Social information rapidly prioritizes overt but not covert attention in a joint spatial cueing task

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Accepted for publication in Acta Psychologica

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Abstract

Coordinating actions with others is crucial for our survival. Our ability to see what others are seeing and to align our visual attention with them facilitates these joint actions. In the present research, we set out to increase our understanding of such *joint attention* by investigating the extent to which social information would be able to prioritize overt (when moving the eyes to attend) and covert (when shifting attention without eye movements) attention in a joint spatial cueing task. Participants saw a cue and detected a target at the same or a different location alongside an unseen partner of either higher or lower social rank. In a novel twist, participants were led to believe that the cue was connected to the gaze location of their partner. In Experiment 1, where participants were told to not move their eyes (covert attention), the partner's social rank did not change how quickly participants detected targets. But in Experiment 2, where participants were free to move their eyes naturally (overt attention), inhibition of return effects (slower responses to cued than uncued targets) were modulated by their partner's social rank. These social top-down effects occurred already at a short SOA of 150ms. Our findings suggest that overt attention might provide a key tool for joint action, as it is penetrable for social information at the early stages of information processing.

Highlights

- Participants carried out a spatial cueing task with a higher or lower rank partner.
- Partner rank modulated inhibition of return effects for overt attention.
- Social inhibition of return effects occurred as early as 150ms after cue onset.
- Our results suggest that overt attention is a key tool for joint action.

Social information rapidly prioritizes overt but not covert attention in a joint spatial cueing task

1. Introduction

Human life is full of acting alongside and together with others. We can shake hands, play a jam session, or beat our opponents in the Super Bowl. In fact, our ability to understand what others are doing and to coordinate our own actions with them is crucial for our survival. Research has shown that we tend to spontaneously co-represent what others are doing (e.g., Atmaca et al., 2011; Böckler & Sebanz, 2012), and that we can spontaneously coordinate our actions with them (e.g., Richardson et al., 2007; Richardson & Dale, 2005). Coordinating actions in space and time is one example of the social dynamics that are intrinsic to human social nature.

One critical mechanism facilitating joint actions is our ability to see what others are seeing and to align our visual attention with them (Clark, 1996; Sebanz et al., 2006). Such *joint attention* builds a common ground for linking two minds with the same physical environment. Joint attention not only helps us to learn from others (Emery, 2000), but knowing where, and with what intention, others are looking can influence our own actions as we collaborate with them (Brennan et al., 2008; Gobel et al., 2018). Thus, visual attention in social contexts is fundamentally influenced by preferentially gazing at, and with, others (Richardson & Gobel, 2015).

In the present research, we set out to increase our understanding of such joint attention by investigating the extent to which social information about an interaction partner would be able to modulate overt (when moving the eyes to attend) and covert (when shifting attention without eye movements) attention in a joint spatial cueing task. We also investigated how early these interpersonal spatial orienting effects occurred. Therein, we add to our understanding of the interplay of perception and action as a key mechanism underlying joint action.

1.1. Joint attention

Looking with another person and following their gaze can reveal a range of useful information about one's environment. For example, it can help us determine where reward is most likely to be found, or where danger is mostly likely to originate from (Emery, 2000). Not surprisingly, humans are skilled gaze followers. Human infants follow the gaze of their caregivers from earliest ages (Farroni et al., 2000), and social learning in infants is facilitated by jointly attending (Wu et al., 2011). In fact, the human eyes have quite uniquely evolved to facilitate this task, as their white sclera increases contrasts and allows for better communication through shifting gaze (Kobayashi & Kohshima, 1997). Thus, following another's gaze is a crucial mechanism facilitating social living.

Crucially, the ability to successfully communicate and collaborate with others through shifting one's gaze depends on two factors: what the other person does and who the other person is. First, humans are aware of the functional value of another person. Thus, gaze cueing effects, the quicker detection of targets in locations that are looked at by another person, are reduced when the person cueing the onlooker wears goggles that prevent them from seeing the target (Morgan et al., 2018; Teufel et al., 2010). Thus, people have a clear understanding of the importance of what another person does and why. Second, and just as important, humans are aware of who directs their attention. For example, for faces that resemble the onlooker (Deaner et al., 2007; Hungr & Hunt, 2012), for faces of ingroup members (Pavan et al., 2011), and for those faces with whom we share political partisanship (Liuzza et al., 2011), gaze cueing effects are larger. Another social category that increases gaze cueing effects is high-status faces

(Dalmaso et al., 2012). Indeed, past research has shown that people pay more attention to higher than lower ranked others (Cheng et al., 2013) and especially their eyes (Foulsham et al., 2010). One reason for why social rank captures and guides onlookers' attention is that social rank plays a crucial role for living in groups, facilitating interpersonal communication and coordination, leading to more efficient decision making and locomotion, and increasing team performance (Van Vugt, 2006; Van Vugt et al., 2008).

Experiments using gaze cueing paradigms, however, are limited by the fact that faces and eyes provide two categories of information. On the one hand, as stimuli, faces and eyes provide directional cues similar to non-social cues, such as arrows. On the other hand, as representations of human beings, faces and eyes provide information about mental states. In other words, people tend to look at targets for a specific reason. Yet, whether attributing mental states onto the gazing agent mediate gaze cueing effects has been questioned. For example, one study showed that in spite of the gazing agent being obstructed by a physical barrier from viewing the target stimulus, robust gaze cueing effects persisted (Cole et al., 2015). Similarly, emotional expressions of the gazing agent do not modulate gaze cueing effects (Graham et al., 2010). Instead, attributing mental states onto the gazing agent seems neither sufficient nor necessary for automatic shifts of social attention in gaze cueing paradigms to occur (Kingstone et al., 2019).

Given these limitations of the gaze cueing paradigm, we investigated the extent to which social information modulates *joint attention* using a joint spatial cueing paradigm (Tufft et al., 2015), in which all stimuli are non-social in nature, and only participants' beliefs about the social nature of the cue are manipulated. In classic spatial cueing experiments using non-predictive cues, attention is cued by the sudden onset of a stimulus (e.g., a red dot) or salient change, and participants are then asked to detect as quickly as possible the appearance of a new target (e.g., a blue square) that may, or may not, appear in the same location as the cue. Even though the cue does not predict the target location, it nevertheless influences behavior (Posner & Cohen, 1984). While at shorter cue-target intervals (SOAs < 100ms), participants are quicker to detect cued targets, the most relevant influence for the present purpose is that at longer cue-target intervals (SOAs > 300ms), participants are slower to detect cued targets (Klein, 2000), a phenomenon known as inhibition of return (IOR) (Posner et al., 1985). This is, because at longer cue-target intervals, participants attend to the cued location, disengage their attention as the cue disappears, and are subsequently slower to reattend to this same location. The present research follows from recent work showing that carrying out a spatial cueing task alongside another person and believing that the cue was connected to the gaze location of this person modulated inhibition of return (Gobel et al., 2018). The authors speculated that such *social inhibition of return* might free attentional resources for the exploration of novel location. If true, this would be a useful mechanism for *joint* visual exploration and potentially help teams to do better overall.

1.2. Overt and covert attention in social contexts

Whether social information prioritizes overt and covert attention in a joint spatial cueing task remains unknown. While overt and covert attention are linked, they are separable (Smith & Schenk, 2012). Some experiments have shown that both overt and covert attention can be reflexively captured by social stimuli, such as faces and eyes (Bindemann et al., 2007; Birmingham & Kingstone, 2009). Other experiments have found that social information yields stronger effects over overt than covert attention. For example, when covertly attending in a cueing task, performance was comparable when the stimuli were social (i.e., face) or non-social (i.e., house) in nature. But when participants were allowed to spontaneously move their eyes, they attended more to social (i.e., face) than non-social (i.e., house) stimuli (Blair et al., 2017).

Similarly, when participants are free to move their eyes, mental attributions did modulate gaze following (Kuhn et al., 2018). Social information also yielded stronger effects in contextually based cueing tasks, when participants spontaneously moved their eyes (Pereira et al., 2019).

Moreover, research suggests that covert attention is less responsive to top-down modulation than overt attention, perhaps because top-down controlled attention seems to heavily rely on eye movements (e.g., Van Der Stigchel & Theeuwes, 2007). For example, a recent study investigating the likelihood of detecting a magic trick found that participants who had received explicit instructions as to where they needed to look were more likely to identify deception when being able to naturally move their eyes (Kuhn et al., 2016). In another study, researchers secretly recorded passers-by looking at a confederate who either raised a hand to the side of his head and said “Hey” into his phone, or who engaged in the same action but said “Hey” to his immediate surroundings. Results showed that passer-by spontaneously moved their eyes towards the confederate when the action could be construed as being directed at them (Laidlaw et al., 2016). Thus, in real-world social contexts, humans often benefit from spontaneously moving their eyes.

1.3. The present research

To test whether social information about another person would modulate overt and covert attention, we used the recently developed joint version of the spatial cueing task (Tufft et al., 2015). In the joint spatial cueing task, pairs of participants take part in a classic spatial cueing task, in which a cue stimulus directs attention to one location on screen, and participants are then asked to quickly detect a target stimulus that either appears in the same or in a different location. They are sat side-by-side, not interacting, looking at a screen with an eye tracker measuring their eye movements. Participants are told that the cue (a red dot) represents where their partner has just looked on the other screen. In such joint spatial cueing tasks, the magnitude of the *social* inhibition of return effect is amplified, and *social* inhibition of return effects can be further increased when participants carry out the task alongside a higher ranked partner (Gobel et al., 2018).

In the present research, we asked whether the social inhibition of return effect would be limited to instances when participants naturally moved their eyes or generalize to instances when attention was covertly employed. We also aimed to find out how early these effects would occur, something that was missing from the literature to date. We hypothesized that the social information about an interaction partner – their relative social rank – would only modify social inhibition of return effects, when participants were able to naturally move their eyes. We held this hypothesis for two reasons: Firstly, as seen above, previous research has suggested that social stimuli and social contexts yield stronger top-down effects when attention is employed overtly rather than covertly. Secondly, and perhaps even more important, we expected that being able to move the eyes would allow for social attention to enact its reciprocal function of encoding and signaling information (Richardson & Gobel, 2015), which we predicted to be a crucial element of successful joint attention. We tested our hypothesis across two experiments. In Experiment 1, participants were told that they were not allowed to move their eyes away from fixation (covert attention). In Experiment 2, however, we did not give participants such an instruction and thus participants were able to naturally move their eyes, if they wanted (overt attention).

2. Experiment 1

Experiment 1 tested whether social information would modulate *covert attention* in a joint spatial cueing task, when participants were instructed to not move their eyes but to maintain fixation at the center of the screen throughout the experiment.

2.1. Method

2.1.1. Participants

Here, and in the subsequent experiment, we estimated sample sizes based on previous research on joint inhibition of return effects, showing moderate to large effect sizes, and targeted to sample at least 45 subjects in each experiment in order to have 80% power for the detection of a medium-sized effect (d = 0.50) when employing the traditional 0.05 criterion for statistical significance. Ethical approval for all experiments was provided by the University of California at Santa Barbara. In all experiments, participants provided informed consent prior to their participation.

Fifty-two participants volunteered to participate in exchange for payment or partial course credit and performed the experiment with a confederate. The confederate was one of four undergraduate research assistants (2 female and 2 male), which were randomly assigned as an interaction partner to a participant, so that none of the observed effects would be due to a specific identity of the confederate. We used confederates as to manipulate the interaction partner's social rank.

Two participants expressed suspicion about the true nature of the experiment, or the role of the confederate, and they were thus excluded from the analysis. One participant chose to not complete the experiment. Thus, we analyzed data from 49 participants (27 females, M_{age} = 18.44, SD_{age} = 0.82). 26 participants were assigned to the higher rank partner condition, and 23 participants were assigned to the lower rank partner condition. Sensitivity analysis suggested that we had 80% power to detect at least an effect size of d = 0.40.

2.1.2. Design

We employed a 2 (Partner Rank: higher rank versus lower rank) × 2 (Target Location: cued versus uncued) × 3 SOA (150ms versus 700ms versus 1100ms) mixed factor design, where the former factor was manipulated between subjects and the latter two factors were within subjects. We measured participants' reaction time to the onset of the target stimulus.

2.1.3. Apparatus

Participants took part in the experiment alongside a confederate pretending to be another participant. They were seated side-by-side with a curtain obstructing direct view on each other's screen. We instructed participants to not talk or interact during the experiment except for their questionnaire answers (see below).

Participants were seated 110 cm in front of a 19" CRT monitor, set to a resolution of 1,024 × 768 pixels and a refresh rate of 60 Hz. In front of the monitor, we placed an eye tribe remote eye tracker at a distance of 60 cm recording participants' eye movements at 30 Hz. This low-cost eye tracker has been shown to provide adequate eye movement data quality (Ooms & Krassanakis, 2018). Participants used a chin rest to maintain the same viewing distance from the monitor and a standard keyboard to respond. All stimuli were generated using the Psychophysics Toolbox extensions on a Mac Mini (Apple, Inc.) running OSX (10.8.5) and MATLAB R2013a (Mathworks).

The trial structure is represented in Figure 1. Each trial depicted two images, and participants were free to attend to them for 1500ms. Next, a fixation cross was shown for 500ms. Images were then overlaid with the cue (dot), which was presented for 100ms, with an intervening cue (star), which was presented for 50ms, 600ms or 1000ms, and finally the target (square), which was presented until participants responded or disappeared after 1500ms at what point a trial ended and a new trial began. Between trials there was a 100ms pause. In total, participants completed 432 trials divided into 4 blocks of 108 trials each, with 12 trials per block being catch trials and the remaining trials being equally distributed across the six within-subject conditions.

Pictures had a resolution of 400 × 300 pixels. Images were presented at a size of 4 degrees of visual angle positioned at the center of the horizontal axes at a distance of 6 visual degrees from each other. The cue (dot) and the target (square) were presented at a size of 1 degree of visual angle at the center of a given image, and the fixation cross was presented at a size of 0.5 degrees of visual angle at the center of the screen.

2.1.4. Procedure

2.1.4.1. Partner social rank manipulation

Before participants started the joint spatial cueing task, we asked them to fill in a brief questionnaire about themselves, including demographic information and how well they did at university. We also told participants that they would exchange questionnaires with their interaction partner as to learn a little more about them. We used the interaction partner's answers in the questionnaire to manipulate the perceived social rank of the interaction partner. In the higher rank partner condition (N = 26), interaction partners reported to have come from an affluent family with parents having prestigious jobs and earning more than the national average income. They also reported to have exceled at university and to have engaged in extra-curriculum activities. In the lower rank partner condition (N = 23), in contrast, interaction partners reported to have come from a less affluent family with parents having less prestigious occupations. Responses, moreover, suggested that the interaction partner struggled at university and did not engage in extra-curriculum activities.

2.1.4.2. The joint spatial cueing task

Participants carried out a joint spatial cueing task alongside a confederate (Tufft et al., 2015). Participants were told that they would view a set of two pictures, which they were free to look at. They were then told that they would see a red dot appear on top of one of these pictures, indicating the imagine that was preferentially looked at by their interaction partner, but that they could ignore this information. Participants learned that their task was to respond as quickly and as accurately as possible to the onset of a blue square by pressing the space bar (i.e., target detection task) with their dominant hand.

We told participants that throughout the experiment the two computers would be connected, and that they would be able to see where their interaction partner was looking on their screen. Specifically, to make participants to believe that the red dot represented the gaze location of their interaction partner, we used eye trackers to monitor participants eye movements. Participants and their interaction partner were walked through an elaborate eye tracking calibration procedure at the beginning of the experiment. Consistent with the idea that eye trackers monitored their eye movements, and that participants could see where their interaction partner had preferentially looked at, the red dot appeared on top of an image that the interaction partner reported to have ostensibly looked at.

2.1.4.3. Partner social rank manipulation check

After participants had completed the joint spatial cueing task, we asked them to fill in another brief questionnaire. This time, we were interested in their impressions of their interaction partner. Among various filler items (e.g., *“My partner seems nice.”, “My partner seems confident.” “My partner seems dependable.”*), we included the following three items assessing the perceived social rank of the interaction partner: *“My partner has high social status.” “My partner occupies high social rank.” “My partner has higher social status than me.”* Participants indicated their agreement with these statements along a 7-point scale ranging from *"1 = strongly disagree"* to *"7 = strongly agree"*. We averaged these three items into a perceived social rank scale (α = .92, *M* = 4.62, *SD* = 1.55). At the end of the experiment, we also verified the extent to which participants were suspicious about their interaction partner being a confederate.

2.2. Results

2.2.1. Perceived social rank of the interaction partner

An independent samples t-test showed that participants perceived their partner to have significantly higher social rank when being paired with the higher rank partner (*N*= 26, *M* = 5.63, *SD* = 1.17) compared to when being paired with the lower rank partner (*N* = 23, *M* = 3.48, *SD* = 1.06), $t(47) = 6.71$, $p < .001$, $d = 1.93$. Our manipulation of partner rank was successful.

2.2.2. Eye movements to target onset

We successfully recorded the eye movements of 42 participants with sufficient quality for data analysis. We were interested in whether or not participants followed our instructions to not move their eyes from fixation at the center of the screen. To this aim, we computed participants' average eye movements in visual degrees, between the onset of the target and their response. Because the fixation cross was presented with 0.5 visual degrees at the center of the screen, we carried out a one-sample t-test against 0.25 visual degrees, which revealed that participants did not significantly move their eyes away from fixation in the direction of the target (*M* = 0.21, *SEM* = 0.10), $t(41) = -0.37$, $p = .716$, $d = 0.11$. Results were robust when testing whether targets appeared on the left or on the right of the screen, and whether the cue had appeared in the same or a different spatial location. Thus, the eye tracking data suggests that participants maintained fixation and employed their attention covertly.

2.2.3. Social modulation of interpersonal spatial orienting

We analyzed trials, for which cue and targets were shown to participants. We excluded trials, for which participants had anticipated their responses (RT < 150ms) or failed to respond within 3SD of their average response to this trail type (2.71% of trials). To test our hypothesis, we ran a mixed-factorial ANOVA with three factors: Target Location (cued and uncued; within subjects), SOA (150ms, 700ms, and 1100ms; within subjects), and Partner Rank (higher rank versus lower rank; between subjects). This analysis yielded a main effect of Target Location, $F(1, 47) = 169.48$, $p < .001$, $\eta^2 = .78$, with cued targets being overall responded to slower (*M* = 407ms, *SEM* = 9ms) than uncued targets (*M* = 380ms, SEM = 9ms), equivalent to an inhibition of return effect of 27 ms.

There was also a main effect of SOA, $F(2, 94) = 83.22$, $p < .001$, $\eta^2 = .64$, such that participants were overall slower to respond at the shorter SOA of 150ms (*M* = 428ms, *SEM* = 11ms), than at the medium SOA of 700ms (*M* = 380ms, *SEM* = 8ms) and at the longer SOA of 1100ms (*M* = 372ms, *SEM* = 9ms). We also observed a significant two-way interaction between SOA and Target Location, $F(2, 94) = 24.30$, $p < .001$, $\eta^2 = .34$ (see contrast analysis below). However, neither the two-way interaction between Target Location and Partner Rank, $F(1, 47) < 1$, $p = .486$, $\eta^2 = .01$, nor the two-way interaction between SOA and Partner Rank, $F(2, 94) < 1$, $p = .686$, $\eta^2 = .01$, nor the three-way interaction between Target Location, Partner Rank, and SOA, $F(2, 94) < 1$, $p = 932$, $\eta^2 = .001$, were significant.

2.2.4. Social modulation of inhibition of return effects at different SOAs

We applied contrast analysis to test the effect of interpersonal spatial orienting at different SOAs. In comparison to more conventional omnibus approaches, contrast analysis allows to directly test the research question of interest preserving greater levels of power (Furr & Rosenthal, 2003; Rosenthal et al., 2000). Specifically, we computed five orthogonal contrasts (see Gobel et al., 2014 for a similar approach). First, we computed a main effect of short SOA relative to medium and long SOAs (λ1). Second, we compared the main effect of medium to long SOAs (λ2). Finally, we compared the high and low rank partner conditions at the different processing stages: 150ms SOA (λ3), 700ms SOA ((λ4) and 1100ms SOA ((λ5)).

The overall model fit was significant, F (5,141) = 9.39, $p < .001$, $R^2 = .25$. Overall, inhibition of return effects were smaller at the short SOA of 150ms (*M* = 10ms, *SEM* = 4ms) compared to at the medium SOA of 700 ms and long SOA of 1100ms, λ1: $b = 0.009$, SE = 0.001, $t = 6.15$, $p < .001$, CI95% [0.006, 0.011], $r = .50$. Inhibition of return effects were larger at the medium SOA of 700ms (*M* = 43ms, *SEM* = 3ms) than at the long SOA of 1100ms (*M* = 29ms, *SEM* = 3ms), λ2: $b = -0.007$, $SE = 0.002$, $t = -2.92$, $p = .004$, CI95% [-0.012, -0.002], $r = -.26$. However, we observed that inhibition of return effects did not differ between the higher compared to the lower rank partner condition at the short SOA of 150ms (λ3: $b = 0.002$, $SE = 0.003$, $t = 0.64$, $p = .521$, CI95% [-0.005, 0.009], $r = .10$), neither at the medium SOA of 700ms (λ4: $b = 0.000$, $SE = 0.003$, $t = 0.14$, $p = .890$, CI95% [-0.006, 0.007], $r = .06$), nor at the long SOA of 1100ms (λ5: $b = 0.002$, $SE = 0.003$, $t = 0.49$, $p = .627$, CI95% [-0.005, 0.008], $r = .09$). Thus, social information about an interaction partner's social rank did not modulate inhibition of return effects at any of the SOAs when attention was covertly employed.

2.4. Discussion

Experiment 1 did not find any evidence that the social information as to whether the interaction partner was higher or lower in social rank influenced social inhibition of return effects in a joint spatial cueing task when attention was covertly employed. Consistent with past research, we observed a typical time course of the magnitude of the inhibition of return effect, which was smaller at the SOA of 150ms, and larger at the SOA of 700ms than at the SOA of

1100ms. Importantly, however, at none of these SOAs were inhibition of return effects modulated by the social information about an interaction partner's social rank.

3. Experiment 2

Experiment 2 tested whether social information would modulate *overt attention* in a joint spatial cueing task. Experiment 2 was identical to Experiment 1, but this time participants did *not* receive any instruction as to whether they should maintain fixation throughout the experiment, and thus they were free to naturally move their eyes.

3.1. Method

3.1.1. Participants

Fifty-eight participants volunteered to participate in exchange for payment or partial course credit and performed the experiment with a confederate. The confederates were one of four new undergraduate research assistants (2 female and 2 male). This time, seven participants expressed suspicion about the true nature of the experiment, or the role of the confederate, and they were excluded from the analysis. Thus, we analyzed data from 51 participants (29 females, $M_{\text{age}} = 18.80$, $SD_{\text{age}} = 1.44$). 26 participants were assigned to the higher rank partner condition, and 25 participants were assigned to the lower rank partner condition. Sensitivity analysis suggested that we had 80% power to detect at least an effect size of $d = 0.40$.

3.1.2. Design

The design of Experiment 2 was identical with that of Experiment 1.

3.1.3. Apparatus

The apparatus of Experiment 2 was identical with that of Experiment 1.

3.1.4. Procedure

The procedure of Experiment 2 was identical with that of Experiment 1 with one critical exception: In Experiment 2, *participants did not receive any instructions as to having to maintain fixation throughout the experiment*. They were thus free to move their eyes naturally.

3.2. Results

3.2.1. Perceived social rank of the interaction partner

As in Experiment 1, a perceived social rank scale was computed (α = .90, *M* = 4.91, *SD* = 1.50). An independent samples t-test showed that participants perceived their partner to have significantly higher social rank when being paired with the higher rank partner (*N* = 26, *M* = 5.88, *SD* = 0.91) compared to when being paired with the lower rank partner (*N* = 25, *M* = 3.89, *SD* = 1.31), $t(49) = 6.32$, $p < .001$, $d = 1.76$. Thus, our manipulation of partner rank was successful again.

3.2.2. Eye movements to target onset

Gazing behavior of 47 participants was of sufficient quality to be analyzed. A one-sample t-test against 0.25 visual degrees revealed that participants significantly moved their eyes in the direction of the target (*M* = 1.67, *SEM* = 0.17), $t(46) = 8.47$, $p < .001$, $d = 2.50$. Results were robust when testing whether targets appeared on the left or on the right of the screen, and whether or not they were cued in the same spatial location. Thus, the eye tracking data suggests that participants significantly deviated from fixation and employed their attention overtly towards the target.

3.2.3. Social modulation of interpersonal spatial orienting

As in Experiment 1, we analyzed trials for which cue and targets were shown to participants. We excluded trials for which participants had anticipated their responses (RT <

150ms) or failed to respond within 3SD of their average response to this trail type (3.54% of trials).

To test our hypothesis, we ran again a mixed-factorial ANOVA with three factors: Target Location (cued and uncued; within subjects), SOA (150ms, 700ms, and 1100ms; within subjects), and Partner Rank (higher rank versus lower rank; between subjects). This analysis yielded a main effect of Target Location, $F(1, 49) = 56.52$, $p < .001$, $\eta^2 = .54$, with cued targets being overall responded to slower ($M = 386$ms, $SEM = 6$ms) compared to uncued targets ($M = 368$ms, $SEM = 7$ms), equivalent to an inhibition of return effect of 18 ms. Participants were also overall quicker to respond when interacting with a higher compared to lower rank partner ($M_{\text{HIGH}} = 357$ms, $SEM_{\text{HIGH}} = 9$ms; and $M_{\text{LOW}} = 397$ms, $SEM_{\text{LOW}} = 10$ms respectively; $F(1, 49) = 8.91$, $p = .004$, $\eta^2 = .15$). Our analysis showed a main effect of SOA, $F(2, 98) = 91.70$, $p < .001$, $\eta^2 = .65$, such that participants were overall slower to respond at the short SOA of 150ms ($M = 398$ms, $SEM = 7$ms), than at the medium SOA of 700ms ($M = 372$ms, $SEM = 5$ms) and at the longer SOA of 1100ms ($M = 362$ms, $SEM = 5$ms). We also observed a significant two-way interaction between SOA and Target Location, $F(2, 98) = 39.12$, $p < .001$, $\eta^2 = .44$ (see contrast analysis below).

Consistent with our prediction, we observed a significant two-way interaction between Partner Rank and Target Location, $F(1, 49) = 5.03$, $p = .029$, $\eta^2 = .09$). Specifically, when interacting with a higher ranked partner, participants were slower to respond to a target presented at a cued compared to uncued location ($M_{\text{cued}} = 369$ms, $SEM_{\text{cued}} = 9$ms; and $M_{\text{uncued}} = 345$ms, $SEM_{\text{uncued}} = 10$ms respectively; $F(1, 49) = 48.59$, $p < .001$, $\eta^2 = .50$). When interacting with a lower ranked partner, this was also the case, but to lesser extent ($M_{\text{cued}} = 404$ms, $SEM_{\text{cued}} = 9$ms; and $M_{\text{uncued}} = 391$ms, $SEM_{\text{uncued}} = 10$ms respectively; $F(1, 49) = 13.65$, $p = .001$, $\eta^2 = .22$). In fact, the inhibition of return effect was almost twice as large in the higher rank partner condition (*M* = 24ms, *SEM* = 3ms) than in the lower rank partner condition (*M* = 13ms, *SEM* = 3ms). Thus, social information about an interaction partner's social rank modulated interpersonal spatial orienting when attention was overtly employed. However, the three-way interaction between Target Location, SOA, and Partner Rank did not reach conventional levels of significance, $F(2, 98) = 2.08$, $p = .13$, $\eta^2 = .04$.

3.2.4. Social modulation of interpersonal spatial orienting effects at different SOAs

To test the absence or presence of the social modulation of IOR at the short, the medium and the long SOA, we again applied contrast analysis using the same five orthogonal contrasts as in Experiment 1. The overall model fit was significant, F (5,147) = 11.94, $p < .001$, $R^2 = .29$. Inhibition of return effects were smaller at the short SOA of 150ms (*M* = 1ms, *SEM* = 3ms) compared to at the medium SOA of 700 ms or the long SOA of 1100ms, λ1: *b* = 0.009, SE = 0.001, *t* = 6.92, *p* < .001, CI95% [0.006, 0.011], *r* = .53. Inhibition of return effects did not differ at the medium SOA of 700ms (*M* = 29ms, *SEM* = 4ms) compared to the long SOA of 1100ms (*M* = 26ms, *SEM* = 3ms), λ2: *b* = -0.002, *SE* = 0.002, *t* = -0.72, *p* = .474, CI95% [-0.006, 0.003], *r* = -.10. Moreover, we observed that inhibition of return effects were already larger in the higher compared to the lower rank partner condition at the short SOA of 150ms (λ3: *b* = 0.007, *SE* = 0.003, *t* = 2.30, *p* = .023, CI95% [0.001, 0.013], *r* = .21), as well as at the medium SOA of 700ms (λ4: *b* = 0.008, *SE* = 0.003, *t* = 2.45, *p* = .016, CI95% [0.001, 0.014], *r* = .22), but not at the long SOA of 1100ms (λ5: *b* = 0.001, *SE* = 0.003, *t* = 0.41, *p* = .680, CI95% [-0.005, 0.008], *r* = .08). These results are depicted in Figure 2. In sum, social information about an interaction partner's social rank only modulated inhibition of return effects at the short SOA of 150ms and at the medium SOA of 700ms, but not at the long SOA of 1100ms when attention was overtly employed.

3.3. Discussion

Experiment 2 found that information about the relative social rank of an interaction partner modulated visual attention in a joint spatial cueing task when participants moved their eyes freely. Inhibition of return effects were overall amplified when participants were made to believe that they interacted with a higher compared to lower ranked partner. This difference was already found at the short SOA of 150ms.

4. General Discussion

4.1. Summary of Results

Believing to interact with a higher rather than lower ranked interaction partner amplified inhibition of return effects in a joint spatial cueing task when participants were naturally moving their eyes (Experiment 2). These findings are consistent with previous research showing larger inhibition of return effects for higher compared to lower ranked partners in an interpersonal version of a spatial cueing task (Gobel et al., 2018). They are astonishing, because in the joint spatial cueing task, in contrast to gaze cueing paradigms, all stimuli presented on screen are non-social in nature. The only thing that we manipulated in the present research was the social meaning of the cue, as we told participants that it represented where either a higher or lower ranked interaction partner had just looked at.

Importantly, we found that the social information about the relative rank of an interaction partner did not modulate inhibition of return effects for covert attention (Experiment 1), when participants were instructed to not move their eyes but to maintain central fixation. These findings are consistent with a literature suggesting that social information has larger top-down effects onto overt than covert attention (Blair et al., 2017; Pereira et al., 2019), and especially in contexts when moving the eyes is functional. Experiments using real-world social contexts, too, have shown stronger top-down effects onto overt than covert attention when participants naturally move their eyes (Kuhn et al., 2016; Laidlaw et al., 2016). Of course, in some specific contexts, it might actually be beneficial to not move the eyes, for example when aiming to detect shifts in gaze direction of a face stimulus in an experiment (Boyer & Wang, 2018). While, our findings corroborate this literature, future research with larger samples is needed to clarify as to whether social modulation of the inhibition of return significantly differs when attention is covertly or overtly employed.

Our research also tested whether social information would modulate visual attention in a joint spatial cueing task at different SOAs. At the short SOA of 150ms, when attention was employed overtly, we found that inhibition of return effects were significantly larger in the higher compared to the lower rank partner condition. While its precise nature (facilitation or inhibition effects) awaits further investigation, it is fascinating to observe that the social information as to who the interaction partner was influenced spatial orienting effects at such an early stage. We think this finding speaks to the fundamental nature of how interpersonal contexts and social information prioritize our visual attention.

Similarly, at the medium SOA of 700ms, we found that inhibition of return effects were significantly larger in the higher compared to the lower rank partner condition when attention was employed overtly. However, at the longer SOA of 1100ms, this difference had disappeared, and participants made to believe that they interacted with a higher or a lower ranked partner showed comparable inhibition of return effects. It is interesting to note that while Gobel and colleagues (2018) did not systematically test the time course of their effects, the descriptive results they provided seem to suggest that they, too, observed larger social inhibition of return effects at the medium SOA (700ms) than the longer SOAs (1100ms and 1500ms). This highlights the possibility that social information of who another person is might affect visual attention early on, before other cognitive processes may come online to shape visual attention at longer SOAs. In sum, our findings suggest that social information may already prioritize visual attention at early processing stages in a joint spatial cueing task.

4.2. Theoretical Implications

Our findings carry important implications for the joint action literature. First and foremost, they underscore the importance of joint attention for establishing common ground (Clark, 1996) and as the underlying mechanism of joint action (Sebanz et al., 2006). Second, the fact that the social rank of the interaction partner yielded significant effects when moving the eyes but not when maintaining fixation is an important finding. Indeed, it has been proposed that the inhibition of return effect is the result of preparing the eyes to move (Rafal et al., 1989). Our findings are consistent with the idea that inhibition of return prepares oculomotor searches.

This interpretation of our results is in line with theorizing about socially distributed cognition (Hutchins, 1995; Tufft & Richardson, 2020). Just as cognitive offloading affords an individual with opportunities to offload cognitive processes to their physical environment in order to reduce the internal cognitive demands (Risko & Gilbert, 2016), so participants in our experiment might have been successful in offloading information to their interaction partner and thus reduced the cognitive demands in the pursuit of quicker target detection. Importantly, they did so depending on who the other person was; that is their relative social rank, which presumably served as a heuristic for the interaction partner’s level of competence (Fiske et al., 2002). It is almost as if higher ranked interaction partners were thought of as taking care of the spatial location they had just looked at, which in turn enabled participants to disengage their attention from this spatial location. If a visual field was split up among group members, and if a priority map helped to indicate that a specific spatial location was taken care of by a higher ranked team member, then one would expect the entire team to do better overall. This is an intriguing interpretation that should be tested in future studies.

It should also be noted that as participants believed that they saw where their interaction partner was looking, they also believed that their interaction partner would see where they were looking. This *reciprocal* nature of social attention (Richardson & Gobel, 2015) raises the question what role social signaling might have played in the present research. Looking at another person is an important social signal. For example, humans are very good at signaling their relative social rank; onlookers pick these signals up and attribute social ranks quite accurately based on this information (e.g., Capozzi et al., 2019; Gobel et al., 2015; Ito et al., 2018; Kraus & Keltner, 2009). Moreover, recent research has documented that participants move their eyes strategically in online games, when they know their opponents can see their eye movements (Newn et al., 2018). Because, participants can signal to their higher and lower ranked interaction partner where they look, an intriguing question is whether they could use this knowledge strategically and deceive others when competing with them.

4.3. Limitations and Future Research

Our research is not without limitations. Because we showed images and maintained them on screen throughout the experiment, the salience of the cue and target stimuli may have varied between trials. This may have rendered our measure noisier than ideal. It should be noted, however, that social inhibition of return effects have been observed without the use of images (Gobel et al., 2018; Exp. 1). We decided to maintain images on screen, because it provided additional justification as to why interaction partners had preferentially looked at a spatial location. If this increased the noise of our measure, it did so for both higher and lower ranked partners. If anything, this suggests that the extent to which social information prioritizes visual attention in the real world might be even stronger and that our experiments provide a rather conservative estimate of its size.

It is beyond the scope of the current research to identify the exact nature of how social rank prioritizes visual attention. Gobel and colleagues (2018) observed that a partner's social rank only prioritized visual attention when participants were made to believe that their interaction partner was task relevant. Another possibility is that top–down processes, such as volitional control or stimulus-associated reward (e.g., Bucker & Theeuwes, 2014; Tipper & Kingstone, 2005) might explain the findings. For example, associating a stimulus with a previously learned reward captures attention (Anderson et al., 2011), and it improves target discrimination (Maclean & Giesbrecht, 2015). These possibilities await further scrutiny.

5. Conclusion

Our ability to see what others are seeing and to align our visual attention with them is a key mechanism for joint actions and thus our survival as social beings. In the present research, we found that social information about an interaction partner – their relative social rank – prioritized overt but not covert attention in a joint spatial cueing task, and we found overt attention to be penetrable for social information at early stages of information processing. This suggests that overt (when moving the eyes to attend) attention might provide a key tool for joint action, as it allows us to both encode information from others and to signal information back to them.

Author Statement

MG and BG designed the study. MG collected and analyzed the data. MG and BG wrote the manuscript. All authors approved the final version of the manuscript for submission.

Funding

MG was support by a SAGE Junior Research Fellowship.

Data

All data is available on the Open Science Framework: https://osf.io/6xs35/?view_only=51cc557bf58342a4a30d9cbe0831d567

Acknowledgements

We would like to thank Daniel Richardson and Miles Tufft for their insightful discussions.

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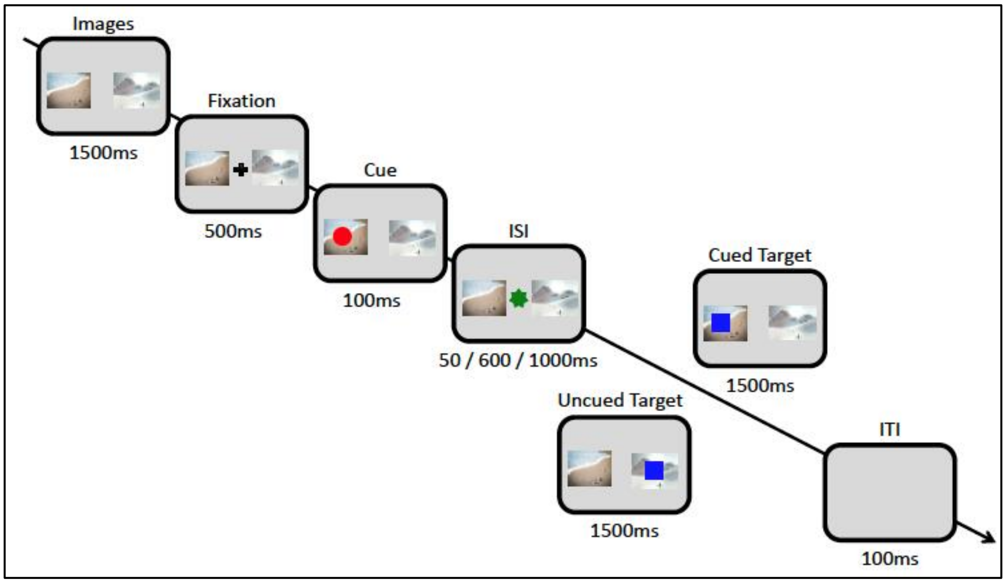

Figure 1. Trial Structure. ISI: Inter-Stimulus-Interval. ITI: Inter-Trial-Interval.

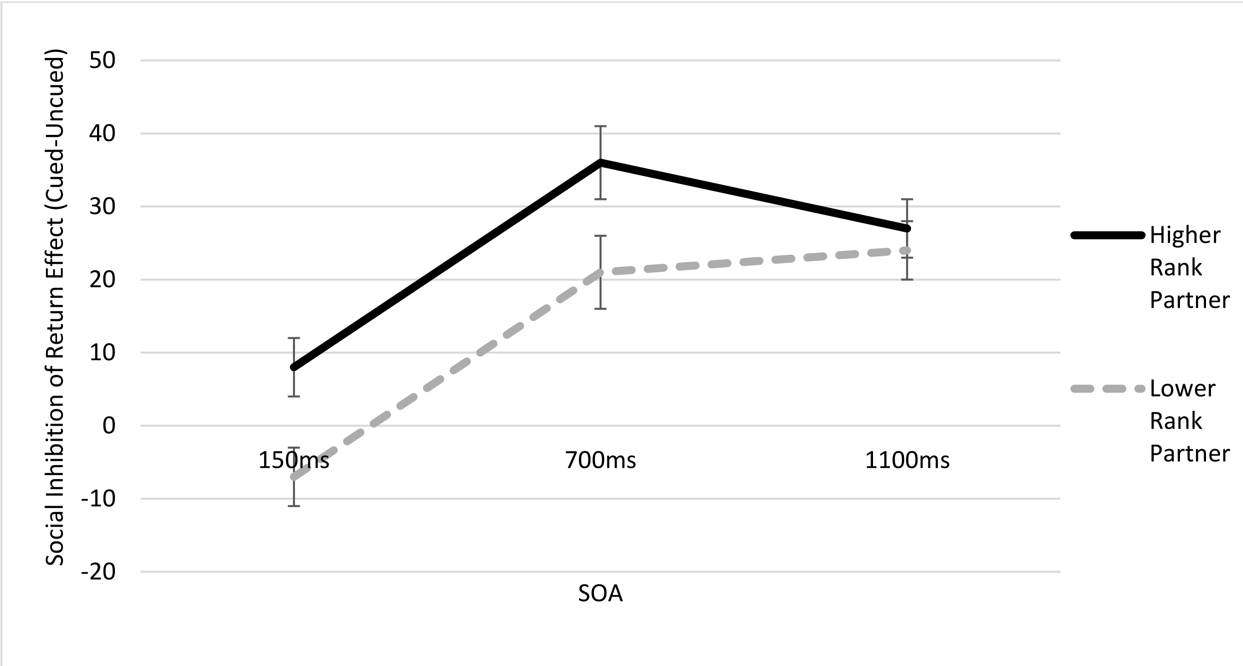

Figure 2. Social inhibition of return effects as a function of partner's social rank at a short, a medium, and a long SOA when attention was employed overtly (Experiment 2). Error bars represent SEM.

Table 1.
Mean RTs in ms (with SEM) for Experiment 1 and 2.

	Experiment 1			
	Higher Rank Partner		Lower Rank Partner	
	Cued Target	Uncued Target	Cued Target	Uncued Target
150ms SOA	425 (14)	413 (17)	441 (15)	433 (18)
700ms SOA	397 (11)	354 (11)	407 (12)	365 (12)
1100ms SOA	381 (13)	351 (12)	391 (14)	364 (13)
	Experiment 2			
	Higher Rank Partner		Lower Rank Partner	
	Cued Target	Uncued Target	Cued Target	Uncued Target
150ms SOA	379 (9)	371 (11)	418 (9)	424 (12)
700ms SOA	370 (9)	334 (10)	402 (10)	381 (11)
1100ms SOA	357 (10)	331 (9)	392 (10)	368 (10)