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The sociality of social inhibition of return

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ABSTRACT

Cognitive processes are traditionally studied in individual settings, while the possible effect of the social context is ignored. The present study focuses on the social inhibition of return effect (SIOR; Welsh et al., 2005). According to it, observation of another person's action at a specific location initiates an inhibitory process in the observer at that location. The aim of the present study was to investigate which processes are influenced by the social context (e.g. action representation, attention, etc.) and whether this effect is elicited only in a social context. In a series of four experiments we examined the SIOR effect by developing a dyadic computerized task in which each participant, in turn, responded to a peripherally presented target in two successive trials. The first trial was performed after the other participant had responded and was designed to examine SIOR. The second trial was aimed at studying self-induced IOR. The first two experiments replicated and extended previous findings by demonstrating that information regarding the counterpart's response location was sufficient to produce SIOR. In the third experiment the participants performed the same task but without a counterpart so that SIOR was eliminated. The fourth experiment demonstrated that believing there is a co-actor is enough to elicit the SIOR effect. These findings suggest that knowing that a location was acted upon before by another person (by observation or by prior knowledge) is the minimal condition for the SIOR effect to be evoked.

1. Introduction

Cognitive processes are usually studied in individuals, while social influences are ignored. Such an approach disregards the fact that humans have evolved as social animals, as members of groups. Both the ability to understand other people's intentions and behavior and the ability to use social information to anticipate the behavior of another are important for humans to survive successfully within a social context (Bandura, 1977; Blandin, Lhuisset, & Proteau, 1999; Constable, Pratt, & Welsh, 2018; Friesen & Kingstone, 1998; Frischen, Loach, & Tipper, 2009; Kingstone, Friesen, & Gazzaniga, 2000; Sebanz, Bekkering, & Knoblich, 2006).

During the past two decades, the social factor has received increasing research attention, with a growing number of studies investigating the effect of interpersonal interactions (i.e., joint action with another individual) on human cognition (Atmaca, Sebanz, Prinz, & Knoblich, 2008; Atmaca, Sebanz, & Knoblich, 2011; Friesen & Kingstone, 1998; Frischen et al., 2009; Richardson et al., 2012; Schuch & Tipper, 2007; Sebanz, Knoblich, & Prinz, 2003; Skarratt, Cole, & Kingstone, 2010; Welsh et al., 2005). When explored in a social context, tasks that had been traditionally examined in an individual setup have yielded fresh insights into the influence of social processes on cognitive mechanisms and motor performance (Böckler, Knoblich, & Sebanz, 2012; Böckler, Knoblich, & Sebanz, 2011; Cole, Skarratt, & Kuhn, 2016; Constable et al., 2018; Frischen et al., 2009; Kuhlen & Abdel Rahman, 2017; Sebanz et al., 2003; Spence, Pavani, & Driver, 2004; Tversky & Hard, 2009; Welsh et al., 2005).

Recently, several studies have explored the social influence of one well-established effect: *inhibition of return* (IOR) (Cole, Skarratt, & Billing, 2012; Doneva, Atkinson, Skarratt, & Cole, 2015; Gobel, Tufft, & Richardson, 2018; Skarratt et al., 2010; Tufft, Gobel, & Richardson, 2015; Welsh et al., 2005; Welsh, Lyons et al., 2007). IOR refers to the outcome that people have slower reaction times (RTs) to targets that appear at previously cued locations than to those that were not cued (Posner and Cohen, 1984). The IOR effect is attributed to an inhibitory mechanism that delays the ability to reorient attention to previously attended locations. Researchers have suggested that this effect has an evolutionary origin and is the basis for foraging abilities (Klein & MacInnes, 1999; Klein, 2000) in that inhibition of previously searched locations facilitates investigation of new locations (Klein, 2000). An indication of the evolutionary origin of IOR is that this effect has been observed even in the archerfish (Gabay, Leibovich, Ben-Simon, Henik, & Segev, 2013; Saban, Sekely, Klein, & Gabay, 2017). It should be noted that IOR is typically observed following a non-informative cue but has

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also been observed at the location of a previous target (Welsh & Pratt, 2006).

From an evolutionary perspective, however, search-based actions such as hunting, gathering, and predatory evasion may well have been carried out by groups and not by isolated individuals (for humans and primates, see, e.g., Barnard, 1992; Jolly, 1985; Lee & DeVore, 2017). Thus, a social inhibitory effect similar to IOR may exist at locations/ targets already investigated by another individual. This effect is termed *social inhibition of return* (SIOR) or between-person IOR (Welsh et al., 2005; Welsh, Higgins, Ray, & Weeks, 2007; Welsh, Lyons et al., 2007). In line with the foraging facilitator hypothesis (Klein, 2000), the logic is that searching (e.g., for food) would be inefficient if one individual investigated a location or an object that had already been inspected by another. Thus, another person's behavior toward a searched location can evoke reflexive inhibitory processes similar to those involved in IOR.

In the classic SIOR task (Welsh et al., 2005) two participants face each other with a board between them and take turns making rapid movements aiming at lateral targets that appear on the board. Each participant performs two successive trials. The first trial is performed after the other participant responds and is designed to examine the social influence of one participant on the other. The second trial for each participant is aimed at studying self-induced IOR, that is, the extent to which participants' performance is influenced by their own previous actions. The typical pattern of results on this task is characterized by longer RTs for targets presented at locations to which the participant previously reacted than for targets at locations to which the participant did not react (personal IOR). In addition, RTs are longer for targets presented at locations to which the participant's counterpart reacted than for targets presented at locations to which the counterpart did not react (SIOR).

A crucial question engaging joint task researchers is what exactly a participant represents when acting alongside another person. According the action representation account only the motor response is being represented regardless of the specific task conditions under which the co-actor performed his response (e.g., Sebanz, Knoblich, Stumpf, & Prinz, 2005; see discussion in Wenke et al., 2011). According to the task representation account, the co-actor's stimulus response mapping (s-r) is represented as if it was the participant's own (Sebanz & Knoblich, 2009; Sebanz, Knoblich, & Prinz, 2005). Alternatively, according to the actor representation account (Wenke et al., 2011) what matters is the representation of whose turn it is to respond (see discussion in this question regarding the social Simon effect in Sebanz, Knoblich, Prinz et al., 2005; Sebanz, Knoblich, Stumpf et al., 2005; Wenke et al., 2011).

In the past few years, a growing body of literature has investigated the cognitive mechanisms underlying the SIOR effect. Three main accounts exist. The co- representation account (Welsh et al., 2005), the movement-congruency account (Ondobaka, de Lange, Newman-Norlund, Wiemers, & Bekkering, 2012) and the attentional/ transient account (Cole et al., 2012). While the first two accounts argue that action and/or task representation mechanisms are a main key to understanding SIOR (Ondobaka et al., 2012; Welsh et al., 2005; Welsh, Lyons et al., 2007), the attentional, transient account claims that SIOR resembles IOR. That is, the representation of the counterpart's action is not crucial and the effect occurs due to an attentional shift generated by observing a spatial cue (i.e., motion transients; Cole et al., 2012; Cole, Welsh, & Skarratt, 2019; Doneva & Cole, 2014). In what follows we will discuss each of the proposed accounts.

According to the *co-representation account* proposed by Welsh and colleagues (Welsh et al., 2005; Welsh, Ray, Weeks, Dewey, & Elliott, 2009; Welsh, Lyons et al., 2007), the effect is the result of attention cuing and action representation combined: during the task, the observer inhibits action toward already acted-upon locations, regardless of who performed the action—another person or the observer. Observing the co-actor's response elicits the same inhibitory mechanism that is associated with a self-response (Sebanz et al., 2003; Welsh & Pratt, 2006). Welsh and colleagues (Welsh, Higgins et al., 2007; Welsh, Lyons et al., 2007) proposed that the mirror neuron system (MNS; Rizzolatti & Craighero, 2004) acts as a mediating mechanism for the inhibitory effect. The MNS is a network of neurons in the prefrontal and posterior parietal cortices that is activated when one performs an action or observes another person's action.

In order to explore the MNS hypothesis, Welsh et al. (2009) examined people with autism spectrum disorder (ASD) who are thought to have an impairment in the MNS network that causes deficits in recognition and imitation of others' actions (Bernier, Dawson, Webb, & Murias, 2007; Blake, Turner, Smoski, Pozdol, & Stone, 2003; Dapretto et al., 2006; Oberman et al., 2005; Williams et al., 2006). The study showed that participants with ASD did not exhibit the SIOR effect. Nevertheless, individuals with ASD did demonstrate the self IOR effect, suggesting a connection between the mechanism that underlies the SIOR effect and the deficit mechanism in ASD.

Consistent with the hypothesis that the MNS codes the endpoint goal of an observed action (as opposed to the means used to achieve that goal) (Rizzolatti, Fabbri-Destro, & Cattaneo, 2009), Skarratt et al. (2010) and Welsh, Higgins et al. (2007), (2009) all demonstrated the presence of SIOR under conditions of restricted visibility (i.e., by manipulating the apparent part of the co-actor's response). Results from the third experiment by Skarratt et al. (2010) revealed that both the gaze direction of another person and the initiation of an aiming response by another person produced an equivalent SIOR effect (despite the many studies that failed to demonstrate IOR with gaze cues; see Friesen & Kingstone, 1998; Langton, Watt, & Bruce, 2000). Another study, however, revealed that sometimes knowledge alone (through auditory cues) about the location of the co-actor's response is insufficient to produce SIOR (Welsh, Manzone, & McDougall, 2014). Subsequently, Welsh et al. (2014) posited that the SIOR effect is mostly dependent on whether the observers witness and represent the spatial aspects of the other actor's action. In other words, since SIOR was suggested as being modulated by low-order sensorimotor aspects, observation of the action (or its initiation) is claimed to be essential to trigger the SIOR effect.

Similarly, to Welsh et al. (2005), the *movement congruency account* of Ondobaka et al. (2012), Ondobaka, Newman-Norlund, de Lange, & Bekkering (2013a), (2013b) postulates that action representation mechanisms are the main drivers responsible for the generation of SIOR. That is, an action of one actor (e.g. reaching to the left) primes for the second actor the same action within an egocentric view (also reaching to the left). Observing another person's response facilitates RT for performing a similar response. In the display-board procedure designed to study SIOR, since the participants sit opposite to each other, the response of one participant facilitates a response toward the opposite side by the observing participant, causing SIOR. Note that in contrast to the co-representation account, according to this proposal, the response location is not important, just the motor action, and the mechanism that produces SIOR is facilitation of action (within an egocentric view), and it is not an inhibitory process.

Alternatively, Cole and colleagues (Atkinson, Simpson, Skarratt, & Cole, 2014; Cole, Atkinson, D'Souza, Welsh, & Skarratt, 2012, 2018) claim that SIOR is IOR-like. That is the SIOR effect is not due to action representation process but may result from another mechanism: the *attentional shift hypothesis,* also being called *the transient account* (Atkinson, Millett, Doneva, Simpson, & Cole, 2018; Cole et al., 2012, 2019). According to this account the inhibitory effect will occur as long as attention is attracted to the relevant location by a salient cue (whether social or not) (Cole et al., 2012; Doneva et al., 2015). Cole et al. (2012) and Doneva and Cole (2014)) examined the mirror neuron-based hypothesis and speculated that if the SIOR effect is goal based, the magnitude of the SIOR effect should be modulated by the degree of (dis)similarity between two action goals. Accordingly, Cole et al. (2012) manipulated the task so that participants were required to perform different actions on an object at the same location (one participant was instructed to write a digit with a pencil and the other participant was instructed to erase it). Results indicated that there was no modulation of SIOR magnitude between the two response conditions. In contrast, when Atkinson et al. (2014) manipulated the properties of the stimuli at the end-point location (i.e., changed the amount of salience of the stimuli) while keeping the movement constant - the SIOR was modulated, see Cole et al. (2019) for extensive overview.

Note that it is also possible that both motor representation and attentional mechanisms are responsible for this effect such that the contribution of each of the mechanisms is dependent on task demands (Cole et al., 2018; Manzone, Cole, Skarratt, & Welsh, 2017). For example, Manzone et al. (2017) revealed that different actions with low ideomotor compatibility do not evoke SIOR under restricted display. They proposed that "action co-representation is one method that can lead to the attentional shift" (p.12).

In addition to the question of what is represented, there is a following question about the social aspect of SIOR. Even though the term "social inhibition of return" suggests that sociality is an integral aspect of SIOR, what are the sufficient social aspects required in order to elicit the effect?

Welsh et al. (2009) claim that the social aspect is an essential factor in evoking the SIOR effect. For example Skarratt et al. (2010) found that when acting with a biological co-actor (a real person), SIOR was elicited under both full and restricted vision conditions. In contrast, when the co-actor was an animated partner (a life-size image of a human participant projected onto a screen), no SIOR was observed under the restricted condition (see also, Welsh, Higgins et al., 2007). Skarratt et al. (2010) concluded that SIOR is elicited only when a real biological behavior/stimulus is observed. In addition, they claimed that the occurrence of the SIOR effect depends on agency[1] attribution of the co-actor's actions. In other words, when the participant knows that the co-actor is not the cause of the behavior and that the co-actor's responses are artificial, the SIOR effect does not appear. Additional supporting evidence with regards to the importance of sociality comes from Gobel et al. (2018) who demonstrated that attributing social relevance to a non-social cue representing the other person, in this case, the location to which she was looking, influences the magnitude of the IOR effect. It should be emphasized that this influence was modulated by social relevance, such as the participant's belief regarding the other person's intentional state, and whether the co-actor was engaged in the same task. This indicates that the mental representation of the co-actor's social relevance can modulate the inhibitory effect.

In contrast to the suggestion that social aspects are essential for the emergence of SIOR, according to the attentional account of SIOR (Cole et al., 2012), as indicated earlier, the social aspects of the co-actor are irrelevant to the effect. That is, any spatial cue will trigger the effect, regardless of its social nature (see also Dolk et al., 2011; Guagnano, Rusconi, & Umiltà, 2010; but see Manzone et al., 2017). Recently, Atkinson et al. (2018) examined the sociality of the SIOR task and found that social contexts (competitive, comparative) did not modulate the SIOR effect, nor did other social factors, such as whether the interaction with the other participant was online or recorded. The only manipulation that eliminated the SIOR effect was a change in the sequence, such that the order of responses between the two participants was random, rather than in the typical turn-taking paradigm. The authors claimed that "the so-called 'social' inhibition of return only reaches a minimal threshold to be considered a social phenomenon" (p.1).

To conclude, the discussion regarding the sociality of SIOR raises two possibilities: (a) Social cues (e.g., real biological stimuli) are stronger generators of a unitary inhibitory mechanism that contributes to both IOR and SIOR (see also Manzone et al., 2017), and/or (b) the representation of a relevant social cue (e.g., a biological agent) activates distinct inhibitory processes that produce SIOR (see Dolk et al., 2011; Dolk, Hommel, Prinz, & Liepelt, 2013 for a similar debate regarding the Social Simon effect).

In the current study, we aimed, first, to replicate and validate the SIOR effect using a novel computerized display (as opposed to the commonly used board display). Moreover, we examined whether the SIOR effect can be observed even if direct observation in the co-actor's action is absent. In the second, third and fourth experiments we aimed to establish the necessary social aspects in the task that are vital initiators of the SIOR effect. By ruling out the attentional shift hypothesis (the transient account) and the movement congruency account as possible mechanisms, we suggest, in line with the co-representation account (Welsh et al., 2005), that it is sufficient for one to believe that another agent has acted upon a specific location for eliciting inhibitory processes toward that location, resulting in SIOR. In other words, we suggest that the minimal condition required to elicit SIOR is the belief that a specific location has been acted upon by another agent.

2. Experiment 1: Replication of the original SIOR effect in a computerized dyadic setting

The aim of this experiment was to replicate the SIOR effect using a computerized version of the board set-up that is typically used as part of the standard procedure for examining this effect (Cole et al., 2012; Doneva & Cole, 2014; Skarratt et al., 2010; Welsh et al., 2005; Welsh, Higgins et al., 2007, Welsh, Lyons et al., 2007). In addition, another crucial question that was examined is whether direct observation of the co-actor's action is essential to elicit the SIOR effect. In this experiment two participants performed the task together, each in two successive turns where the first turn examined the SIOR effect and the second examined the self-induced IOR effect. We expected this design to replicate the typical IOR and SIOR effects observed in previous studies (Welsh et al., 2005). We predicted that participants would be slower to react to targets appearing at the same location as the previous target, regardless of whether they or their co-actor responded to it. In other words, we expected to reveal a significant personal IOR effect and a significant SIOR effect.

The typical task is characterized by a turn-based sequence in which each participant performs two successive trials. Atkinson et al. (2018) suggested that this set sequence is necessary to elicit the SIOR effect since it requires participants to attend to the actions of their co-actor. In the present task (and all subsequent tasks) we followed the typical turn-based sequence; however, a central color cue was presented at the beginning of each trial to indicate which participant should respond. This color cuing reduced the need for the participant to attend to the co-actor's actions in order to know when to act. Thus, although the co-actor's responses do not have to be tracked it would be interesting to see if SIOR still emerges under these circumstances.

2.1. Sample size

In previous studies (see, e.g., Cole et al., 2018, 2012; Ondobaka et al., 2013a, 2013b; Welsh et al., 2005; Welsh, Higgins et al., 2007; Welsh, Lyons et al., 2007) the common sample size used to examine the SIOR effect ranged from 16 to 18 participants (8–9 couples). In the following experiments, we employed a similar sample size.

2.2. Participants

Eighteen undergraduate students (nine pairs) participated in the experiment in exchange for course credit or payment (Age range: 19–28; $M = 23.7$, $Sd = 2.48$). All participants were unaware of the purpose of the experiment.

Note that in all of the following experiments, we examined only women in order to keep the social characteristics constant. We wanted

[1] The sense of agency enables people to determine whether it is their own action that makes a change in the environment (Haggard and Tsakiris, 2009).

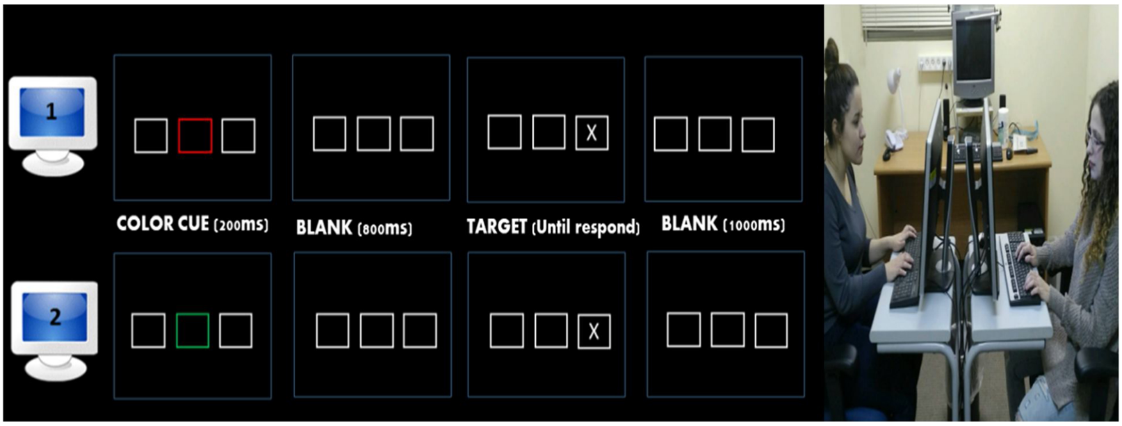

Fig. 1. Left—illustration of a typical experimental trial; right—illustration of the experimental setup. Each trial began with the appearance of a color cue seen by both participants. After an interval of 800 ms, a target (X) appeared on the left or on the right and remained on the screen until the participant responded. The participants were required to perform a localization task and press the key indicating the target location.

to avoid mixed gender pairs of participants which may have introduced additional social variables (e.g. attraction) which are not the focus of the current study. Moreover, there are some indications that women are more sensitive to social attentional cues (Alwall, Johansson, & Hansen, 2010; Bayliss, di Pellegrino, & Tipper, 2005; Merritt et al., 2007). Interestingly Gobel et al. (2018) did not find gender differences when examining an orienting task in pairs of participants. Even so, in the current study, through all the experiments we used only women in order to reduce variability in this new version of the task. This will be further discussed later as a limitation of these experiments.

2.3. Task and stimuli

Participants were tested in pairs while seated facing each other, each in front of a separate LCD screen on which the stimuli were presented (see Fig. 1). Both screens and both keyboards were connected to a single computer. Each participant was seated ~57 cm from the screen. Throughout the experiment three boxes (size in visual angle: $1.5^0*1.5^0$) were displayed on the screen. One box was displayed at the center of the screen and the other two boxes were located peripherally (13^0 from the central box). Each turn began with a red or green flash displayed in the middle box for 200 ms. The color of the flash indicated which participant should respond to the target appearing in that specific trial. After an interval of 800 ms, the target ("X") was displayed either in the left or the right box until the participant made a response. After the participant responded, a 1000 ms interval was interposed. The ISI between the offset of one target and the onset of the following target was 2000 ms. See Fig. 1 for an illustration of a trial.

2.4. Procedure

A 2 × 2 design was employed, with the person responding in the previous trial (same, different) and target location (same, different) as factors. Each pair of participants completed 20 blocks of 33 successive key presses in response to the appearance of a target stimulus at one of two locations. The task was a localization task (participants were required to respond according to target location). Participants were instructed to press the "p" key with their right index finger if the target appeared on the right side of the screen and to press the "q" key with their left index finger if the target appeared on the left side of the screen. In addition, participants were instructed to maintain fixation on the central square throughout the experiment. The location of the targets for each trial was pseudo-randomized. Specifically, we wanted to ensure that every block had a constant and equal number of same and different trials both for the previous self-trial (IOR) and for the previous co-actor trial (SIOR). Moreover, the target was displayed at the left and right locations for an equal number of trials across the entire experiment. Participants alternated pairs of responses in a block, such that one participant completed two successive trials and then the other participant completed two successive trials (and so on). Before each trial the middle square was illuminated in either green or red (a color cue that both participants saw). Prior to the experiment, each participant was assigned a color. Participants were instructed to respond only on trials that began with presentation of their specific color. (Note: participants were informed that on each turn they would have to respond to two successive trials.) Each block of 33 trials included 16 within-person trials (e.g., A-A) and 16 social, different-person trials (e.g., A–B). Because the very first response in each block was obviously not preceded by a response, the participant who began the sequence of responses completed one additional unpaired response at the end of the block. This additional trial was added to ensure an equal number of different-person and within-person trials. Overall, each participant started an equal number of blocks (ten). Participants understood that their partner had no influence on their own task and that they should respond only to their own targets and as quickly and accurately as possible.

2.5. Results and discussion

RT was calculated as the time from target onset until the participant pressed the response key. Note that in the original task with the board display (Welsh et al., 2005), RT (response selection) was differentiated from MT (response execution). It is important to mention that RT is the consistent measure that yields the SIOR effect (see Manzone et al., 2017, for a demonstration that the proposed measure yields a pattern equivalent to the RT in the original task). In the present computerized display with a keyboard, only RT was measured. Trials in which participants responded incorrectly as well as trials in which RTs were less than 100 ms (anticipatory errors) or greater than 1500 ms (inattention error (were removed from the data set (1.25 %). These filters were kept constant throughout the different experiments. To investigate whether this computerized procedure succeeded in replicating the typical results of the SIOR task, we conducted an analysis of variance (ANOVA) with the person responding in the previous trial (same, different) and target location (same, different) as within-subject factors and RT as the dependent measure.

In addition, since in some of the experiments in the current study we predicted in favor of the null hypothesis, we also calculated Bayes factors (BF) for the main effect, the interaction effect, and the simple effect. The Bayes factor (BF10) is the ratio between the evidence in favor of the predicted hypothesis and the null hypothesis. Bayes factors with a value less than 1/3 indicate support for the null hypothesis. In contrast, a BF10 greater than 3 suggests that the analysis is sensitive enough to accept the experimental hypothesis (Dienes, 2008). In the present studies Bayes factors were calculated using the free software JASP (https://jasp-stats.org).

The main effects of person and target location were significant ($F_{(1,17)}$ =7.32, $p < .05, \eta_p^2 = .3$, $BF10 = 2.38$; $F_{(1,17)} = 42.29$, $p < .01$ $\eta_p^2 = .71$, $BF10 = 5848$; respectively), replicating previous findings. The interaction between target location and person was marginally significant ($F_{(1,17)} = 3.73$, $p = .07$, $\eta_p^2 = .17$, $BF10 = 1.23$). Planned comparisons revealed a significant effect of target location (same location RT > different location RT) for the same-person trials ($F_{(1,17)} = 20.9$, $p < .01$, $\eta_p^2 = .55$, $BF10 = 234.5$), indicating the presence of personal IOR, and a significant effect of target location (same location RT > different location RT) for the different-person trials ($F_{(1,17)} = 25.5$, $p < .01$, $\eta_p^2 = .6$, $BF10 = 570.5$), indicating the presence of SIOR[2] ; see Fig. 2).

The results of Experiment 1 demonstrate that participants had longer RTs when initiating a response to the location of a previous target than to a new target location, whether they or their counterpart responded to it. This pattern of results replicates the typical result in the SIOR task (Cole et al., 2012; Welsh et al., 2005).

A crucial question regarding the SIOR effect is whether direct observation of the spatial aspects of the co-actor's action is necessary to elicit the SIOR effect. In a recent study, Welsh et al. (2014) did not observe an SIOR effect when participants were given only auditory information, without direct visual observation of the location of their partner's response.). Yet it is possible that in the aforementioned experiment (Welsh et al., 2014), the auditory signal was not a strong marker of the counterpart's response. Hence the spatial characteristics were too weak to elicit SIOR. In the present study, participants did not directly observe the co-actor's action (the computer screens restricted their view) yet SIOR was still apparent. Thus, the ability to represent the actions and/or the action location of the co-actor (regardless of the direct view of the action itself) is sufficient to elicit SIOR.

As in previous studies (Welsh et al., 2005; Welsh, Lyons et al., 2007), in the current experiment participants observed all targets, regardless of whose turn it was to respond. Observing the target may attract attention to the target location in both conditions (same person, different person). Thus, from the perspective of the attentional shift (transient) account that was proposed by Cole et al. (2012); Cole et al. (2019) the SIOR is only an attentional-perceptual effect. That is, the social effect resembles the individual effect but is influenced by a different reference cue. To examine this suggestion, we conducted a second experiment in which the possible locations of the targets were masked during the counterpart's turn so that participants could not observe the appearance and disappearance of the co-actor's targets.

Experiment 2a: SIOR is independent of observing the spatial aspects of the partner's targets

In the first experiment we managed to replicate the typical finding of SIOR (Welsh et al., 2005; Welsh, Higgins et al., 2007; Welsh, Lyons et al., 2007) but as already mentioned the onset and offset of the target of the co-actor could still cause the effect just as any other perceptual cue could. Exploring whether having a mental representation of another person actions toward a specific location would suffice to elicit SIOR was the main aim of the current experiment. Accordingly, we examine whether SIOR can be elicited even without directly observing the target. We masked the target's possible locations for the observing participant. In addition, immediately after the response, we used a central arrow that informed both participants of the location at which that response was made. Thus, the participants could know the location at which the other participant made a response without actually observing the target. The purpose of this experiment is to examine Cole's attentional shift (transient) theory. If *SIOR* is *IOR-like* phenomena, a central cue (arrow) that is known to initiate a facilitatory effect (Birmingham & Kingstone, 2009; Friesen & Kingstone, 1998; Frischen & Tipper, 2004; McKee, Christie, & Klein, 2007) but that does not generate inhibitory effects should not evoke IOR or SIOR. Yet there is evidence that in the SIOR task, a central cue from the other participant's motion, head direction or eye direction indeed causes an inhibitory effect (Skarratt et al., 2010).

Welsh et al. (2005) also manipulated the visibility of the target onset and offset by using goggles with liquid crystal lenses that have the ability to become opaque. This procedure, despite the inability of the observing participant to perceive the peripheral target, still produced the SIOR effect. Yet, the fact that the participant partially saw the response of the other participant was argued to be a sufficient peripheral cue, which still did not rule out the attentional shift (transient) account (Cole et al., 2019).

In the present experiment, the participants did not observe the onsets and offsets of the targets, but saw only a central arrow that provided information regarding the location to which the other participant responded (see also Doneva et al., 2015). The arrow allows us to differentiate the effect of the inherent significance of the stimuli—which may capture attention and cause the SIOR effect (as in previous studies using eye gaze for example)—from the effect of the meaning assigned to the stimuli (the arrow as a sign indicating the other's actions location). Demonstrating SIOR when using social central cues (e.g., faces, hands) strengthens the quantitative explanation regarding this effect (i.e., social cues might be more salient than non-social cues). In contrast, our treatment of the central cues as social only by means of further interpretation have the protentional to provide evidence that sociality has an integral part in the SIOR effect and that the inhibitory process is guided by a qualitatively different mechanism (see also Gobel et al., 2018) which primarily showed that when a non-social cue is given social meaning it results in social influence on a spatial orienting effect, but note that in our experiment the cue is not exogenous but central.

It should also be mentioned that a previous study by Doneva et al. (2015, exp. 1) also used an arrow to inform the other participant about the target location. In that case, however, there was also a peripheral cue that followed the arrow, thus capturing attention.

We predicted that SIOR would be exhibited regardless of direct observation of the co-actor's action (unseen, as in Experiment 1) or target location (in contrast to Experiment 1), so long as information regarding the co-actor's action location was provided. Knowing that a location was acted upon before by another person is predicted to be the minimal condition for the SIOR effect. This prediction is in line with the evolutionary explanation of IOR (Klein, 2000). Accordingly, the inhibition is supposed to facilitate foraging ability in a social context.

3.1. Participants

Thirty undergraduate female students (15 pairs) participated in the experiment in exchange for course credit or payment (age range: 19–36; $M = 24.28$, $Sd = 4.12$). All participants were naive to the purpose of the experiment.

3.2. Task and stimuli

The task and stimuli were similar to those in Experiment 1, with the following exceptions: 1) On trials in which participants only observed but did not respond to the target, peripheral squares (possible target locations) were masked with gray patches. 2) Immediately after each response an arrow appeared in the middle box, informing both participants (acting and observing) of the location toward which a response was executed (an arrow pointing to the left indicated that the q button was pressed, and an arrow pointing to the right indicated that the p button was pressed). 3) After an interval of 1000 ms the next trial

[2] There was no interaction with player ($F < 1$).

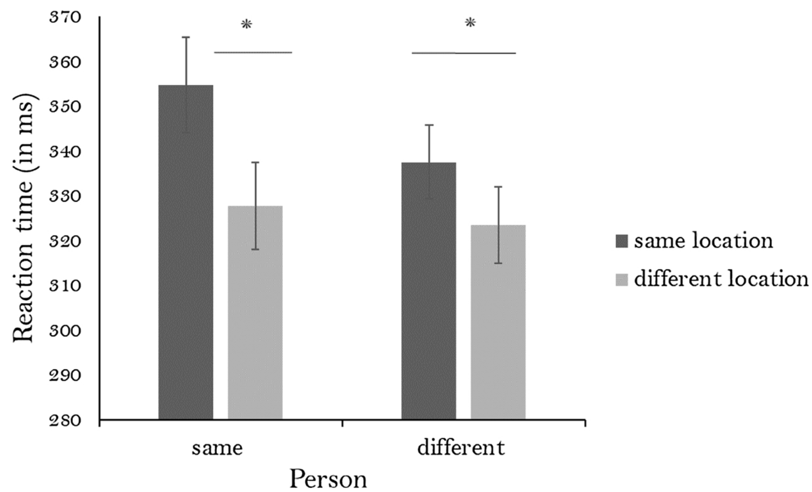

Fig. 2. RT of Experiment 1 by target location (same, different) and person (same-person trials, different-person trials). The Y axis shows the RTs in ms. Error bars represent standard error.

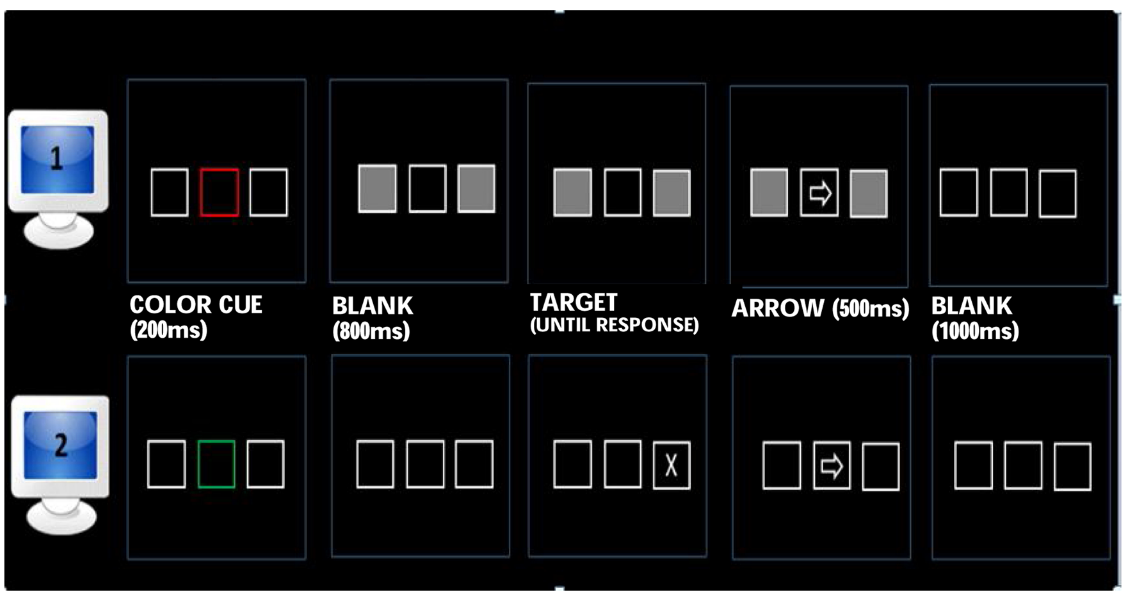

Fig. 3. Illustration of a typical experimental trial.

began. The SOA between the onset of the arrow and the onset of the following target was 2500 ms. Fig. 3 shows an illustration of a trial.

Each trial began with the appearance of a color cue seen by both participants. After an interval of 800 ms, a target (X) appeared on the display of the acting participants. The target could appear on the left or on the right and remained until response. The participants were asked to perform a localization task and to press according to the location where the target appeared. After the response was made, an arrow appeared at the middle, signaling the location of the response direction. The observing participant could not see the target's onset and offset (the target locations were masked) but did see the informative arrow.

3.3. Procedure

A 2 × 2 design was used, with the person responding in the previous trial (same, different) and target location (same, different) as factors. The same procedure was used as in the first experiment, with the following changes: 1) Participants were informed that they would not see the co-actor's targets but that arrows would inform them of the location of the response. 2) The arrows were presented both after the self-initiated action and after the co-actor's action.

3.4. Results

As in Experiment 1, trials in which participants responded incorrectly as well as trials in which RTs were less than 100 ms (anticipatory errors) or greater than 1500 ms (inattention error (were removed from the data set (0.88 %). We conducted a two-way analysis of variance (ANOVA) with repeated measures on RT data, with the person responding in the previous trial (same person, different person) and target location (same location, different location) as within-subject factors. The main effect of target location was significant ($F_{(1,29)} = 28.67$, $p < .001$, $\eta_p^2 = 0.49$, *BF10* = 104.8). The main effect of person was not significant ($F_{(1,29)} = 2.22$, n.s., $\eta_p^2 = 0.07$, *BF10* = 0.81). The interaction was marginally significant ($F_{(1,29)} = 4.15$, $p = 0.05$, $\eta_p^2 = .12$, *BF10* = 0.96). Planned comparisons revealed a significant effect of target location (same location RT > different location RT) for the same-person trials ($F_{(1,29)} = 21.13$, $p < 0.01$, $\eta_p^2 = 0.42$, *BF10* = 652.5), indicating the presence of IOR, as well as a significant effect of target location (same location RT > different location RT) for

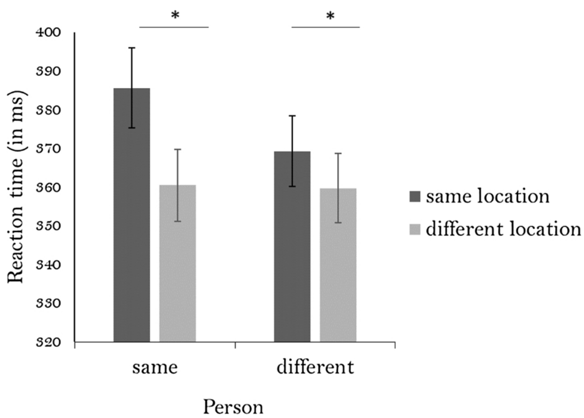

Fig. 4. RT of Experiment 2a by target location (same, different) and by the person responding in the previous trial person (same-person trials, different-person trials). The Y axis represents the RTs in ms Error bars represent standard error.

the different-location trials ($F_{(1,29)} = 4.64$, $p < 0.05$, $\eta_p^2 = 0.14$, *BF10* = 2.82), indicating the presence of SIOR[3] . See Fig. 4.

4. Experiment 2b: Replication of SIOR with shorter target-to-target interval

The first aim of experiment 2b was to replicate the findings of experiment 2a, but with a shorter experiment length in order to diminish participants' fatigue during the task. To do so, we reduced the SOA interval between arrow to target from 2500 ms to 1300 ms. Furthermore, previous studies indicated that action representation persists for at least several seconds (Gangitano, Mottaghy, & Pascual-Leone, 2004; Lestou, Pollick, & Kourtzi, 2008), yet in Doneva et al. (2015, exp.2) SIOR was not found in long SOAs. In the current experiment we wanted to examine the time course of the social effect, by reducing the SOA employed. Here, SOA refers to the interval between seeing an arrow indicating the location of the previous action and the appearance of the next target. Note that the action has already been completed before the arrow indicating its location appears.

4.1. Participants

Eighteen undergraduate female students (nine pairs) participated in the experiment in exchange for course credit or payment (age range: 19–30; $M = 23.05$, $Sd = 2.85$). All participants were naive to the purpose of the experiment.

4.2. Task and stimuli

The task and stimuli in Experiment 2b were identical to those of Experiment 2a.

4.3. Procedure

The trial procedure of the current experiment was as follows: 100 ms of color cue; 400 ms of interval, followed by appearance of the target until response. Subsequently, the arrow was presented for 400 ms, followed by an interval of 400 ms. Overall, the SOA from arrow onset to target onset was1300 ms.

4.4. Results

Trials in which participants responded incorrectly as well as trials in which RTs were less than 100 ms (anticipatory errors) or greater than 1500 ms (inattention error) were removed from the data set (overall 1 %). We conducted a two-way analysis of variance (ANOVA) with repeated measures on RT data, with the person responding in the previous trial (same person, different person) and target location (same, different) as within-subject factors. The main effect of target location was significant ($F_{(1,17)} = 25.55$, $p < 0.01$, $\eta_p^2 = 0.6$, *BF10* = 13.61). The main effect of person was not significant ($F_{(1,17)} = 0.33$, *n.s.*, $\eta_p^2 = 0.01$, *BF10* = 0.32). The interaction was also not significant ($F_{(1,17)} = 2.91$, *n.s.*, $\eta_p^2 = 0.14$, *BF10* = 0.52). Planned comparisons revealed a significant effect of target location (same location RT > different location RT) for the same-person trials ($F_{(1,17)} = 17.85$, $p < 0.01$, $\eta_p^2 = 0.51$, *BF10* = 121.9), indicating the presence of IOR, and a significant effect of target location (same location RT > different location RT) for the different-person trials ($F_{(1,17)} = 6.12$, $p < 0.05$, $\eta_p^2 = 0.26$, *BF10* = 5.04), indicating the presence of SIOR)[4] . See Fig. 5.

Overall BF was calculated for the social and self-effects by combining the data from Experiments 2a and 2b (long and short target-to-target intervals). We combined the data from the two experiments since no interaction effect was found between the two versions of the target-to-target interval. See the supplemental material. The *BF10* for the same-person trials, that is the self-IOR effect was 72800 and the *BF10* for the different-person trials, that is the SIOR effect was *14.46*.

Similar to the results found in Experiment 1, the results of Experiments 2a, and 2b demonstrated that participants had longer RTs when initiating a response to the location previously acted upon than to a new location, whether they or their counterpart responded to it. The results of Experiment 2 (a and b) demonstrated that IOR and SIOR were both evoked even though the co-actor's targets and actions were not directly observed. These results are inconsistent with the notion proposed by Welsh et al. (2014) that witnessing execution of an action is crucial for eliciting the SIOR effect. The same is true for the movement congruency account (Ondobaka et al., 2013a, 2013b) since in the current version of the task the participant did not observe the execution of the action. Moreover, demonstrating these effects despite the use of a central arrow cue as the main source of information called into question the proposal by Cole et al. (2012) that SIOR is IOR-like. The central cues that previously evoked an inhibitory effect have social properties of their own (gaze cues, head motion). Yet in the current experiment merely the interpretation of the central cue (as providing relevant social information) was enough to evoke an SIOR effect. Furthermore, our findings that SIOR was observed in both long and short SOAs, weaken the attentional account (see Doneva et al., 2015). Nevertheless, the results of Experiment 2 (a and b) do not enable us to reject the attentional, transient explanation entirely as the main initiator of the SIOR effect. Therefore, in Experiment 3 we aimed to explore the role of social properties in the SIOR effect.

5. Experiment 3: Sociality as a key component of the SIOR effect

While the attentional (transient) account (Cole et al., 2012, 2019; Doneva et al., 2015) is unlikely in light of the results obtained in Experiments 1 and 2, it is still possible to argue that the arrow used in Experiment 2 produced a shifting of attention toward the acted-upon location and hence elicited an inhibitory effect. If this argument is valid, then under the same visual display the SIOR effect is expected to emerge regardless of the presence of an additional actor in the room.

Accordingly, the task in the present experiment was identical to that used in Experiment 2, except that the participants performed the task alone, without a counterpart. Participants were informed that the direction of the arrow displayed during the trials to which they did not respond was randomly chosen by the computer. If the social situation is the source of the SIOR effect, then SIOR should not be evoked when

[3] There was no interaction with player, $F < 1$.

[4] There was no interaction with player $F < 1$

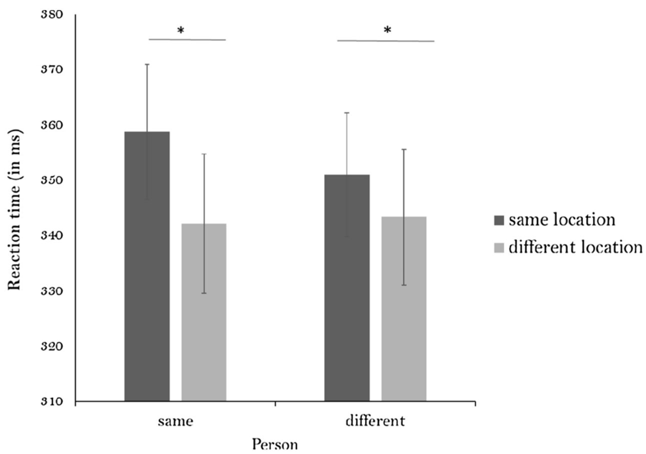

Fig. 5. RT of Experiment 2b by target location (same, different) and the person responding in the previous trial (same person, different person). The Y axis shows the RT in ms. Error bars represent the standard error.

participants perform the task without a counterpart, even though the visual display was identical to that in Experiment 2. In other words, if the SIOR effect is an attentional effect per se that is influenced only by the properties of the stimulus (e.g. motion, saliency, etc.), then SIOR will emerge under the same conditions as in Experiment 2. However, if the social context is important for the SIOR effect to emerge, and the notion that an agent acted upon that location is the cause for this phenomenon, then no SIOR effect should be evoked in the current experiment.

5.1. Participants

Twenty-seven undergraduate female students participated in the experiment in exchange for course credit or payment (age range: 19–38; M = 24.04, Sd = 4.24). All participants were unaware of the purpose of the experiment.

5.2. Task and stimuli

The task and stimuli in Experiment 3 were similar to those of Experiment 2, with the following exceptions: 1) Participants performed the experiment without a counterpart. They were all informed that they needed to respond only on trials that began with presentation of their specific color. ("You need to respond as quickly and accurately as possible on trials that begin with a green cue and refrain from responding on trials that begin with a red cue"). 2) Participants were informed that when it was their turn, the arrow would point to the location at which they executed their response. In contrast, when it was not their turn (e.g., after a red cue), the arrow would be randomly directed to one of the two possible locations. On trials in which the participant did not respond, the arrow appeared after a constant time interval following the disappearance of the central color cue (1170 ms, imitating a response after 370 ms from target presentation).

5.3. Results

As in the previous experiments, trials in which participants responded incorrectly as well as trials in which RTs were less than 100 ms (anticipatory errors) or greater than 1500 ms (inattention error (were removed from the data set (overall 0.8 %). To investigate whether SIOR was still apparent without the social context, we conducted a two-way analysis of variance (ANOVA) with repeated measures on RT data, with the person responding in the previous trial (same person, no person) and target location (same, different) as within-subject factors. The main effects of target location, the main effect of person and the interaction effect were all significant ($F_{(1,26)=}$40.18, p < .01, η_p^2 =0.6, $BF10$ = 12.13; $F_{(1,26)=}$7.97, p < 0.01, η_p^2 =0.23, $BF10$ = 70; $F_{(1,26)=}$21.32, p < .01, η_p^2 = 0.45, $BF10$ = 14.1; respectively). Planned comparisons revealed a significant IOR effect (i.e., in the same-person trials, same location RT > different location RT) (IOR- $F_{(1,26)}$ = 57.87, p < 0.01, η_p^2=.69, $BF10$ = 636630) and a non-significant effect after the randomly assign arrow (i.e., in the no-person trials, same location RT = different location RT); 'SIOR'- $F_{(1,26)}$ = 0.2, *n.s.*, η_p^2 = 0. 007, $BF10$ = 0.29). See Fig. 6.

RT of Experiment 3 by target location (same, different) and the person responding in the previous (same-person trials, no-person trials). The Y axis shows the RTs in ms. Error bars represent the standard error.

The results of Experiment 3 demonstrate that the inhibitory effect was absent when participants performed the exact same task as in Experiment 2 but without the social context (no counterpart). That is, while there was a significant IOR effect, there was no SIOR effect (Fig. 5). These results strengthen the role of sociality as a key component of the SIOR effect. If SIOR is an attentional effect *per se*, then we would expect an inhibitory effect to be elicited (as in Experiment 2). However, this was not the case.

In the next experiment we continued to explore the role of the social context in producing the SIOR effect. We examined whether the belief that one is performing the task with a counterpart (an agent) would suffice in eliciting SIOR.

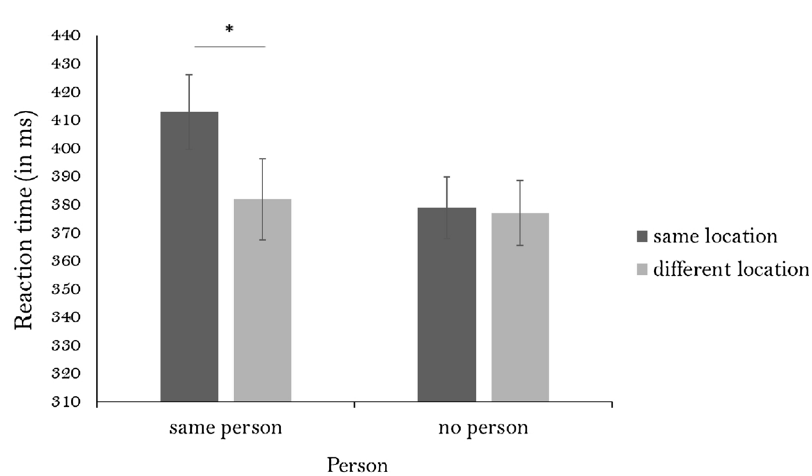

Fig. 6. RT of Experiment 3 by target location and the person responding in the previous trial (same person, no person).

6. Experiment 4: SIOR from a distance

Scholars have suggested that observation of another person's behavior influences the behavior of the observer, since it leads to activating a similar response code within the observer (Elsner & Hommel, 2001; Sebanz et al., 2003; Welsh, Higgins et al., 2007; Welsh, Lyons et al., 2007). The question arises whether it is necessary to see the co-actor's action or whether believing that a co-actor is acting with you is enough. According to the ideomotor and common coding theory[5], observation of an action (or part of it) is necessary to trigger a motor representation (Greenwald, 1970; Hommel, 2009; Jeannerod & Frak, 1999; Welsh, Higgins et al., 2007; Welsh, Lyons et al., 2007). For instance, Welsh, Higgins et al. (2007) found that believing that a co-actor is performing the task in another room is not enough to elicit the Social Simon effect. Actually seeing the other's response is what is important.

In contrast, there are other indications that in the Social Simon task, knowing about the co-actor's actions can initiate the social effect (Sebanz et al., 2003; Tsai, Kuo, Hung, & Tzeng, 2008; Sebanz et al., 2003; Tsai et al., 2008; see also Dittrich, Bossert, Rothe-Wulf, & Klauer, 2017, for additional evidence from the social flanker task).

In the current experiment we aimed to determine whether a participant's belief that a co-actor is performing the task with the participant would be sufficient to induce the SIOR effect. Atkinson et al. (2018) found that the presence of a co-actor (specifically, observation of a real-time biological motion) is not necessary in order to elicit the SIOR effect. In their experiment, however, the participants were continually exposed to a social cue, whether real or a video-recorded image of a person. Moreover, the within-subject design used in Atkinson et al. may cause a carry-over effect that masks possible modulation of the SIOR effect.

From an evolutionary point of view- the self IOR is explained by the foraging facilitator hypothesis which suggests that the inhibitory process is aimed to improve the individual's visual search (Klein & MacInnes, 1999; Klein, 2000). Respectively, the SIOR too could be explained in that view, that is, the need to inhibit an already searched location from being searched again by another agent seems to be essential for maximizing group outcomes. What follows is that knowledge alone regarding the already searched location should produce the SIOR effect. But when Welsh et al. (2014) examined this prediction they did not find SIOR effect when they used auditory information. Yet, it is possible that using visual information is a stronger spatial cue and would induce the SIOR effect.

In the present experiment we examined two conditions. In the first condition we used a cover story in which the participant was introduced to a collaborator at the beginning of the experiment. The collaborator pretended to be another participant that would perform the dyadic task with the participant but from another experiment room. This procedure enabled us to see whether the presence of a co-actor was required to evoke the SIOR effect, or a mental representation of a co-actor acting toward a location would suffice. The second condition was similar to Experiment 3 in which only one participant performed the task. Here, however, the participants performed the task in an individual set-up (in contrast to the dyadic setup employed in Experiment 3 in which participants saw an empty chair and computer setup in front of them). This allowed us to examine whether different interpretations given to the arrow would modulate the SIOR effect. Specifically, we predicted that when the arrow was perceived as indicating another person's response, SIOR would be observed. In contrast, when the arrow was perceived as a computer-generated random stimulus, SIOR would not be elicited. We predicted that the participants who believed that they were performing the task with a co-actor, would demonstrate SIOR even though they did not directly observe the collaborator during the task.

6.1. Participants

Thirty-nine undergraduate female students participated in the experiment in exchange for course credit or payment. They were assigned to one of the two conditions. Twenty-three participants were assigned to the experimental condition. Six participants from the experimental condition reported that they did not believe they had acted with a real person and hence were removed from the analysis. Thus, 17 participants were included in the analyses of the experimental condition and 16 in the control condition (the experimental condition: age range: 20–30; M = 25.09, Sd = 2.62, the control condition: age range: 20–28; M = 24.06, Sd = 2.1).

6.2. Task and stimuli

Since the short target-to-target interval exhibited both the self-IOR and SIOR effects, we employed the 1300 SOA in the following experiment. Thus, the task and stimuli in this experiment were similar to those of Experiment 2b, with the following modifications: 1) The arrow appeared for a constant time interval after the disappearance of the central color cue (770 ms, as in Experiment 3). 2) In the first condition, participants were first introduced to their co-actor (who was actually a collaborator). Both actor and co-actor signed consent forms to participate in the experiment and were instructed about the experiment together. Then, the real participant entered a separate room with a single computer screen (in contrast to all previous experiments described above, which were conducted in a dyadic setting). Another means of strengthening the cover story was employed in the experimental room. There, participants answered several demographic questions by entering their responses into the computer (age, gender). Then, a recording of another participant filling the form was shown on the computer screen, indicating that there was an agent acting in the other room. The task was identical to the one described in Experiment 2b. The perceived appearance of the arrow, supposedly showing the direction in which, the other participant responded, was fixed and set at 370 ms (as in Experiment 3). At the end of the experiment, participants were asked to what degree they believed someone else was performing the task with them, ranging from 1—disbelief to 10—full belief. Participants whose response was less than 5 were excluded from the analysis because we wanted only participants for whom the manipulation was effective. See the supplemental material for Fig. 1 that presents the SIOR effect by the amount of belief that another person was performing the task in the other room.

In the second condition, participants acted alone without the cover story (no collaborator as a co-actor was introduced) and were instructed, by the experimenter, to respond in trials that began with a presentation of one color and refrain from responding in trials that began with a presentation of a second color.

6.3. Results

6.3.1. Condition 1 – SIOR from afar

As mentioned, participants who reported that they did not believe they acted with a real person were removed from the analysis (n = 6). Trials in which participants responded incorrectly as well as trials in which RTs were less than 100 ms (anticipatory errors) or greater than 1500 ms (inattention error (were also removed from the data set (overall 1 %). To investigate whether SIOR was elicited merely by

[5] According to the ideomotor theory (Hommel, Müsseler, Aschersleben, & Prinz, 2001; James, 1890; Prinz, 1997), people form bidirectional links between the perceived sensory effects and the motor pattern producing them. Thus, the theory of event coding (TEC) postulates that the representation of intended action effects is considered to be causally responsible for the selection of associated actions (Elsner & Hommel, 2001; Hommel et al., 2001; Hommel, 2009). For instance, it is assumed that the individual Simon effect is an outcome of a distal overlap between two effect codes (stimulus-response). The similar finding from the joint Simon effect is further evidence that individuals represent the actions of another as if they were their own (Sebanz et al., 2003).

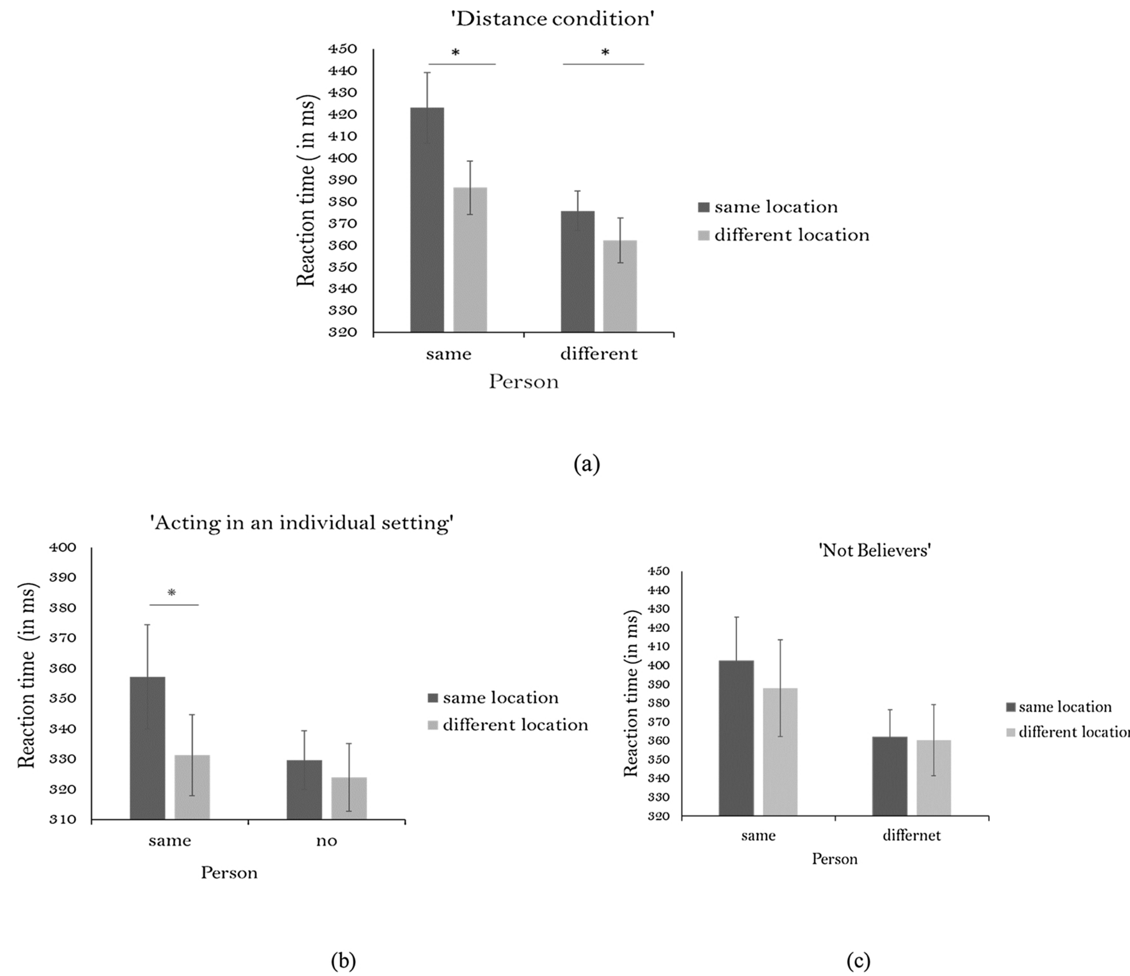

Fig. 7. RT of Experiment 4 by target location (same, different) and person (same-person, no-person). Figure (a) shows the pattern of results for participants in the condition in which they were made to believe they are acting with another person. Figure (b) shows the pattern of result for participants who acted alone in an individual setting. Figure (c) shows the pattern of results for the six participants who reported they do not believe they were performing the task with another person. Error bars represent standard error.

interpreting the information from the arrow as an indication of another person's action, we conducted a two-way analysis of variance (ANOVA) with repeated measures on RT data, with the person responding in the previous trial (same person, different person) and target location (same, different) as within-subject factors. The main effects of target location ($F_{(1,16)=}$ 51.41, $p < 0.01$, $\eta_p^2 = 0.76$, $BF10 = 26.89$), the main effect of person ($F_{(1,16)=}$30.65, $p < 0.01$, $\eta_p^2 = 0.65$, $BF10 = 11844.84$) and the interaction effect ($F_{(1,16)=}$ 5.05, $p < 0.05$ $\eta_p^2 = 0.23$, $BF10 = 2.12$) were all significant. Planned comparisons revealed a significant IOR effect (i.e., in the same-person trials, same location RT > different location RT); (IOR- $F_{(1,16)} = 24.77$, $p < 0.01$, $\eta_p^2 = 0.6$, $BF10 = 429.2$), and a significant SIOR effect (i.e., in the different person trials, same location RT > different location RT); SIOR-$F_{(1,16)} = 7.87$, p < 0.05, $\eta_p^2 = 0.32$ $BF10 = 8.76$). Thus, participants who believed they were performing the task with a co-actor demonstrated SIOR. It is important to note that participants who did not believe in the manipulation did not exhibit the SIOR effect; see Fig. 7 and the supplemental material.

6.3.2. Condition 2 – Acting in an individual setting

Trials in which participants responded incorrectly as well as trials in which RTs were less than 100 ms or greater than 1500 ms were excluded from the analysis (overall, 0.9 % trials were removed). A two-way analysis of variance (ANOVA) with repeated measures was conducted on RT data, with person (same person, no person) and target location (same, different) as within-subject factors. The main effects of target location ($F_{(1,15)} = 15.1$, $p < 0.01$, $\eta_p^2 = 0.5$, $BF10 = 3.15$), the main effect of the person ($F_{(1,15)} = 4.42$, $p = 0.05$, $\eta_p^2 = 0.22$, $BF10 = 5.68$) and the interaction effect ($F_{(1,15)} = 8.63$, $p < 0.05.$, $\eta_p^2 = 0.36$, $BF10 = 1.05$) were all significant. Planned comparisons revealed a significant IOR effect (i.e., in the same-person trials, same location RT > different location RT); ($F_{(1,15)} = 18.16$, $P < 0.05$, $\eta_p^2 = 0.54$, $BF10 = 106.4$), but there was no significant SIOR effect (i.e., in the no-person trials, same location RT > different location RT); SIOR-$F_{(1,15)} = 1.68$, *n.s.*, $\eta_p^2 = 0.1$, $BF10 = 0.52$). Thus, SIOR was not elicited without the presence of a co-actor. See Fig. 7.

To conclude, the results indicate that participants who believed they were performing the task with a co-actor demonstrated SIOR even though they did not observe the co-actor during the task. These results strengthen the interpolation of the foraging facilitator hypothesis in a social context (Cole et al., 2019; Klein & MacInnes, 1999; Klein, 2000) which predicts that knowledge regarding an already-searched location suffices to produce an inhibitory process toward that location (Cole et al., 2019).

The result of this experiment reinforces the notion that social information regarding the location to which another person acted on (at this point we cannot distinguish the information regarding the action per se from the action toward a specific location) is enough to elicit the social effect. This goes in line with evidence of Gobel et al. (2018) which found that cue-target compatibility was greater in trials where participants were led to believe that the cue they saw was related to a gaze location of their partner in contrast to trials in which it was randomly assigned by the computer. Notably, in both cases the cue appeared peripherally.

7. General discussion

In the present study we demonstrated that SIOR cannot be explained by attentional- effects per se, but that the social context is a crucial element in eliciting the SIOR effect. In Experiment 1 (full access to the co-actor's target presentation) and in Experiments 2a and 2b (without presentation of the co-actor's targets), participants were slower to react to targets appearing at the same location as the previous target, regardless of whether they (self-induced IOR) or their counterpart (SIOR) responded to it. This finding, together with the elimination of SIOR in Experiment 3 (and its absence in Experiment 4, condition 2), where participants performed the same task as in Experiment 2 with the same visual display but without a counterpart, suggests that the social context plays an important role in this process. Furthermore, our findings suggest that under the same visual display the appearance of the SIOR effect depends on the interpretation participants gave to the perceptual cue (the arrow). The findings of Experiment 4, in which merely believing there is a partner acting with you is a sufficient social cue to induce the SIOR effect, reinforce the conclusion that SIOR is indeed a social effect and only appears in a social context.

The observation that SIOR is evoked only in a social context rules out the attentional (transient) account explanation (Cole et al., 2012, 2019) as the exclusive explanation for the SIOR effect. The attentional (transient) account suggests that the social aspect acts as an exogenous cue that triggers the IOR effect. The present study strengthens the notion that the social aspect of the task does not behave like an ordinary perceptual cue that captures the participant's attention, but rather makes a unique contribution and has a unique influence. First, in all the experiments the participants did not directly observe the action of the other participant since they were each seated in front of a computer screen that blocked their direct view of the other participant. Next, in the second, third and fourth experiments the participant could not observe the onset and offset of the other participant's target but was only informed by a central cue about the other's response/target location. Although in the past (Skarratt et al., 2010) central cues were found to elicit SIOR, these cues were social cues (e.g., gaze or body gestures) that are inherently social. In the current study the central cue was *intrinsically* not social, and the sociality was added only by manipulating the participant's belief that he/she was acting with someone else (see also Gobel et al., 2018; Tufft et al., 2015). It is important to note that in experiments 2–4 the arrow was non-predictive (it did not predict the future target's location). The main difference between experiments was whether the participant believed that the arrows were informative (regarding the co-actor's previous target location) or randomly assigned by the computer. Only when the arrow was perceived to be informative was SIOR observed. Future studies could manipulate the type of information provided by the arrow and examine its influence on SIOR.

In addition, a previous study by Atkinson et al. (2018) found that SIOR was not established when participants were not required to perform the task in the original turn-taking rhythm. These researchers suggested that the regular turn-based sequence in which participants were required to pay attention to the other participant's movement to determine when it was their turn was the only factor that made this task social, if at all. Throughout all the social experiments in the current study, the participants were not required to attend to the other participant's performance in order to know when it was their turn. A central color cue at the beginning of each trial informed them whose turn it was. Nevertheless, SIOR was observed. Our results indicate that even when a task does not require attending to the co-actor's action, SIOR is elicited, indicating the reflexive nature of the inhibition that occurs when acting on the same environment with another person. We argue, according to the foraging facilitator hypothesis which had been suggested for the IOR effect (Klein, 2000) that the minimal condition required to elicit SIOR is the belief that a specific location has been acted upon by another agent (see also Cole et al., 2019; Welsh et al., 2005). This argument follows not only from the current experiments but is also supported by Atkinson et al. (2014) who found that when participants performed the same action but toward different locations (i.e. the action locations were not shared - two left, two right) - no SIOR was observed. This is in line with the co-representation account (Welsh et al., 2005) with one exception, that seeing the other participant's behavior is not a necessary condition but what matters is the believing that another person acted upon a specific location.

Moreover, in all the experiments we found IOR in the same-person trials. The IOR effect in the current study was consistently larger in magnitude than the SIOR effect (see also Welsh, Lyons et al., 2007). One difference between the same-person and different-person trials, in experiments 2–4, is the presentation of the target. In the different-person trials, the other participant's target was masked and there were no peripheral stimuli; thus, the information regarding the co-actor's response was provided by a central arrow. In the same-person trials, the participants directly observed the previous target (and responded to it), therefore in addition to the central arrow, the target could also attract attention to its location (similar to an exogenous peripheral cue that produces IOR). It is possible that the presentation of the peripheral target enhanced the inhibitory effect in the same-person trials compared to the inhibitory effect in the different-person trials.

A growing body of literature has been exploring the social aspects of the *Social Simon effect* (Sebanz et al., 2003). In this task two participants are seated side by side and each is instructed to respond only to one of two stimuli (e.g., a green or a blue target). While social factors such as group affiliation and relatedness between co-actors modulated the Social Simon effect (Hommel, Colzato, & van den Wildenberg, 2009; Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011; McClung, Jentzsch, & Reicher, 2013), other evidence has shown that the social effect emerges even when participants act alongside virtual non-human co-actors (e.g., a Japanese waving cat, scrambled patterns and a wooden hand, Dolk et al., 2011, 2013). One explanation for this non-social evidence is the Referential Coding Account (2013, Dolk et al., 2014), according to which, similarities between external action events and a participant's own action events require discriminating one from the other. This discrimination focuses on which task representation is relevant and which is irrelevant. The more similarities there are, the greater the overlap between the stimulus features and the response, resulting in the Social Simon effect. In the Social Simon task, the participants see all the targets that should be reacted to; however, in our set-up the co-actor's target was masked, reducing the need to discriminate the self and other's action events, yet SIOR was still observed. Nevertheless, it would still be worth examining whether SIOR involves a similar mechanism.

In the current study we tested only women in order to reduce the interpersonal variability which however limited our ability to generalize our results. Yet, a previous study examining social relevance on IOR did not find gender differences (Gobel et al., 2018). Future research could address this issue by including gender as a variable that may modulate the SIOR effect.

The novelty of the current experiment is in examining the minimal conditions in which SIOR can be evoked and to measure whether the mere representation of a social agent can produce SIOR. In order to do so we had to make changes to the typical procedure used to explore SIOR, since it was confounded with perceptual visual cues (e.g., the presentation of the target). Previous studies did not dissociate completely the effect of knowing that another person responded to a target in a specific location from seeing the person performing the action, at least partially (except for Welsh et al., 2014). The fact that in the current study participants did not have a direct view of each other (as the computer monitors were stationed between them) demonstrates that direct observation of the co-actor is not vital for the SIOR to emerge. In our study, the co-actor's targets and responses were not directly observed and hence SIOR was elicited by a more abstract representation of the co-actor's response. Even though the setup of the current study differed significantly from the typical setup employed to study SIOR, the presence of a similar social inhibitory effect in both setups, suggests that the same inhibitory mechanism is being measured.

To conclude, it seems that the social aspect is vital for the SIOR effect to occur. Thus, social processes may influence and initiate reflexive automatic inhibitory processes toward an acted-upon location by another agent. We argue that neither the direct observation of an action nor the onset or offset of a stimulus in a specific location is required for the SIOR to emerge, but only the notion that the location was acted upon by another person. Nevertheless, whether the social effects are automatically formed every time an individual acts in a social setting and with any person remains an open question. The SIOR effect is an outstanding demonstration of the importance of considering social context when exploring cognitive processes. Future studies should examine whether the influence of social context is a result of qualitatively different mechanisms or whether its effect is a product of the relevancy and saliency of social cues.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.cognition.2019.104108.

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