12). A one sample t-test revealed this to be significant, t(27) = 3.5, p <. 002, Cohen's d =. 66, (95% confidence interval: lower = 44.7%, upper = 48.9%). Moreover, the within-person IOR effect was significant (t (27) = 2.6, p <. 05, Cohen’s d =. 49). However, this effect went in the opposite direction to what is expected for IOR, so that participants significantly preferred going to the same location relative to their own previous response (M = 53.4%; SD = 7.0).

Responses with respect to the specific judgement (i.e., most attractive, least attractive) were also analysed. This again showed no reliable effect of decision type, with ‘most attractive’ accounting for 45.1% of same responses, and ‘least attractive’ accounting for 48.1%, t(27) = 2.0, p >.05, Cohen’s d =. 46. There was also no RT effect; same RT = 1300 (SD = 494), different RT = 1294 (SD = 528), t(27) =. 37, p >. 71, Cohen’s d =. 01. Finally, the random-pairs analysis we performed in Experiments 10 and 11 again showed that same responses did not differ from chance, 49.3% (SD = 3.1), t(27) =. 27, p > 0.27, Cohen’s d = 0.23. In sum, these results reveal that social IOR can influence relative judgements, concerning facial attractiveness. These data thus concur with those from Experiments 10 and 11.

5.3 Experiment 13

The results of Experiments 10–12 suggested that participants tended to avoid selecting stimuli occupying the same location as their partner’s previous choice. The final Experiment 13 examined the possibility that instead of social IOR, a response strategy or bias underlies the effect. It is of particular importance to examine this issue in the present context because certain biases, for example a tendency to respond to one side of the display, could generate a pattern of data that resembles the observed phenomenon. For instance, if both participants happen to have a response bias to their right (or both to their left), this would appear as if they are avoiding each other’s previous location. Indeed, although no significant laterality bias was present in Experiments 10 and 12, there was such in Experiment 11 (Experiment 10: 49.9% of responses to the left, t (15) = 0.04, p > 0.96; Experiment 11: 53.4% of responses to the right, t(25) = 4.6, p < 0.01; Experiment 12: 51.9% of responses to the right, t(27) = 1.0, p > 0.32).

This issue is currently addressed in each experiment by analysing the data of the randomly combined participant pairs. Although the results suggest the bias account does not explain the effect, the present experiment offered a direct test of this possibility. Experiment 13 was a close replication of the method employed in Experiment 12 with the exception that one of the co-actors was the author who acted as a confederate. Her responses were predetermined such that she made an equal number of left and right responses. This approach is analogous to a standard visual attention experiment in which ‘cues’ are equally distributed between left and right, a design that controls for any issues associated with response bias. Thus, if participants were simply biased to go to a particular side, then no social IOR effect in responses should occur, as the confederate’s choice was equally balanced between left and right and consequently, the same and different locations.

Method

All aspects of the method were as reported in Experiment 12 with the exceptions that 21 participants (16 females) aged between 20 and 27 years performed with a confederate who is also the author. All participants were right-handed.

A small grey dot appeared at the far bottom corner of the display, under the face to which the confederate had to respond (See Fig 5.2). When asked after the experiment, none of the participants stated that they saw the dot. Because the basic effect in Experiments 11 and 12 did not differ according to type of decision (e.g., preferred or non-preferred), participants in Experiment 13 only performed one block of trials in which they were required to reach to the face that would be considered more attractive by most people. As in all other experiments in Chapter 5, the task was performed under a full vision condition.

Fig 5.2 The stimuli in Experiment 13. The figure illustrates a trial where the confederate is meant to respond according to the location of the small grey dot, appearing at the far bottom corner of the screen. Note that an arrow has been placed here for illustration purposes only and one did not appear in the actual experiment.

Results and Discussion

Only one response was not registered by the touch-screen. Results showed that participants were less likely than chance to choose the face located in the position where the confederate had just responded to (47.7%; SD = 4.8; see Fig 5.1 for all 'same' responses in Experiment 13). A one sample t-test revealed this to be significant, t(20) = 2.2, p <. 038, Cohen's d =. 49, (95% confidence interval: lower = 45.7%, upper = 49.8%). Again, there was no effect of RT; same RT = 1054 (SD = 212), different RT = 1053 (SD = 232); t(20) =. 13, p >. 89, Cohen's d

<. 01. Moreover, as in Experiments 11 and 12, no within-person IOR effect was found: same response = 51.5%; SD = 7.1, t(20) =. 97, p >.35, Cohen's d =. 21.

There was however a bias towards reaching to the right (67.3% of responses were executed to the right, t(25) = 6.0, p < 0.01). It should be emphasized that even though such a right-ward bias emerged, this does not have any bearing to the proportion of responses to the same and different locations.

In sum, these findings replicate the effect that emerged in Experiment 12 concerning facial attraction and more generally the results of Experiments 10 and 11.

5.4 General Discussion

This last empirical chapter examined whether similarly to IOR, social IOR could influence decision making. Moreover, while Experiments 10 and 11 tested personal preference, Experiments 12 and 13 tested relative judgement. Results revealed that participants tended to choose the item that appeared in the different location in respect to where their partner responded on a previous trial. This was regardless of whether they were selecting between two identical squares, commercial products or faces. The present findings also indicated that the partner's choices influenced one's decisions.

These results are in line with those from previous studies examining free choice in both basic IOR (e.g., Wilson & Pratt, 2007) and social IOR (Reid et al., 2013). For instance, in their IOR free choice task, Wilson and Pratt (2007) found that when the SOA between a peripherally-presented cue and a 'go' tone was long (800 ms), participants were more likely to choose the uncued location. Moreover, in almost identical to the present task, Reid et al. (2013) found that participants were significantly less likely to select the 'same' location (44%) as compared to the ‘different’ location (which was chosen on the remaining 56% of the trials). The same was found in all of the present four experiments – participants demonstrated a preference for the location, opposite to the one their partner went to on a previous trial. Moreover, this was found not only when participants had to make a relatively simple choice where no strong personal preference was likely to be present (Experiment 10) but also in situations where the observed effect presumably competed with such a preference as in Experiments 11-13 where a more considered decision was required. However, although participants exhibited a much stronger preference for the ‘different location’ as they chose the ‘same’ on only 40.6% of the trials in Experiment 10 and this difference was less apparent in the other three experiments (47.6%, 46.6% and 47.7%, respectively), participants’ choice still significantly differed from chance, suggesting that the observed effect is rather robust and can override presumably higher-order personal preferences.

The results of Chapter 5 are generally consistent with the two social IOR accounts of the observed effect (both with Cole et al.’s and Welsh et al.’s, explained in Section 1.1.3), according to which inhibitory processes are involved in biasing attention and consequently, action away from previously examined locations. As mentioned previously, the social IOR procedure is very similar to the basic (within-participant) IOR one. Thus, in the present context, the observation of the partner’s target and/or arm reach together with the relatively long interval between this ‘cue’ and the participant’s target (See Method) possibly resulted in an inhibition of subsequent attentional shifts and/or motor programming to that location. The present results do not provide greater support for one of the two social IOR accounts over the other (i.e., whether what is inhibited is the response codes, generated by the observation of the partner’s action (Welsh et al.) or the physical location that has been previously cued; Cole et al.). Neither do they go against the action co-representation account of the effect according to which the bias to choose the 'different' location stems from a response facilitation to repeat an observed movement (Ondobaka et al., 2012, 2013; explained in detail in Sections 1.2.1 & 1.2.4 and Chapter 3). Thus, instead of avoiding the partner's location, participants might have been choosing the 'different' location as it requires a movement congruent action to the one just observed. However, in light of the findings of Chapters 2-4, the present results are more likely to be due to social IOR than action co-representation. As proposed by Welsh et al. (2007, 2009) it must be equally uneconomical from an evolutionary perspective to reexamine an already familiar area, regardless of whether it has been investigated by the individual himself or by someone else. Such strategy is likely to have evolved to promote novelty and optimize search behaviour to ensure the adequate provision of food, shelter and avoidance of predators.

Still, it should be noted that some aspects of the present results do not entirely concur with the standard findings of forced-choice IOR and social IOR studies. There could be several explanations for the latter. First, a social IOR bias only emerged in terms of the response location participants went to but not in terms of an actual slowing of RTs when going to the 'same' location, as usually found in IOR and social IOR paradigms (Cole et al. 2012; Hayes et al., 2010; Skarratt et al. 2010; Posner & Cohen, 1984; Weger et al., 2008; Welsh et al., 2005, 2007, 2009; etc.). Although one could argue that the inhibitory effects in free choice tasks do not reveal in RT, significant RT differences were found in the free choice IOR task by Wilson and Pratt (2007) and the only other free choice task on social IOR (Reid et al., 2013). However, it is likely that such slowing down was not present in the current studies, due to participants not being instructed to respond as quickly as possible but rather to aim to make a response 'within a second or so of the cue' (See the Methods sections). However, alternatively, the present measure of temporal difference might not have been optimal as some have argued that IOR reveals itself only in the 'initial RT' component which is the time to orient attention to the inhibited stimulus (e.g., Howard & Lupianez, 1999). No such measure was obtained in the present studies; however, this would have corresponded to the interval between the appearance of one's target to the release of the home button. Still, Reid et al. (2013) found social IOR only in their Total Time (TT) measure (which is equivalent to the present RT measure) but failed to find such a difference in initial RTs. The second aspect of the data which differs from the standard findings of forced-choice IOR paradigms is that a significant within-participant IOR in response location occurred only in Experiment 10 but not in any of the other experiments (See the Results sections). However, as mentioned earlier, as the last three experiments presumably involved the activation of higher-order processes, it is possible that these interfered with the inhibitory bias in Experiments 11-13. Thus, the more considered decision in these last studies, as opposed to when participants had to choose between one of two identical locations, could have resulted in the previously-reported reduction in social IOR and a lack of within-participant IOR effect.

Finally, the present results have theoretical implications as they undermine the possibility that the 'gambler's fallacy' (Croson & Sundali, 2005) could be responsible for social IOR effects in general. The gambler's fallacy could be characterised as an illusion that patterns exist in random events or expressed in another way, it is one's tendency to believe that a repeat is less likely to occur when according to probability theory both a new and a repeated event have an equal chance (Wilke, Scheibehenne, Gaissmaier, McCanney & Barrett, 2014). Thus, it is possible that instead of being the result of inhibitory effects, social IOR is driven by the gambler's fallacy where co-actors implicitly assume that the upcoming target is less likely to occur at the same location relative to the different location. Thus, because they are anticipating the target to appear at the different location, they are less prepared to act to the same location, resulting in longer RTs. However, the present findings indicate that this is not the case as social IOR still occurred even when participants freely chose where to respond. Still, although less likely in light with what has been demonstrated about social IOR in Chapters 2-4, there is a possibility that to some extent participants tried to evenly distribute their responses[21] so that when they observed a response to one location, then on their turn, they went to the opposite one.

In the course of four experiments, ranging from making a simple to a more considered choice, the present chapter revealed that social IOR can bias decision making when one needs to make a speeded decision. The present effect, however, revealed itself in the percentage of responses to the same and different locations only, but it did not result in RT difference as in the previous chapters. Although the present results do not undermine the action co-representation account of the effect, they have theoretical implications for the understanding of social IOR and free choice in general.

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[21] Participants could have done this only to some extent as they consistently demonstrated a bias to avoid the 'same' location across all four experiments.

CHAPTER 6

6.0 GENERAL DISCUSSION

The present thesis explored an effect bridging the gap between two different branches of literature. On one hand, previous work has suggested that this so called ‘social IOR’ resembles a classic visual orienting phenomenon, often reported in the attentional literature (Inhibition of Return; Posner & Cohen, 1984). On the other hand, the interactive set-up of the paradigm reminds of an effect, arising from the co-representation of observed action (a movement-congruency effect), examined in the increasingly growing joint-action research (Ondobaka et al., 2012, 2013). Alternatively, however, the phenomenon could be the result of a combination of the two – it might stem from visuomotor inhibition, triggered by the stimulation of witnessed motor action (Welsh et al.’s account). In a series of four empirical chapters, the present work examined various characteristics of social IOR by making a reference to the predictions of both the bottom-up and top-down accounts of the phenomenon. Moreover, through manipulations of the standard paradigm, the current thesis also directly evaluated the plausibility of the three competing accounts, and thus researched the causes of the effect. Finally, Chapter 5 tested a novel, ‘side property’ of the effect – i.e., whether it expands to free choice decisions. Thus, by exploring the phenomenon from different angles, the present work firstly aimed to test (and possibly expand) what is known about this particular effect, standing at the borders of attentional and joint-action research. However, more generally, both through empirical investigation in Chapters 2-5 and a careful review of the joint-action literature, the present work also evaluated the contribution of low-level attentional processes to effects, considered to involve higher-order mental simulation of movement and/or action goals. Organised in four separate sections below, the General Discussion first provides a summary of the findings of each chapter, followed by the implications and limitations of the present research, and finally presents some ideas for future research on social IOR.

6.1 Summary of the Present Findings

First, Chapter 2 assessed whether social IOR possessed properties, characteristic of an attentional effect, and more specifically, classic IOR. By testing the standard social IOR effect under four different SOA conditions, Experiment 1 examined the temporal interval of the effect. The results revealed that it occurred only during the shortest SOA which agreed with what is already known about classic IOR (e.g., Castel et al., 2003, 2005; Samuel & Kat, 2003). Moreover, perceptual load modulated the effect so that it appeared only during low perceptual load and disappeared when the number of stimuli in the visual scene increased. These results are in line with what would be expected for classic IOR (Liu et al., 2014) and could be explained with the load theory of selective attention and cognitive control (Lavie et al., 2004). Finally, when the performance of low- and high-trait anxious individuals on the social IOR task was compared, Experiment 3 indicated that trait anxiety had no effect on the magnitude of the phenomenon. The same has been reported for classic IOR when neutral cues are used (Fox et al., 2002; Pérez Dueñas et al., 2009). Thus, in sum, social IOR was found to be a short-lived effect modulated by one of the mechanisms of selective attention (perceptual load) but not influenced by trait anxiety. These findings are in line with an attentional explanation of the effect, according to which social IOR is based on inhibition of return processes. However, Chapter 2 did not challenge the two alternative explanations of the effect which advocate either a partial or full reliance on action co-representation.

The aim of Chapter 3 was to disentangle the effects of ‘response location’ and ‘action type’ to the observed phenomenon. As outlined previously, the general findings of the paradigm fit three alternative explanations so that the slower responses to the ‘same’ location, typical of social IOR, could either stem from movement congruency effects (Ondobaka et al.), from an IOR-like inhibition (Cole et al.) or from a combination between the two (Welsh et al.). Therefore, when type of action is manipulated in the paradigm, each theory makes a different prediction about what should happen to the effect. First, in contrast with findings that similarity promotes action co-representation (Avenanti et al., 2010; Loula, Prasad, Harber & Shiffrar, 2005) and that the representation of the movement of different body parts is somatotopically-represented in the motor cortex (Buccino et al., 2001), a significant social IOR effect occurred in Experiment 4 even when there was a kinematic mismatch between the observed and the required-to-perform actions. Furthermore, Experiment 5 demonstrated that social IOR was not affected even when the co-actor's action was fully occluded from view, as long as participant's attention was directed to the target location via an attentional cue. Finally, in contrast to Ondobaka et al. (2012) when the effects of action type and location type were disentangled in Experiment 6, again a significant social IOR effect was observed but no movement congruency effect emerged. Overall, these findings challenged an account of the phenomenon based on action co-representation and do not fit with Ondobaka et al.'s and Welsh et al.'s theories. Rather, the present findings suggested that the effect is more likely to be due to IOR, induced by an attentional shift (Cole et al.).

The following Chapter 4 provided a logical continuation of the theme concerning the role of action co-representation in the social IOR effect. It assessed the impact and importance of a biological co-actor to the effect. First, Experiment 7 presented contrary findings to previous research, which demonstrated that joint-action effects can be modulated by social cues (Leighton et al., 2010), as well as by the valence of the relationship between the two co-actors (Hommel et al., 2009; Iani et al., 2011). Nonetheless, in two separate manipulations, Experiments 7a and

7b indicated that social IOR did not manifest in a greater magnitude when participants acted with a person they presumably felt more confident with and that a significant effect emerged irrespective of the relationship between the two co-actors. Moreover, Experiments 8 and 9 further examined the socialness of the effect by testing whether social IOR would still occur if respectively, no partner was present during the task or instead of a biological co-actor, attention-capturing transients moved to the target on the partner's trial. Although the findings of Experiment 8 did not provide a definite answer, Experiment 9 showed that the presence of a biological partner is not necessary for the effect to emerge. The opposite is predicted if the present effect relied on action co-representation as clearly no simulation/mental integration of represented action (Sebanz et al., 2003, 2006; Tsai et al., 2008) was possible in these last two experiments. Chapter 4 thus suggested that the effect of interest is not likely to be social in nature. These findings also fit with Cole et al.'s attentional shift hypothesis that the phenomenon stems from inhibition of return processes, rather than from direct matching between observed and required actions.

Finally, having examined the causes of the effect and some of its basic characteristics, Chapter 5 went on to explore a further property, reported for some perceptuo-attentional effects (e.g., Kiesel, 2006; Klapp & Hinkley, 2002), among which classic IOR (Posner et al., 1985; Wilson & Pratt, 2007). Thus, the last Chapter 5 assessed whether social IOR could influence speedy, free choice decisions. Using the standard social IOR paradigm, over the course of four experiments, participants either freely chose one of the locations where the usual target appeared (Experiment 10), made a decision about their preference for a commercial product (Experiment 11) or the *relative* attractiveness of two presented human faces (Experiments 12 and 13). Thus, the participants' choice varied from simple (‘select a location’) to more complex (‘which face is more/less attractive?’) and from personal to relative, respectively. A significant social IOR effect emerged in all four experiments, indicating that one’s decisions were influenced by the partner’s choices, irrespective of what type of decision was required. Despite not in contrast with the action co-representation account, these results support previous studies examining free choice in both basic IOR (e.g., Wilson & Pratt, 2007) and social IOR (Reid et al., 2013).

6.2 Implications and Contributions to the Literature

The present work has several theoretical implications both to the visual attention and the joint-action literature. On first place, it replicated previous findings concerning the social IOR effect. For example, in line with prior research, the present experiments always revealed significant social IOR when the task was performed with a biological co-actor and within the standard trial time course, used in previous research (e.g., Atkinson et al., 2014; Hayes et al., 2010; Skarratt et al., 2010; Welsh et al., 2005). Moreover, an effect emerged both when barriers were employed in the paradigm, as in earlier studies (Skarratt et al., 2010; Welsh et al., 2007, 2009) and when the two co-actors had a full vision of the apparatus and the partner’s actions, as reported in more recent papers (e.g., Atkinson et al., 2014; Cole et al., 2012; Reid et al., 2013; Welsh et al., 2014). In this vain, these studies also supported the general movement congruency effect, as another way to interpret the difference in RT in the standard social IOR procedure (where participants sit opposite) is that movement-congruent responses are executed more swiftly than movement-incongruent ones (e.g., Brass et al., 2000; Liepelt et al., 2008; Ondobaka et al., 2012, 2013). Moreover, the findings of the present thesis are also in line with other research and well-established theories, such as the load theory of selective attention and cognitive control (Lavie et al., 2004), Eysenck et al.'s (2007) attentional control theory, the referential coding account (Dolk et al., 2011, 2013; Guagnano et al., 2010), the coordination dynamics approach (Fine & Amazeen, 2011; Fineet al., 2013; Richardson et al., 2009), etc.

The present research, however, also made several novel contributions to the literature. On first place, it researched the basis of the effect from several different angles by addressing four original research questions. These were: What characteristics does social IOR share with IOR? (Chapter 2); What role does action play in the effect? (Chapter 3); What is the importance of the relationship between the two co-actors and the co-actor's intentionality to social IOR (Chapter 4) and Can the phenomenon influence other processes, such as decision making? (Chapter 5). This involved conceiving and utilizing an original modification of the paradigm (Experiment 6) to neatly distinguish between the two potential factors, contributing to the effect – 'location type' and 'action type'. By examining these in isolation, the present work provided convincing evidence that the effect is driven by IOR processes. This is a particularly important methodological implication as previous research has confounded the effects of these two factors both when using the standard social IOR paradigm (Atkinson et al., 2014; Cole et al., 2012; Hayes et al., 2010; Ondobaka et al., 2012; Reid et al., 2013; Skarratt et al., 2010; Skarratt et al., 2012; Welsh et al., 2005, 2007, 2009b, 2014) and to some extent, even when attempting to distinguish between the two (Welsh et al., 2009a). This is so as when two co-actors sit next to each other, as in Welsh et al. (2009a), still different actions are executed to the shared target location, placed in the middle and to the two outer locations, which does not provide as neat comparison as the one in the present Experiment 6. Furthermore, Experiment 6 is the only study up to date that investigated hemifield inhibition (as opposed to location-based inhibition) in the social IOR effect. The latter revealed a significant RT advantage when the cue and target appeared at different hemifields as opposed to the same hemifield which is consistent with studies demonstrating hemifield inhibition in classic IOR (e.g., Tassinari et al., 1987, 1994; Berlucchi et al., 1989). However, although the findings of Experiment 6 made a contribution to the literature on social IOR, these still need to be interpreted with caution before they have been replicated by a further investigation. Moreover, the present investigation into the socialness of the effect also had important theoretical and methodological implications. More specifically, while a previous study had researched the effect of the co-actor's animacy on social IOR (Skarratt et al., 2010), the impact of the personal relationship between the two co-actors, examined in Experiment 7, has never been explored before. The latter results not only provided further support to the theory that the present effect is similar to IOR but also had another valuable theoretical implication. By demonstrating that an effect termed 'social IOR' is not modulated by social factors, this chapter also questioned the appropriateness of the term 'social IOR' and invited a discussion onto what other term could be more suitable (one option is substituting the term 'social' for 'joint', similarly to Dolk et al. who refer to the SSE as the Joint Simon effect). Finally, the findings of Chapter 5 provided both important insights from a theoretical perspective as well as novel information of how the present effect could spread to and influence higher-order processes. Thus, on first place they confirmed that social IOR is a robust, stable phenomenon which cannot be accounted for by an implicit assumption that the target is less likely to appear at a repeated location (the effect is not driven by the gambler's fallacy; Croson & Sundali, 2005). This was particularly important to examine as the results of the standard forced-choice social IOR task are indeed consistent with such an assumption. However, the results of Chapter 5 convincingly demonstrated that the effect occurs even when the co-actors freely chose where to respond. Moreover, these findings expanded the single previous study on social IOR and free choice (Reid et al., 2013) by demonstrating that social IOR biased not only simple choices (i.e., location preference) but also more complex preferences (i.e., choosing between two commercial products), as well as relative judgements about facial attractiveness. However, such a bias was only studied as long as social IOR lasts, meaning that Chapter 5 explored how it affects speedy decisions in particular. Studying the after-effects of this bias was beyond the scope of the present research. However, it seems an interesting idea for a future exploration.

Finally, in more general terms, the present work has potential implications to joint-action research as it evaluated the importance of low-level attentional processes to one particular joint-action phenomenon. The latter effect has been largely neglected in the action observation and joint-action literature, especially after the quick advance of mirror neuron research. In contrast, the present thesis provided research evidence that a phenomenon, interpreted by some as stemming from the imitation/co-representation of action (Ondobaka et al., 2012, 2013) is in fact more likely to be based on low-level inhibitory processes. Thus, the current work contributed to the quickly growing literature advocating an alternative explanation to some joint-action effects. One such account is the referential coding account of the SSE in which actions are coded with respect to their relative location and in this vain the co-actor’s agency (rather than intentionality) triggers the formation of a spatial reference frame (Dolk et al., 2011, 2013, 2014). Moreover, as mentioned in the General Introduction, Liepelt et al. (2011, 2013) proposed a somewhat similar alternative to the action co-representation account – that the SSE depends on low level feature integration based on the requirements of the previous trials. Finally, even more closely related to the present paradigm, the Coordination

Dynamics Approach argues against the involvement of action co-representation in the movement congruency effect. Within this account, the effect is driven by the anatomical congruence of the two co-actors' actions, rather than the mental simulation of action (e.g., Fine & Amazeen, 2011). Thus, the present work might facilitate a more considerate examination of low-level attentional processes in future joint-action studies.

6.3 Limitations of the Present Work

There are two main limitations of the present work – one is focusing solely on visually-induced social IOR, while neglecting how (and whether) other types of sensory cues could influence the effect; the other concerns the inconsistent use of barriers during the different experiments.

First, a somewhat minor limitation of the present work is that all reported experiments in the current thesis explored only the effect of visual cues in the paradigm but not how auditory cues influence it. While there is evidence that classic IOR could occur in response to auditory stimuli (Schmidt, 1996), a very recent social IOR study reported the opposite for the present effect (Welsh et al., 2014). It was found that when access to any other visual cues was restricted and participants could only hear their partner's response – no significant social IOR effect emerged. Thus, incorporating an auditory condition in the present Experiments 8 and 9, for instance, would have provided a more complete insight into what type of sensory cues drive the phenomenon (i.e., Is it just visually-induced?).

Second, the present thesis incorporated experiments, some of which done under partial viewing conditions (a barrier was introduced), and some – under full viewing conditions. While the first method has been recommended by earlier papers

(Skarratt et al., 2010; Welsh et al., 2007, 2009), in the Discussion section of Chapter 4, the present author argues that the latter is not necessarily 'the strictest test of socially-induced IOR' (as submitted by Skarratt et al., 2010, p. 49) as it is essentially based on Welsh et al.'s (2007) explanation of the effect. According to it, social IOR occurs because of a combination between the generation of response-evoked motor codes and IOR processes. Essentially, this method excludes an alternative explanation of the effect, such as Cole et al.'s attentional shift hypothesis as it assumes that the effect is inherently social. However, although the latter interpretation provided a reasonable rationale why not to incorporate a barrier, the impact of visual condition on the magnitude of social IOR was examined only in a couple of experiments in the present thesis (Experiments 3 & 5). It should be noted that indeed, a barrier was not used in many of the other experiments as the effect of the partner's transients was exactly the one being assessed as capable to produce a significant social IOR (e.g., Experiments 8 & 9). Nevertheless, a better, more robust measure of the impact of viewing condition on the effect would have been the incorporation of a barrier in all experiments where this was possible.

6.4 The Future of Social IOR Research

Until recently, social IOR research was still in its 'infancy', as until 2013, only a handful of papers, calling the effect social IOR/between-participants IOR were published. As described earlier, the very recent years have seen a growth in research, exploring the suspected bottom-up basis of some joint-action effects, which in turn, also resulted in a greater interest in the present phenomenon. However, being a relatively unexplored effect, social IOR still provides a lot of room for novel research ideas.

Future research should on first place examine the neural correlates of the observed slowing down of responses, characteristic of the effect. This will by far provide the strictest test of the plausibility of each theory on social IOR. Therefore, a research into the ERP components, associated with the effect, could lead to invaluable insights into the basis of the phenomenon as a lot is known about the ERP markers of both IOR and motor action. Indeed, up to date only behavioural work on social IOR has been conducted, which makes such an investigation not only desirable but also necessary. As outlined in Section 1.1.2.1 of the General Introduction, while traditional IOR is associated with a peak in the early P1 and/or N1 ERP components, it does not have an effect on the LRP, which is a marker of motor selection and preparation (Prime & Ward, 2004, 2006). At the same time, LRP is known to rise during action observation and when the observed action is predictable, to even occur prior to its onset (e.g., Kilner, Vargas, Duval, Blakemore, & Sirigu, 2004). Data collection on such an ERP study on social IOR is currently conducted by the author.

Moreover, as a continuation of Chapter 5, one could also examine the effect of social IOR on other behaviours and processes. For example, one could explore whether the social IOR bias overrides the objective perceptual processing of the characteristics of presented objects. Similarly to Experiments 10-13, in the two possible target locations, instead of pictures, two vertical lines, could be simultaneously presented. So that while on some trials one is slightly longer than the other, on other trials – the two lines will be of a similar length. Then, participants would have to make a speedy decision about which line was the longer/shorter one, by responding to it. Thus, it would be interesting to examine whether participants will be able to make a correct perceptual judgement about the length of the lines or similarly to Experiments 10-13, their decisions will be compromised depending on the location their partner selected on a previous trial. The same could be done with various other perceptual characteristics, such as judging the brightness of two objects of a similar colour (i.e., reach for the brighter/less bright object).

Finally, the proposition that social IOR might be a visual search facilitator, like classic IOR (Klein & MacInnes, 1999) could also be explored. One way in which this could be done is testing participants in a search-letter paradigm where among several letter distractors, displayed on both sides of the screen, a target letter is presented. Consistent with the standard social IOR procedure, on half of the trials, this target should appear on the right handside of the screen, while on the other half – on the left handside. If social IOR is indeed essentially an IOR effect, participants should identify the target letter more quickly when it is presented at a novel location, compared to their partner's previous response. Consequently, they should inhibit the processing of the letter if it appears at the 'same' location and thus be slower to identify it among the distractors.

6.5 Conclusion

The present work examined the causes and properties of the social IOR effect, defined by the slowing down of RT whenever a participant, sitting opposite another happens to repeat the response location of their co-actor. Thirteen original experiments, organised thematically in four empirical chapters investigated the effect from various angles. The results of the experiments of each chapter were consistent with one another as well as with the findings of the other chapters. Moreover, each empirical chapter gradually built on the previous one, aiming to present a complete picture of the effect, its basis and properties. Thus, Chapter 2 indicated that social IOR shared a number of similarities with its within-participants counterpart (classic IOR) such as having a similar time-course, being modulated by perceptual load but not by trait anxiety. Further, Chapter 3 directly examined the role of action type on the phenomenon. The first two experiments demonstrated that the present effect was not influenced by the kinematic match between the observed and the required actions or whether the co-actor's action was visible or not. Moreover, importantly the third experiment showed that when the paradigm was modified in such a way that the effect of action congruency could be isolated, no such effect emerged. Chapter 4 further demonstrated that paradoxically, social IOR is *not social* in nature as it occurred as long as a sufficiently salient event was introduced in the task. Thus, the effect did not change as a function of the valence of the relationship between the two partners nor depending on whether there was a biological partner to take turns with the participant. Finally, the last Chapter 5 demonstrated an interesting property of the present effect – that the social IOR bias was capable of influencing free choice decisions beyond chance level. Moreover, this was found to extend to both simple decisions and more complex ones as well as to both personal and relative judgements.

Taken together, the present findings are mostly consistent with Cole et al.'s attentional shift hypothesis according to which the effect is triggered by visuomotor inhibition, like classic IOR and that contrary to Ondobaka et al.'s prediction, action co-representation does not seem to contribute to the effect. Although not without limitations, the present thesis has significant implications not only for the better understanding of the social IOR effect but also concerning the role of attentional orienting in joint-action paradigms in general.

7.0 REFERENCES

Abrams, R.A., & Dobkin, R.S. (1994). Inhibition of return: Effects of attentional cuing on eye movement latencies. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 467–477.

Abrams, R.A., & Pratt, J. (1996). Spatially-diffuse inhibition affects multiple locations: A reply to Tipper, Weaver, and Watson (1996). *Journal of Experimental Psychology: Human Perception and Performance, 22,* 1294-1298.

Ainley, V., Brass, M., & Tsakiris, M. (2014). Heartfelt imitation: high interoceptive awareness is linked to greater automatic imitation. *Neuropsychologia*, *60,* 21-28.

Andersen, S.M., & Chen, S. (2002). The relational self: An interpersonal social-cognitive theory. *Psychological Review, 109,* 619–645.

Aron, A., Aron, E.N., Tudor, M., & Nelson, G. (1991). Close relationships as including other in the self. *Journal of Personality and Social Psychology, 60,* 241–253.

Ashby, F., G., Isen, A. M. & Turken, U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review, 106(3),* 529-550.

Atkinson, M. A., Simpson, A., Skarratt, P. A., & Cole, G. G. (2014). Is social inhibition of return due to action co-representation?. *Acta Psychologica*, *150*(14), 85-93.

Atmaca, S., Sebanz, N., & Knoblich, G. (2011). The joint flanker effect: Sharing tasks with real and imagined co-actors. *Experimental Brain Research, 211,* 371–385.

Atmaca, S., Sebanz, N., Prinz, W., & Knoblich, G. (2008). Action co-representation: The joint SNARC effect. *Social Neuroscience, 3,* 410-420.

Avenanti, A., Sirigu, A., & Aglioti, S. (2010). Racial bias reduces empathic sensorimotor resonance with other-race pain. *Current Biology: CB*, *20*(11), 1018-1022.

Baron-Cohen, S., Jolliffe, T., Mortimore, C., & Robertson, M. (1997). Another advanced test of theory of mind: evidence from very high functioning adults with autism or Asperger Syndrome. *Journal of Child Psychology and Psychiatry, 38*, 813-822.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a theory of mind? *Cognition, 21,* 37-46.

Bäuml, K.-H., & Kuhbandner, C. (2009). Positive moods can eliminate intentional forgetting. *Psychonomic Bulletin and Review, 16,* 93-98.

Bayliss, A. P., & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism spectrum as a function of target context. *British Journal of Psychology. 96,* 95-114.

Berlucchi, G., Tassinari, G., Marzi, C.A., & Di Stefano, M. (1989). Spatial distribution of the inhibitory effect of peripheral non-informative cues on simple reaction time to non-fixated visual targets. *Neuropsychologia, 27,* 201-221.

Binkofski, F., & Buccino, G. (2006). The role of ventral premotor cortex in action execution and action understanding. *Journal Of Physiology-Paris*, *99*(4-6), 396-405.

Böckler, A., Knoblich, G., & Sebanz, N. (2011). Giving a helping hand: Effects of joint attention on mental rotation of body parts. *Experimental Brain Research, 211*, 531-545.

Böckler, A., Knoblich, G., & Sebanz, N. (2012). Effects of a coactor's focus of attention on task performance. *Journal Of Experimental Psychology: Human Perception And Performance*, *38*(6), 1404-1415.

Botvinick, M., & Cohen, J. (1998). Rubber hands "feel" touch that eyes see. *Nature, 391*(6669), 756.

Brass, M., Bekkering, H., & Prinz, W. (2001). Movement observation affects movement execution in a simple response task. *Acta Psychologica*, *106*(1-2), 3-22.

Brass, M., Bekkering, H., Wohlschlager, A., & Prinz, W. (2000). Compatibility between observed and executed finger movements: Comparing symbolic, spatial, and imitative cues. *Brain Cognition, 44*(2), 124–143.

Braun, D. A., Ortega, P.A., Wolpert, D. M. (2011). Motor coordination: when two have to act as one *Experimental Brain Research 211,* 631-641.

Brefczynski, J. A., & DeYoe, E. A. (1999). A physiological correlate of the'spotlight'of visual attention. Nature neuroscience, 2(4), 370-374.

Broadbent, D. E. (1958). *Perception and communication*. London: Pergamon Press.

Buccino, G., Binkofski, F., Fink, G., Fadiga, L., Fogassi, L., Gallese, V., & Freund, H. (2001). Action observation activates premotor and parietal areas in a somatotopic manner: an fMRI study. *The European Journal Of Neuroscience*, *13*(2), 400-404.

Buck, J., & Buck, E. (1976). Synchronous fireflies. *Scientific American, 234*, 74-79.

Buonocore, A., & McIntosh, R. (2012). Modulation of saccadic inhibition by distractor size and location. *Vision Research*, *69,* 32-41.

Calvo, M. G., & Castillo, M. D. (1995). Phonological coding in reading comprehension: The importance of individual differences. *European Journal of Cognitive Psychology, 7,* 365–382.

Calvo, M. G., & Eysenck, M. W. (1996). Phonological working memory and reading in test anxiety. *Memory, 4,* 289–305.

Caparos, S. & Linnell, K. (2009). The interacting effect of load and space on visual selective attention. *Visual Cognition*, *17*(8), 1218-1227.

Castel, A. D., Chasteen, A. L., Scialfa, C. T., & Pratt, J. (2003). Adult age differences in the time course of inhibition of return. *Journal of Gerontology: Psychological Sciences, 58,* 256–259.

Castel, A. D., Pratt, J., Chasteen, A. L., & Scialfa, C. T. (2005). Examining Task Difficulty and the Time Course of Inhibition of Return: Detecting Perceptually Degraded Targets. *Canadian Journal Of Experimental Psychology/Revue Canadienne De Psychologie Expérimentale*, *59*(2), 90-98.

Cattaneo L, Fabbri-Destro M, Boria S, et al. (2007). Impairment of actions chains in autism and its possible role in intention understanding. Proc Natl Acad Sc iUSA, 104(45), 17825-17830.

Cattaneo, L., & Rizzolatti, G. (2009). The Mirror Neuron System. *Archives Of Neurology*, *66*(5), 557-560.

Chen, Q., Wei, P., & Zhou, X. (2006). Distinct neural correlates for resolving stroop conflict at inhibited and noninhibited locations in inhibition of return. *Journal Of Cognitive Neuroscience*, *18*(11), 1937-1946.

Chica, A. B., & Lupiáñez, J. (2009). Effects of endogenous and exogenous attention on visual processing: an Inhibition of Return study. *Brain Research*, *1278,* 75-85.

Chun, M. & Wolfe, J.(2005). Visual attention. In: Goldstein E B (ed.) *Blackwell handbook of sensation and perception* (pp.273-300). Malden, MA: Blackwell Publishing.

Clohessy, A. B., Posner, M. I., Rothbart, M. K., & Vecera, S. (1991). The development of inhibition of return in early infancy. *Journal of Cognitive Neuroscience, 3*, 345–350.

Cole, G. G., & Kuhn, G. (2009). Appearance matters: attentional orienting by new objects in the precuing paradigm. *Visual Cognition, 17*, 755–776.

Cole, G. G., & Kuhn, G. (2010). Attentional capture by object appearance and disappearance. *Quarterly Journal of Experimental Psychology, 63*, 147-159.

Cole, G. G., Smith, D, & Atkinson, M. (2015). Mental state attribution and the gaze cueing effect. *Attention, Perception & Psychophysics, 77*(4):1105-1115.

Cole, G., Skarratt, P., & Billing, R. (2012). Do action goals mediate social inhibition of return?. *Psychological Research*, *76*(6), 736-746.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Review Neuroscience*, *3*, 201–215.

Corbetta, M., Akbudak, E., Conturo, T., Snyder, A., Ollinger, J., Drury, H., Linenweber, M., Petersen, S., Raichle, M., Van Essen, D. & Shulman, G. (1998). A common network of functional areas for attention & eye movements. *Neuron, 21,* 761–773.

Croson, R., & Sundali, J. (2005). The Gambler's Fallacy and the Hot Hand: Empirical Data from Casinos. *Journal Of Risk & Uncertainty*, *30*(3), 195-209.

Cross, E. S., Hamilton, A. F., & Grafton, S. T. (2006). Building a motor simulation de novo: Observation of dance by dancers. Neuroimage, 31, 1257–1267.

Dalton, K. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience*, *8*(4), 519-526.

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: Social orienting, joint attention, and attention to distress. *Developmental Psychology, 40,* 271-283.

de Fockert, J., Caparos, S., Linnell, K. & Davidoff, J. (2011) Reduced Distractibility in a Remote Culture. *PLoS ONE, 6*(10), e26337.

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews, 3*(2), 71– 100.

Dehaene, S., Changeux, J., Naccache, L., Sackur, J., & Sergent, C. (2006). Conscious, preconscious, and subliminal processing: a testable taxonomy. *Trends In Cognitive Sciences*, *10*(5), 204-211.

Derryberry, D., & Reed, A. (1998). Anxiety and attentional focusing: trait, state and hemispheric influences. *Personality and individual differences, 25*, 745-761.

Deutsch, J. A., & Deutsch, D. (1963). Some theoretical considerations. *Psychological Review*, *70*, 80-90.

Dolk, T., Hommel, B., Colzato, L. S., Schütz–Bosbach, S., Prinz, W., & Liepelt, R. (2011). How 'social' is the social Simon effect? *Frontiers in Psychology, 2,* 84.

Dolk, T., Hommel, B., Colzato, L. S., Schütz-Bosbach, S., Prinz, W., & Liepelt, R. (2014). The joint Simon effect: a review and theoretical integration. *Frontiers In Psychology*, *5*974.

Dolk, T., Hommel, B., Prinz, W., & Liepelt, R. (2013). The (Not So) Social Simon Effect: A Referential Coding Account. *Journal of Experimental Psychology: Human Perception and Performance*.

Downing, P., Dodds, C., & Bray, D. (2004). Why does the gaze of others direct visual attention?. *Visual Cognition*, *11*(1), 71-79.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze Perception Triggers Reflexive Visuospatial Orienting. *Visual Cognition*, *6*(5), 509-540.

Eastough, D., & Edwards, M. G. (2007). Movement kinematics in prehension are affected by grasping objects of different mass. *Experimental Brain Research*, *176*(1), 193-198.

Elwood, L. S., Wolitzky-Taylor, K., & Olatunji, B. O. (2012). Measurement of anxious traits: a contemporary review and synthesis. *Anxiety, Stress & Coping*, *25*(6), 647-666.

Eriksen, C. W., & Hoffman, J. E. (1973). Extent of processing of noise elements during selective encoding from visual-displays. *Perception & Psychophysics, 14,* 155-160.

Eriksen*,* C.W.*, &* Yeh*,* Y.Y *(*1985*).* Allocation *of* attention *in the* visual field*. Journal of Experimental Psychology*: *Human Perception and Performance, 11,* 583-597.

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition and Emotion, 6,* 409–434.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7*(2), 336- 353.

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: a magnetic stimulation study. *Journal Of Neurophysiology*, *73*(6), 2608-2611.

Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *Neuroimage , 26,* 471–479.

Fine, J. M., & Amazeen, E. L. (2011). Interpersonal Fitts's law: When two perform as one. *Experimental Brain Research, 211,* 459–469.

Fine, J. M., Gibbons, C. T., & Amazeen, E. L. (2013). Congruency effects in interpersonal coordination. *Journal Of Experimental Psychology: Human Perception and Performance*, *39*(6), 1541-1556.

Flanagan, T., Brodeur, D. A., & Burack, J. A. (2015). A Point of Departure in the Comparison of Social and Nonsocial Visual Orienting Among Persons With Autism Spectrum Disorders. *Autism Research: Official Journal Of The International Society For Autism Research*.

Fletcher-Watson, S., Findlay, J. M.*,* Leekam, S. R. and Benson, V. (2008). Rapid detection of person information in a naturalistic scene. *Perception*, *37*(*4),* 571-583*.*

Fogassi, L., Ferrari, P., Gesierich, B., Rozzi, S., Chersi, F., & Rizzolatti, G. (2005). Parietal Lobe: From Action Organization to Intention Understanding. *Science*, *308*(5722), 662-667.

Fox, E. (1993). Attentional bias in anxiety: selective or not? *Behaviour Research and Therapy, 31*, 487-493.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition & Emotion*, *16*(3), 355-379.

Frischen, A., Loach, D., & Tipper, S. (2009). Seeing the world through another person's eyes: simulating selective attention via action observation. *Cognition*, *111*(2), 212-218.

Frith, U. (2003). *Autism: Explaining the Enigma.*(2nd ed.). Blackwell: Oxford.

Fuentes, L. (1999). Inhibitory Tagging of Stimulus Properties in Inhibition of Return: Effects on Semantic Priming and Flanker Interference. *The Quarterly Journal Of Experimental Psychology: Section A*, *52*(1), 149-164.

Galantucci, B., & Sebanz, N. (2009). Joint action: Current perspectives. *Topics in Cognitive Science, 1,* 255–259.

Gallese, V., Fadiga, L., Fogassi, L. & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain, 119*, 593–609.

Gandhi, S. P., Heeger, D. J., & Boynton, G. M. (1999). Spatial attention affects brain activity in human primary visual cortex. Proceedings of the National Academy of Sciences, 96(6), 3314-3319.

Gasper, K., & Clore, G. L. (2002). Attending to the big picture: Mood and global versus local processing of visual information. *Psychological Science, 13,* 34-40.

Greenwald, A. G. (1970) Sensory feedback mechanisms in performance control: With special reference to the ideomotor mechanism. *Psychological Review,* 77, 73–99.

Guagnano, D., Rusconi, E., and Umiltà, C. A. (2010). Sharing a task or sharing space? On the effect of the confederate in action coding in a detection task. *Cognition, 114,* 348–355.

Hamilton, A., Wolpert, D., & Frith, U. (2004). Your own action influences how you perceive another person. *Current Biology, 14,* 493–498.

Hamilton, A., Wolpert, D., Frith, U., & Grafton, S. (2006). Where does your own action influence your perception of another person's action in the brain?. *Neuroimage*, *29*(2), 524-535.

Hayes S., Hansen S. & Elliott, D. (2010). Between nervous system effects on attention and action: Joe and Fred revisited. *Psychological Research 74,* 302–312.

Heider, F. (1958). *The psychology of interpersonal relations.* New York: Wiley.

Helmholtz, H. v. (1866;1911).*Treatise on physiological optics*. Rochester: Continuum.

Hickok, G. (2009). Eight Problems for the Mirror Neuron Theory of Action Understanding in Monkeys and Humans. *Journal Of Cognitive Neuroscience*, *21*(7), 1229-1243.

Hommel, B. (1993). The role of attention for the Simon effect. *Psychological Research, 55,* 208–222.

Hommel, B. (1996). S-R compatibility effects without response uncertainty. *Quarterly Journal of Experimental Psychology, 49,* 546–571.

Hommel, B. (2009). Action control according to TEC (theory of event coding). *Psychological Research*, *73*(4), 512-526.

Hommel, B., Colzato, L. S., & van den Wildenberg, W. M. (2009). How social are task representations?. *Psychological Science*, *20*(7), 794-798.

Hommel, B., Müsseler, J., Aschersleben, G. & Prinz, W. (2001).The theory of event coding (TEC): a framework for perception and action planning. *Journal of Behavioral and Brain Science, 24,* 849–878.

Hopfinger, J., & Mangun, G. (2001). Tracking the influence of reflexive attention on sensory and cognitive processing. *Cognitive, Affective & Behavioral Neuroscience*, *1*(1), 56-65.

Howard, L. A., & Lupianez, J. (1999). Inhibition of Return in a Selective Reaching Task: An Investigation of Reference Frames. *Journal Of General Psychology*, *126*(4), 421-442.

Hu, Y., Jiang, H., Liu, C., Wang, J., Yu, C., Carlson, S., & ... Hu, X. (2013). What interests them in the pictures? — Differences in eyetracking between rhesus monkeys and humans. *Neuroscience Bulletin*, *29*(5), 553-564.

Hutchins, E. (1995). How a cockpit remembers its speeds. *Cognitive Science*, *19*, 265–288.

Iani, C., Anelli, F., Nicoletti, R., Arcuri, L., & Rubichi, S. (2011). The role of group membership on the modulation of joint action. *Experimental Brain Research*, *211*(3-4), 439-445.

James, W. (1890/1981) *The principles of psychology.* Macmillan/Harvard University Press. (Original work published 1890).

Jastorff, J., Begliomini, C., Fabbri-Destro, M., Rizzolatti, G., & Orban, G. A. (2010). Coding observed motor acts: different organizational principles in the parietal and premotor cortex of humans. *Journal Of Neurophysiology*, *104*(1), 128-140.

Jeannerod, M., Arbib, M. A., Rizzolatti, G., & Sakata, H. (1995). Grasping objects: the cortical mechanisms of visuomotor transformation. *Trends In Neurosciences*, *18*(7), 314-320.

Kaneko, S., & Murakami, I. (2009). Perceived duration of visual motion increases with speed. *Journal Of Vision*, *9*(7), 14.

Kiesel, A., Wagener, A., Kunde, W., Hoffmann, J., Fallgatter, A. J., & Stocker, C. (2006). Unconscious manipulation of free choice in humans*. Consciousness & Cognition, 15*, 397–408.

Kilner, J., Paulignan, Y., & Blakemore, S. (2003). An interference effect of observed biological movement on action. *Current Biology, 13 (6),* 522– 525.

Kingstone, A., & Pratt, J. (1999). Inhibition of return is composed of attentional and oculomotor processes. *Perception and Psychophysics, 61,* 1046-1054.

Klein, R., & MacInnes, W. (1999). Inhibition of Return is a Foraging Facilitator in Visual Search. *Psychological Science*, *10*(4), 346-352.

Klemmer, E. T. (1956). Time uncertainty in simple reaction time. *Journal of Experimental Psychology, 51,* 179-184.

Klin, A., Jones, W., Schultz, R., Volkmar, F & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry, 59,* 809–816.

Knoblich G, Butterfill S, Sebanz N. (2011).Psychological research on joint action: theory and data. In: Ross B (ed) *The psychology of learning and motivation, vol 54*. Academic Press, Burlington, pp 59–101.

Kohler, E., Keysers, C., Umilta, M. A., Fogassi, L., Gallese, V., & Rizzolatti, G. (2002). Hearing sounds, understanding actions: Action representation in mirror neurons. *Science, 297,* 846–848.

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus–response compatibility—a model and taxonomy. *Psychological Review, 97,* 253–270.

Kowler, E., Anderson, E., Dosher, B. & Blaser, E. (1995). The role of attention in the programming of saccades. *Vision Research, 35*, 1897–1916.

Kraut, R. E., & Johnston, R. E. (1979). Social and emotional messages of smiling: An ethological approach. Journal of Personality and Social Psychology, 37, 1539–1553.

Kuhbandner, C., Pekrun, R., & Maier, M. A. (2010). The role of positive and negative affect in the 'mirroring' of other persons' actions. *Cognition & Emotion*, *24*(7), 1182-1190.

Kuhn, G. & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Perception* & *Psychophysics*, *71(2),* 314–327.

Kuhn, G. & Land, M. F. (2006). There's more to magic than meets the eye. *Current Biology*, *16,* R950–R951.

Kuhn, G., Tatler, B., & Cole, G. (2009). You look where I look! Effect of gaze cues on overt and covert attention in misdirection. *Visual Cognition*, *17*(6-7), 925-944.

LaBerge, D. & Brown, V. (1989).Theory of attentional operations in shape identification. *Psychological Review, 96,* 101-124.

Lakin, J. L., & Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science*, *14*(4), 334-339.

Lambert, N. M., Gwinn, A. M., Baumeister, R. F., Strachman, A., Washburn, I. J., Gable, S. L., & Fincham, F. D. (2013). A boost of positive affect: The perks of sharing positive experiences. *Journal Of Social & Personal Relationships*, *30*(1), 24-43.

Langton, S. R. H., & Bruce, V. (2000) You *must* see the point: Automatic processing of cues to the direction of social attention. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 747-757.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General,* 133, 339-354.

Leighton, J., Bird, G., Orsini, C., & Heyes, C. (2010). Social attitudes modulate automatic imitation. *Journal Of Experimental Social Psychology*, *46*(6), 905-910.

Lepsien, J., & Pollmann, S. (2002). Covert reorienting and inhibition of return: An event-related fMRI study. *Journal of Cognitive Neuroscience, 14,* 127–144.

Liepelt, R., & Brass, M. (2010). Top-down modulation of motor priming by belief about animacy. *Experimental Psychology*, *57*(3), 221-227.

Liepelt, R., Cramon, D. V., & Brass, M. (2008). What is matched in direct matching? Intention attribution modulates motor priming. *Journal Of Experimental Psychology: Human Perception And Performance*, *34*(3), 578-591.

Liepelt, R., Stenzel, A., & Lappe, M. (2012). Specifying social cognitive processes with a social dual-task paradigm. *Frontiers in Human Neuroscience, 6,* 86.

Liepelt, R., Wenke, D., & Fischer, R. (2013). Effects of feature integration in a hands-crossed version of the Social Simon paradigm. *Psychological Research*, *77*(2), 240-248.

Liepelt, R., Wenke, D., Fischer, R., & Prinz, W. (2011). Trial-to-trial sequential dependencies in a social and non-social Simon task. *Psychological Research, 75*, 366–375.

Lingnau, A., Gesierich, B., & Caramazza, A. (2009). Asymmetric fMRI adaptation reveals no evidence for mirror neurons in humans. *Proceedings Of The National Academy Of Sciences Of The United States Of America*, *106*(24), 9925-9930.

Linnell, K. J., Caparos, S., de Fockert, J. W., & Davidoff, J. (2013). Urbanization decreases attentional engagement. *Journal Of Experimental Psychology: Human Perception And Performance*, *39*(5), 1232-1247.

Liu, X. J., Fan, Z. H., & Zhou, J. Z. (2014). The Influence of Perceptual Load on Inhibition of Return. *Advanced Materials Research*, *989*(1), 1093-1096.

Lotze, R. H. (1852) *Medicinische Psychologie oder Physiologie der Seele.* Weidmann.

Loula, F., Prasad, S., Harber, K., & Shiffrar, M. (2005). Recognizing People From Their Movement. *Journal Of Experimental Psychology. Human Perception & Performance*, *31*(1), 210-220.

Luck, S. J., Hillyard, S. A., Mouloua, M., Woldorff, M. G., Clark, V. P., & Hawkins, H. L. (1994). Effect of spatial cueing on luminance detectability: Psychophysical and electrophysiological evidence for early selection. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 887–904.

Lupiáñez, J., Milán, E. G., Tornay, F. J., Madrid, E., & Tudela, P. (1997). Does IOR occur in discrimination tasks? Yes, it does, but later. *Perception & Psychophysics*, *59*(8), 1241-1254.

Lupiáñez, J., Milliken, B., Solano, C., Weaver, B., & Tipper, S. P. (2001). On the strategic modulation of the time course of facilitation and inhibition of return. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 54,* 753-773.

Macdonald, J.S.P & Lavie, N. (2008). Load Induced Blindness. *Journal of Experimental Psychology: Human Perception and Performance 34(5*), 1078-1091.

Mayer, A. R., Dorflinger, J. M., Rao, S. M., & Seidenberg, M. (2004). Neural networks underlying endogenous and exogenous visual-spatial orienting. *Neuroimage, 23,* 534–541.

Mayer, A. R., Seidenberg, M., Dorflinger, J. M., & Rao, S. M. (2004). An Event-related fMRI Study of Exogenous Orienting: Supporting Evidence for the Cortical Basis of Inhibition of Return?. *Journal Of Cognitive Neuroscience*, *16*(7), 1262-1271.

Maylor, E. A., & Lavie, N. (1998). The influence of perceptual load on age differences in selective attention. *Psychology and Aging*, *13*, 563–573.

McDonald, J.J., Ward, L.M. & Kiehl, K.A. (1999). An event-related brain potential study of inhibition of return. *Perception & Psychophysics*, *61*, 1411–1423.

Mukamel, R., Ekstrom, A., Kaplan, J., Iacoboni, M. & Fried, I. (2010). Single-Neuron Responses in Humans during Execution and Observation of Actions. *Current Biology, 20(8),* 750-756.

Müller, B. N., Brass, M., Kühn, S., Tsai, C., Nieuwboer, W., Dijksterhuis, A., & van Baaren, R. B. (2011). When Pinocchio acts like a human, a wooden hand becomes embodied. Action co-representation for non-biological agents. *Neuropsychologia*, *49*(5), 1373-1377.

Müller, N. G., & Kleinschmidt, A. (2007). Temporal dynamics of the attentional spotlight:Neuronal correlates of attentional capture and inhibition of return in early visual cortex. *Journal of Cognitive Neuroscience, 19,* 587–593.

Néda, Z., Ravasz, E., Brechet, Y., Vicsek, T., & Barabási, A. (2000). Self-organizing processes: The sound of many hands clapping. *Nature*, *403*(6772), 849-850.

Nobre, A., Gitelman, D., Dias, E. & Mesulam, M. (2000).Covert visual spatial orienting and saccades: overlapping neural systems. *NeuroImage, 11,* 210–216.

Obhi, S. S., & Sebanz, N. (2011). Moving together: toward understanding the mechanisms of joint action. *Experimental Brain Research*, *211*(3-4), 329-336.

Ondobaka, S., de Lange, F. P., Newman-Norlund, R. D., Wiemers, M., & Bekkering, H. (2012). Interplay Between Action and Movement Intentions During Social Interaction. *Psychological Science (Sage Publications Inc.)*, *23*(1), 30-35.

Ondobaka, S., de Lange, F. P., Wittmann, M., Frith, C. D., & Bekkering, H. (2015). Interplay Between Conceptual Expectations and Movement Predictions Underlies Action Understanding. *Cerebral Cortex (New York, N.Y.: 1991)*, *25*(9), 2566-2573.

Ondobaka, S., Newman-Norlund, R. D., de Lange, F. P., & Bekkering, H. (2013). Action recognition depends on observer's level of action control and social personality traits. *Plos One*, *8*(11), e81392.

Otte*.* D. & Smiley*,* J. (1977). Synchrony in Texas fireflies with a consideration of male interaction models. *Biology of Behaviour, 2,* 143-158.

Pacherie, E. (2008). The phenomenology of action: A conceptual framework. *Cognition, 107,* 179-217.

Partridge*,* B. (1982). The structure and function of fish schools*. Scientific American,* 246, 114–123.

Paukner, A., Ferrari, P., & Suomi, S. (2011). Delayed imitation of lipsmacking gestures by infant rhesus macaques (Macaca mulatta). *Plos One*, *6*(12), e28848.

Paulus, M., & Moore, C. (2011). Whom to ask for help? Children’s developing understanding of other people’s action capabilities. *Experimental Brain Research, 211,* 593–600.

Peirce, J. W. (2009). Generating Stimuli for Neuroscience Using PsychoPy. *Frontiers In Neuroinformatics, 2,* 10.

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32(4),* 249–261.

Penfield, W. & Rasmussen, T. (1952). *The Cerebral Cortex of Man*. MacMillan. New York.

Pérez Dueñas, C., Acosta, A., & Lupiáñez, J. (2009). Attentional capture and trait anxiety: evidence from inhibition of return. *Journal Of Anxiety Disorders*, *23*(6), 782-790.

Pérez Dueñas, C., Acosta, A., Megías, J.L. & Lupiáñez, J. (2010). Evaluación de las dimensiones de valencia, activaci ón, frecuencia subjetiva de uso y relevancia para la ansiedad, la depresión y la ira de 238 sustantivos en una muestra universitaria. *Psicológica, 31*, 241-273.

Pickering, A.(1995). *The Mangle of Practice*. Chicago, University of Chicago Press.

Pikovsky, A., Rosenblum, M., & Kurths, K. (2001). *Synchronization: A universal concept in nonlinear sciences.* Cambridge, UK: Cambridge University Press.

Posner, M. I. (1980). Orienting of attention*. Quarterly Journal of Experimental Psychology*, *32*, 3–25.

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25–42.

Posner, M. I., Rafal, R. D., Choate, I. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology*, *2*, 211–228.

Posner, M.I. & Cohen, Y., (1984). Components of visual orienting. In: Bouma, H., Bouwhuis, D. (Eds.), *Attention and Performance*, vol. X. Lawrence Erlbaum, London, pp. 531-554.

Posner, M.I., Nissen,M.J. & Ogden, W.C. (1978). Attended and unattended processing modes: The role of set for spatial location. In Pick,H.L. & Saltzmai. N.J., (Eds), *Modes of Perceiving and Processing Information.* Hillsdale, N.J.: Lawrence Erlbaum Associates.

Prime, D. J., & Ward, L. M. (2004). Inhibition of return from stimulus to response. *Psychological Science*, *15*(4), 272-276.

Prime, D. J., & Ward, L. M. (2006). Cortical expressions of inhibition of return. *Brain Research*, *1072*, 161–174.

Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology, 9*, 129-154.

Purves, D., Augustine, G.A., Fitzpatrick, D., Katz, L.C., LaMantia, A.S. & McNamara, J.O. (Eds).(2001). *Neuroscience.* (2nd ed.). Sunderland, MA: Sinauer Associates.

Rafal, R. D., Calabresi, P. A., Brennan, C. W., & Sciolto, T. K. (1989). Saccade preparation inhibits reorienting to recently attended locations. *Journal Of Experimental Psychology: Human Perception And Performance*, *15*(4), 673-685.

Rapee, R. M., & Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behaviour Research and Therapy, 35,* 741–756.

Reed, C. L., Grubb, J. D., & Steele, C. (2006). Hands up: Attentional prioritization of space near the hand. *Journal Of Experimental Psychology: Human Perception And Performance*, *32*(1), 166-177.

Reid, C., Wong, L., Pratt, J., Morgan, C., & Welsh, T. N. (2013). IOR Effects in a Social Free-Choice Task. *Journal Of Motor Behavior*, *45*(4), 307-311.

Renner, P., Klinger, L. G., & Klinger, M. R. (2006). Exogenous and endogenous attention orienting in autism spectrum disorders. *Child Neuropsychology, 12,* 361-382.

Riby, D. M., & Hancock, P. B. (2008). Viewing it differently: Social scene perception in Williams syndrome and autism. *Neuropsychologia*, *46*(11), 2855-2860.

Richardson, M., Campbell, W., & Schmidt, R. (2009). Movement interference during action observation as emergent coordination. *Neuroscience Letters*, *449*(2), 117-122.

Richardson, D. C., Street, C. H., Tan, J. M., Kirkham, N. Z., Hoover, M. A., & Ghane Cavanaugh, A. (2012). Joint perception: gaze and social context. *Frontiers In Human Neuroscience*, *6*194.

Rinehart, N. J., Bradshaw, J. L., Moss, S. A., Brereton, A. V., & Tonge, B. J. (2008). Brief report: Inhibition of return in young people with autism and Asperger's disorder. *Autism*, *12*(3), 249-260.

Rizzolatti, G. & Craighero, L. (2004).The mirror neuron system. *Annual Review of Neuroscience, 27*, 169–192.

Rizzolatti, G., Fabbri-Destro, M. & Cattaneo, L. (2009).Mirror neurons and their clinical relevance. *Nature Clinical Practice Neurology*, *5,* 24–34.

Rizzolatti, G., Fadiga, L., Gallese, V. & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research, 3*, 131–141.

Rizzolatti, G., Riggio, L., Dascola, I. & Umiltfi, C. (1987) Reorienting attention across the horizontal and vertical meridians: evidence in favour of a premotor theory of attention. *Neuropsychologia, 25,* 31–40.

Rolke, B., & Hofmann, P. (2007). Temporal uncertainty degrades perceptual processing. *Psychonomic Bulletin & Review*, *14*(3), 522-526.

Romero, V., Coey, C., Schmidt, R. C., & Richardson, M. J. (2012). Movement Coordination or Movement Interference: Visual Tracking and Spontaneous Coordination Modulate Rhythmic Movement Interference. *PLoS ONE 7*(9): e44761.

Ruz, M. & Lupianez, J. (2002). A review of attentional capture: On it's automaticity and sensitivity to endogenous control*. Psicologica, 23,* 283– 309.

Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (2010). Seeing it their way: evidence for rapid and involuntary computation of what other people see. *Journal Of Experimental Psychology. Human Perception And Performance*, *36*(5), 1255-1266.

Samuel, A. G., & Kat, D. (2003). Inhibition of return: A graphical meta-analysis of its time course and an empirical test of its temporal and spatial properties. *Psychonomic Bulletin and Review, 10,* 897–906.

Santiago, J., & Lakens, D. (2014). Can conceptual congruency effects between number, time, and space be accounted for by polarity correspondence?. *Acta Psychologica*, *156,* 179–191.

Sarter, M., Gehring, W. J. & Kozak, R. (2006). More attention must be paid: the neurobiology of attentional effort. *Brain Research Review, 51,* 145-160.

Satel, J., Hilchey, M. D., Wang, Z., Reiss, C. S., & Klein, R. M. (2014). In search of a reliable electrophysiological marker of oculomotor inhibition of return. *Psychophysiology*, *51*(10), 1037-1045.

Schiller, P.H*.* (1977)*.* The effect of superior colliculus ablation on saccades elicited by cortical stimulation*. Brain Research*, *122*, 154–156*.*

Schlaghecken, F., & Eimer, M. (2000). A central-peripheral asymmetry in masked priming*. Perception & Psychophysics, 62*, 1367–1382.

Schmidt, W. C. (1996). Inhibition of return without visual input. *Neuropsychologia*, *34*(10), 943-952.

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: bodies and minds moving together. *Trends In Cognitive Sciences*, *10*(2), 70-76.

Sebanz, N. & Knoblich, G. (2009). Prediction in Joint Action: What, When, and Where. *Topics In Cognitive Science*, *1*(2), 353-367.

Sebanz, N., Knoblich, G., & Prinz, W. (2003). Representing others' actions: Just like one's own? *Cognition, 88,* B11–B21.

Sebanz, N., Knoblich, G., & Prinz, W. (2005). How two share a task. *Journal of Experimental Psychology: Human Perception and Performance, 31,* 1234–1246.

Sebanz, N., Knoblich, G., Prinz, W., & Wascher, E. (2006). Twin peaks: an ERP study of action planning and control in co-acting individuals. *Journal Of Cognitive Neuroscience*, *18*(5), 859-870.

Sereno, A., Briand, K., Amador, S., & Szapiel, S. (2006). Disruption of reflexive attention and eye movements in an individual with a collicular lesion. *Journal of Clinical and Experimental Psychology*, *28*, 145–166.

Shintel, H., & Keysar, B. (2009). Less is more: A minimalist account of joint action in communication. *Topics in Cognitive Science, 1,* 260–273.

Silver, M. A., Ress, D., & Heeger, D. J. (2005). Topographic maps of visual spatial attention in human parietal cortex. *Journal of neurophysiology, 94(2),* 1358-1371.

Simon, J. R. (1990). The effects of an irrelevant directional cue on human information processing. In R. W. Proctor & T. G. Reeve (Eds.), *Stimulus-response compatibility: an integrated perspective* (pp. 31–86). Amsterdam: North-Holland.

Simon, J. R., & Rudell, A. P. (1967). Auditory S–R compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology, 51,* 300–304.

Skarratt, P. A., Cole, G. G., & Kingstone, A. (2010). Social inhibition of return. *Acta Psychologica*, *134*(1), 48-54.

Skarratt, P. A. Cole, G. G. & Kuhn, G. (2012). Visual cognition during real social interaction. *Frontiers in Human Neuroscience*, *6*, 196.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Stenzel, A., Dolk, T., Colzato, L. S., Sellaro, R., Hommel, B., & Liepelt, R. (2014). The joint Simon effect depends on perceived agency, but not intentionality, of the alternative action. *Frontiers in Human Neuroscience, 8,* 595.

Tassinari, G., Aglioti, S., Chelazzi, L., Marzi, C.A., & Berlucchi, G. (1987). Distribution in the visual field of the costs of voluntarily allocated attention and of the inhibitory after-effects of covert orienting. *Neuropsychologia, 25,* 55-72.

Tassinari, G., Aglioti, S., Chelazzi, L., Peru, A., & Berlucchi, G. (1994). Do peripheral non-informative cues induce early facilitation of target detection? *Vision Research, 34,* 179-189.

Taylor, T. L., & Klein, R. M. (2000). Visual and motor effects in inhibition of return. *Journal Of Experimental Psychology: Human Perception And Performance*, *26*(5), 1639-1656.

Theeuwes, J., & Godijn, R. (2002). Irrelevant singletons capture attention: Evidence from inhibition of return. *Perception and Psychophysics, 64,* 764-770.

Theeuwes, J., Godijn, R., & Pratt, J. (2004). A new estimation of the duration of attentional dwell time. *Psychonomic Bulletin and Review, 11*, 60-64.

Thompson, K.G., Biscoe, K.L. & Sato, T.R. (2005) Neuronal basis of covert spatial attention in the frontal eye field. The *Journal of Neuroscience, 25*, 9479–9487.

Tipper, S.P., Driver, J., & Weaver, B. (1991). Object-centred inhibition of return of visual attention. *The Quarterly Journal of Experimental Psychology, 43,* 289–298.

Tipper, S.P., Grison, S., & Kessler, K. (2003). Long term inhibition of return of attention. *Psychological Science, 14,* 19–25.

Tipper, S.P., Weaver, B., & Watson, F. (1996). Inhibition of return to successively cued spatial locations: A commentary on Pratt and Abrams (1995). *Journal of Experimental Psychology: Human Perception and Performance, 22,* 1989-1293.

Treisman, A. (1969). Strategies and models of selective attention. *Psychological Review 76 (3)*, 282–299.

Treue, S. (2001). Neural correlates of attention in primate visual cortex. *Trends in Neuroscience, 24(5),* 295–300.

Tsai, C. C., & Brass, M. (2007). Does the human motor system simulate Pinocchio's actions? Co-acting with a human hand versus a wooden hand in a dyadic interaction. *Psychological Science, 18,* 1058–1062.

Tsai, C., Kuo, W., Hung, D. L., & Tzeng, O. L. (2008). Action co-representation is tuned to other humans. *Journal Of Cognitive Neuroscience*, *20*(11), 2015-2024.

Tversky, B., & Hard, B. M. (2009). Embodied and disembodied cognition: Spatial perspective-taking. *Cognition, 110,* 124 –129.

Umiltà, M. A., Kohler, E., Gallese, V., Fogassi, L., Fadiga, L., Keysers, C., & Rizzolatti, G. (2001). I know what you are doing. a neurophysiological study. *Neuron*, *31*(1), 155-165.

van der Lubbe, R. H., Vogel, R. O., & Postma, A. (2005). Different effects of exogenous cues in a visual detection and discrimination task: Delayed attention withdrawal and/ or speeded motor inhibition? *Journal of Cognitive Neuroscience*, *17*, 1829–1840.

van der Wel, R. P., Sebanz, N., & Knoblich, G. (2014). Do people automatically track others' beliefs? Evidence from a continuous measure. *Cognition*, *130*(1), 128-133.

van Schie, H. T., van Waterschoot, B. M., & Bekkering, H. (2008). Understanding action beyond imitation: Reversed compatibility effects of action observation in imitation and joint action. *Journal Of Experimental Psychology: Human Perception And Performance*, *34*(6), 1493-1500.

Vesper, C., Butterfill, S., Knoblich, G., & Sebanz, N. (2010). A minimal architecture for joint action. *Neural Networks: The Official Journal Of The International Neural Network Society*, *23*(8-9), 998-1003.

Vesper, C., van der Wel, R.P.R.D., & Sebanz, N., & Knoblich, G. (2011). Making oneself predictable: Reduced temporal variability facilitates joint action coordination. *Experimental Brain Research, 211,* 517-530.

Visser, T. W., & Barnes, D. (2009). The impact of multiple irrelevant visual events at the same spatial location on inhibition. *Attention, Perception & Psychophysics*, *71*(2), 392-402.

Vlainic, E., Liepelt, R., Colzato, L. S., Prinz, W., & Hommel, B. (2010). The virtual co-actor: The social Simon effect does not rely on online feedback from the other. *Frontiers in Psychology, 1,* 208.

Wascher, E., & Tipper, S. P. (2004). Revealing effects of noninformative spatial cues: An EEG study of inhibition of return. *Psychophysiology*, *41*, 716–728.

Watanabe, K. (2008). Behavioral speed contagion: Automatic modulation of movement timing by observation of body movements. *Cognition, 106* (3), 1514-1524.

Weger, U., Abrams, R., Law, M., & Pratt, J. (2008). Attending to objects: Endogenous cues can produce inhibition of return. *Visual Cognition*, *16*(5), 659-674.

Welsh, T. N., Elliot, D., Anson, J. G., Dhillon, V., Weeks, D. J., Lyons, J. L. & Chua, R. (2005). Does Joe influence Freds actions? Inhibition of return across different nervous systems. *Neuroscience Letters, 385,* 99–104.

Welsh, T. N., Lyons, J., Weeks, D. J., Anson, J. G., Chua, R., Mendoza, J., & Elliott, D. (2007). Within- and between-person inhibition of return: Observation is as good as performance. *Psychonomic Bulletin and Review, 14,* 950–956.

Welsh, T. N., Manzone, J., & McDougall, L. (2014). Knowledge of response location alone is not sufficient to generate social inhibition of return. *Acta Psychologica, 153*(1), 153-159.

Welsh, T. N., McDougall, L. M., & Weeks, D. J. (2009a). The performance and observation of action shape future behaviour. *Brain and Cognition, 71,* 64–71.

Welsh, T. N., Ray, M. C., Weeks, D. J., Dewey, D., & Elliott, D. (2009b). Does Joe influence Fred's action? Not if Fred has autism spectrum disorder. *Brain Research*, *1248,* 141-148.

Wenke, D., Holländer, A., Atmaca, S., Liepelt, R., Baess, P., & Prinz, W. (2011). What is shared in joint action? The contents of co-representation. *The Review of Philosophy and Psychology, 2*, 147–172.

Wilke, A., Scheibehenne, B., Gaissmaier, W., McCanney, P., & Barrett, H. C. (2014). Illusionary pattern detection in habitual gamblers. *Evolution And Human Behavior*, *35*(4), 291-297.

Williams, J. H., Whiten, A., Suddendorf, T. & Perrett, D. I. (2001). Imitation, mirror neurons and autism. *Neuroscience & Biobehavioral Reviews, 25,* 287–295.

Wilson, D. E., & Pratt, J. (2007). Evidence from a response choice task reveals a selection bias in the attentional cueing paradigm. *Acta Psychologica*, *126*(3), 216-225.

Wilson, D. E., Castel, A. D., & Pratt, J. (2006). Long-term inhibition of return for spatial locations: Evidence for a memory retrieval account. *Quarterly Journal Of Experimental Psychology*, *59*(12), 2135-2147.

Wilson, M. & Knoblich, G. (2005).The case for motor involvement in perceiving conspecifics. *Psychological Bulletin, 131,* 460–473.

Wolfe, J. M., Alvarez, G. A., & Horowitz, T. S. (2000). Attention is fast but volition is slow. Nature, 406, 691.

Wright, R. D., & Richard, C. M. (1996). Inhibition-of-return at multiple locations in visual space. *Canadian Journal Of Experimental Psychology/Revue Canadienne De Psychologie Expérimentale*, *50*(3), 324-327.

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal Of Experimental Psychology: Human Perception And Performance*, *10*(5), 601-621.

Zaehle, T., Jordan, K., Wüstenberg, T., Baudewig, J., Dechent P, et al. (2007) The neural basis of the egocentric and allocentric spatial frame of reference. *Brain Research 1137*(4), 92–103.