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Reflexive Spatial Attention to Goal-Directed Reaching

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Abstract

Social interaction involves cues such as gaze direction, head orientation, and pointing gestures that serve to automatically orient attention to a specific referent or spatial location. In this paper we demonstrate that an observed reaching action similarly results in a reflexive shift in attention as evidenced by faster responses that are congruent with the direction of the reach, than responses that are incongruent. This facilitation is evident quickly after the onset of the reach action and is due to the rapid prediction of the reach-goal. When the task involves a saccadic response (Experiment 1) this prediction is inhibited and results in a reverse-congruence, faster responses to incongruent than congruent cues, when the cue occurs after the reach is completed. This reverse-congruence is not present when the task involves a key press (Experiment 2) or a mouse movement (Experiment 3). We propose that the inhibition of the predictive saccade is overcome when the eye movements toward the goal are activated to guide the mouse movement. The three experiments together demonstrate that automatic attention distribution and its effects on behavior depend on the response.

Keywords: action perception; reflexive attention; action prediction

Introduction

Social cues that guide another person's attention to a specific location come in various forms such as eye-gaze, head orientation, and pointing gestures (Langton, Watt, & Bruce, 2000). The observer often processes these cues automatically as their attention is quickly deployed in such a way that it is hard to inhibit. For example, when presented with a face that displays averted gaze, participants are faster to detect a target when the gaze is in the same direction as the target's location than when it appears in the opposite location (Driver et al., 1999; Friesen & Kingstone, 1998). Similar compatibility effects are seen following the presentation of a pointing hand (Bertenthal, Boyer, & Harding, 2014; Crostella, Carducci, & Aglioti, 2009). Furthermore, this shift in spatial attention may influence responses differently based on the type of response required. Crostella, et al. (2009) report that observation of a distracting gaze cue interferes with saccadic responses, whereas, a distracting point gesture interferes with a pointing response.

Paradoxically, a grasping hand does not automatically capture attention in the location of the grasped object (Fischer & Szymkowiak, 2004) even though it, too, is a social cue. Furthermore, grasping actions will modulate perspective taking, but not spatial orienting (Mazzarella, Hamilton, Trojano, Mastromauro, & Conson, 2012). Fischer & Syzmkowiak (2004) suggest that a point is a deictic gesture that continues to represent the intentions of the actor, whereas, a grasp is an indication that an action has already been performed and observers are not reflexively drawn to attend to an object that has already been acted upon.

While this claim may apply to the observation of a static grasping hand, there is evidence to suggest that it is less likely to apply to a dynamic reaching and grasping action. Indeed, a static presentation of a pre-shaped grasping hand, unlike the completed grasp, results in automatic spatial attention to a congruently shaped object (Fischer, Prinz, & Lotz, 2008), and even infants as young as 5 months will orient faster to a target that is in the same direction as a static pre-shaped grasping hand (Daum & Gredebäck, 2011).

In fact, recent studies measuring eye movements during the observation of reaches find that observers will predictively shift their gaze to the goal of the reach prior to the completion of the action (Flanagan & Johansson, 2003). These predictive saccades are very similar to the proactive eye movements made by an actor during reaching. It has been hypothesized that this coordination between the observer's gaze and the actor's reach could be attributable to observers mapping perceived actions to a corresponding system of motor representations including the prospective looks to the goal (Flanagan & Johansson, 2003). Alternative explanations for the prediction of observed action goals involve cognitive, rather than motor, mechanisms such as statistical learning or the attraction to goal salience (Eshuis, Coventry & Vulchanova, 2009).

If the prospective eye movements to the reach goal are automatically activated during observation then we expect that covert spatial attention will likewise be automatically shifted in the direction of the reaching action. Furthermore, if spatial attention is captured by a reaching action then observation of a dynamic reach will facilitate fast and accurate responses in the same direction during a spatial cuing task, even if the reach is irrelevant to the task.

The current study aims to investigate the relation between perceiving dynamic, goal-directed actions and spatial attention. We followed the approach of Crostella et al. (2009), and presented a video of a goal-directed reach in conjunction with a spatial cueing task. The reaching action
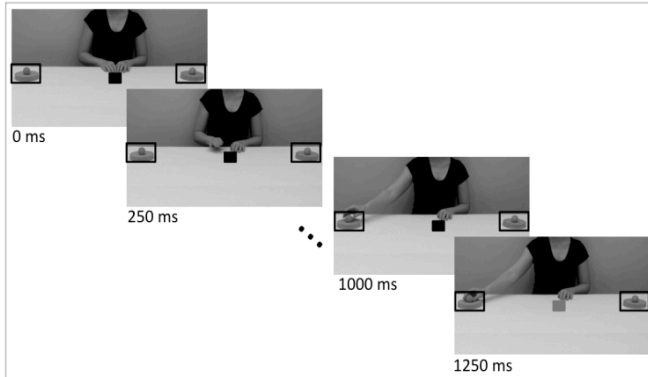
Figure 1: Still images showing the stimulus video of reaching actions with the cue and response targets overlaid. In this trial, the cue to respond occurred after the reach-to-grasp action was completed at 1250 ms.

is non-predictive of target locations and participants were instructed to ignore it. Thus, if we see that responses that are congruent with the direction of the reach are facilitated in comparison to responses that are incongruent, we can assume that observation of the reach automatically shifted the participant's spatial attention toward the reach-goal. Furthermore, we manipulated the timing of the reaching action with regard to the stimulus cue. In this way, we could assess the automatic processing of the reach at multiple time points and evaluate the effects of both ongoing and completed actions.

Experiment 1: Saccadic Response

Methods

Participants Thirty undergraduate students in introductory psychology courses at Indiana University participated in this experiment (Mean age: 19.6 years, SD: 0.8 years; Left handed: n=6; Male: n=9).

Stimuli & Apparatus The stimuli (Figure 1) consisted of videos of an actress, visible from the neck down, reaching to grasp one of two objects resting on the table in front of her. The actress reached with either her right or left hand to the object on her ipsilateral or contralateral side. The full duration of the reach was 1000 ms and the grasp around the object was completed after 1250 ms. Trials were presented in a pseudorandom order with no more than three consecutive trials of the same reach type or same goal location. The stimulus cue began as a filled black square centered on the screen and the two response targets were unfilled black rectangles placed around the location of each potential reach goal.

Stimulus presentation was performed using E-Prime (Psychology Software Tools, Pittsburg, PA). Gaze data was collected with a Tobii TX300 eye tracking system (Stockholm, SE) sampling at 120Hz.

Design and Procedure On each trial the video began with the actress placing her hands on the table in front of her and then reaching for one of the objects. After a variable amount of time (stimulus onset asynchrony, SOA) the stimulus cue

changed from black to either blue or red to cue a target. Participants were instructed to fixate the stimulus cue and wait for the color change, then to shift their gaze to the rectangle around the object on the right when the cue was red and to the rectangle on the left when the cue was blue. They were also told that if they looked away from the cue before it changed the trial would be repeated. When gaze was detected within the correct response-target AOI for a minimum of 500ms the color of the response-target rectangle changed to grey to indicate to the participant that a response had been recorded. On 50% of the trials the cued direction was congruent with the direction of the reach and on 50% of the trials the cued direction was incongruent with the direction of the reach. Immediately following the response the video stopped and remained on the screen for a variable inter-trial interval between 300 and 1000ms.

In order to explore the effects of the time course of the observed action on spatial attention, the following SOAs were used in this experiment: -250, 0, 250, 500, 750, 1000, and 1250ms. A negative SOA indicates the stimulus cue changed color before the onset of the reach, whereas a positive SOA indicates the cue occurred after the reach. Participants completed 6 blocks of 60 trials for a total of 360 trials, with congruent and incongruent trials counterbalanced. The number of ipsilateral and contra-lateral trials as well as the number of right and left handed reaches were also counterbalanced.

Results and Discussion

Response Time Figure 2a presents the mean saccadic response times for congruent and incongruent trials at each SOA. Saccadic response times were analyzed in a 2 (congruence) x 7 (SOA) within subjects ANOVA. This analysis revealed a significant main effect of SOA ($F(6,24)=12.65$, $p<.0001$, $\eta^2=.76$) and a significant interaction between SOA and Congruence ($F(6,24)=3.22$, $p=.018$, $\eta^2=0.45$). Paired comparisons revealed significantly faster responses to congruent than incongruent cues at 250ms ($t(29)=3.55$, $p=.001$, $d=0.60$), but the opposite effect, faster responses to incongruent than congruent cues, at 1250ms ($t(29)=2.73$, $p=0.011$, $d=0.26$).

Replication In the preceding study we could not predict a priori which SOAs would show a congruence effect or reverse-congruence effect, which was the reason for a partial replication. We focused on SOAs that previously showed a significant effect (250 and 1250ms) as well as an even longer SOA (1600ms) to determine if this reverse-congruence effect continues beyond the end of the observed reaching action. Analysis of the saccadic response times revealed main effects of SOA ($F(2,23)=5.24$, $p=.01$, $\eta^2=.31$) and congruence ($F(1,24)=7.59$, $p=.01$, $\eta^2=.24$) as well as an interaction between SOA and Congruence ($F(2,23)=6.08$, $p=.008$, $\eta^2=.35$). Paired comparisons revealed congruent responses are faster than incongruent at 250ms ($t(24)=3.67$, $p.=001$, $d=0.48$), and incongruent faster than congruent at both 1250 ms ($t(24)=2.80$, $p=.01$, $d=0.88$) and 1600 ms ($t(24)=3.21$, $p=.004$, $d=0.88$).
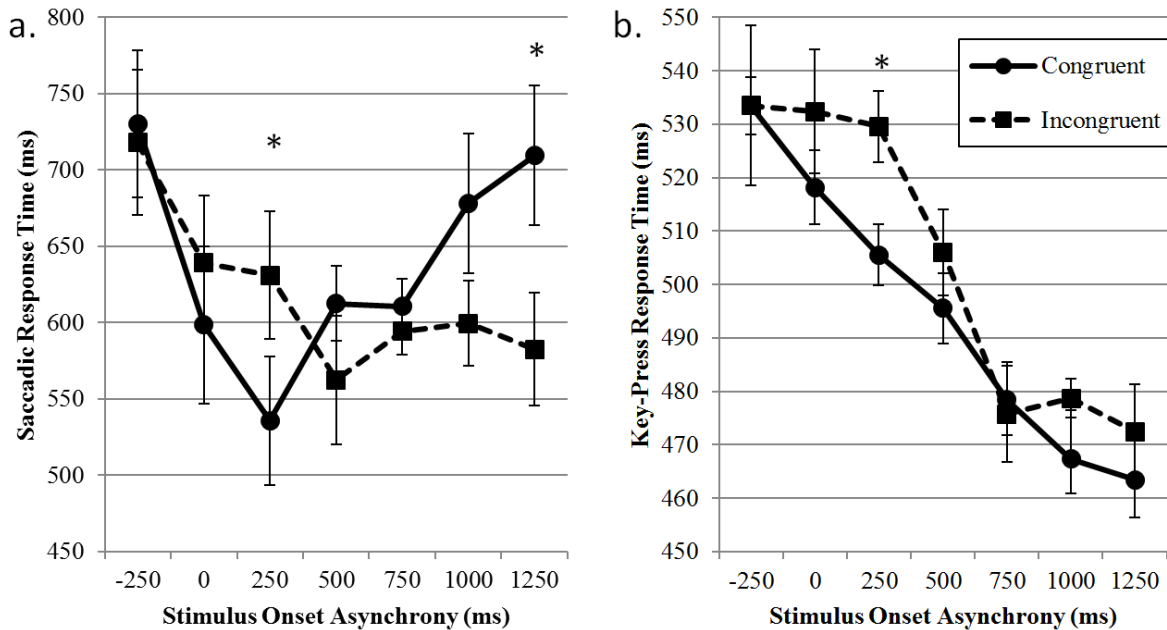
Figure 2. Saccadic response times (a) and Key-Press response times (b) for congruent and incongruent trials in Experiments 1 and 2 respectively. Error bars represent ± standard error of the mean. * p<.05.

Discussion The results from this experiment demonstrate that the observation of a reach reflexively shifts attention in the direction of the goal. Even though participants were instructed to ignore the reaching action, their attention was captured by this stimulus and they were unable to inhibit covertly orienting in the reach direction, which resulted in faster saccadic responses to congruent targets and slower responses to incongruent targets. We speculate that this shift in spatial attention is a consequence of the automatic activation of the predictive saccade to the reach goal due to the direct matching of the observed action to its corresponding motor representation. This congruence effect was strongest at 250 ms SOA, and then began to dissipate as participants had sufficient time to inhibit their reflexive attentional shift and instead plan an intentional, controlled response. It is possible that observing the reaching action nearing its completion also contributed to a reduction in the activation of the eye movement response. This experiment, however, cannot dissociate these two factors because long SOAs and reach completion are confounded.

The reverse-congruence effect seen at longer SOAs was an unexpected result and one that is not typically reported in spatial cueing studies with social stimuli (for an exception see Friesen and Tipper, 2004). This pattern of responses is similar to the well-established phenomenon of inhibition of return (IOR) where saccades toward a previously attended location are slower compared to an unattended location (Posner & Cohen, 1984). In this experiment, however, the time course of the effect is significantly delayed relative to the typical IOR pattern (Klein, 2000), and it has previously been reported that social cues do not result in IOR even at long SOAs (for a review see Frischen, Bayless & Tipper, 2007). A related concept is the 'Social IOR' (Skarratt, Cole,

& Kingstone, 2010) which describes the tendency for people to perform slower reaches to a location where their joint-action partner has recently reached. For these reasons, we are hesitant to suggest that the reverse-congruence effect is another example of IOR. Instead, we believe that it is in part due to the task instructions associated with this experiment as we will discuss later on.

The congruence effect in this experiment is consistent with the premotor theory of attention which proposes that a shift in spatial attention necessarily precedes a goal directed action such as an eye movement (Rizzolatti, Riggio, & Sheliga, 1994). This theory would also predict that automatic shifts in attention would be associated with responses in any modality. This is in contrast to the results of Crostella et al. (2009) where there was a one-to-one mapping of the stimulus and the affected response. Those results can be attributed to the automatic activation of a

To test if both the congruence as well as reverse-congruence effects of the current experiment would be replicated with another motor response, we modified the current task by substituting a key-press for a saccadic response.

Experiment 2: Key-Press Response

Methods

Participants Twenty students participated in this experiment (Mean age: 19.7 years, SD: 1.3 years Left handed: n=6 Male: n=5).

Stimuli and Apparatus The stimuli and the SOAs in this experiment were identical to Experiment 1. All stimulus presentation and response collection procedures were

performed using E-Prime (Psychology Software Tools, Pittsburg, PA).

Design and Procedure Participants were instructed to press the 'J' key on a standard American computer keyboard with their Right index finger when the stimulus cue changed to red and the 'F' key with their Left index finger when the cue changed to blue.

Results and Discussion

Response Time Analysis of key-press response times revealed a main effect of SOA ($F(6,14)=4.12$, $p=.02$, $\eta^2=.62$), but no main effect of congruence ($F(1,19)=1.42$, $p=.23$, $\eta^2=.07$) nor interaction between SOA and congruence ($F(6,14)=0.91$, $p=.32$, $\eta^2=.36$). Planned comparison revealed participants were significantly faster to congruent than incongruent cues at 250 ms SOA ($t(19)=2.89$, $p=0.009$, $d=0.15$, Figure 3).

Replication Because there was no evidence of a reverse-congruence effect at the longer SOAs we decided to focus our replication efforts on the range of SOAs where we expected the congruence effect. The analysis of response times confirmed significant main effects for SOA ($F(6,14)=13.77$, $p<.001$, $\eta^2=.86$) and Congruence ($F(1,19)=11.33$, $p=.003$, $\eta^2=.37$) with significantly faster responses to congruent than incongruent trials at 125, 250, 375 and 500 ms SOAs (all $t(19)>2.38$, all $p<.03$).

Discussion The results of this experiment were consistent with our expectation that participants would again respond faster to the congruent target at short SOAs. In contrast to Experiment 1, this experiment showed no evidence of a reverse-congruence effect at long SOAs. This result suggests that the effects of the irrelevant reach and grasp action were different as a function of response mode.

We hypothesize that the reason for a reverse-congruence effect in only Experiment experiment1 is because the saccadic response was influenced by both the irrelevant stimulus facilitating a congruent response as well as the task demands that inhibited a congruent response. As illustrated by Figure 3, each trial begins with inhibition of an eye movement in any direction because participants are instructed to fixate the stimulus cue and not move their eyes. Once the reaching action begins at time 0 ms, there is a covert shift in attention as well as a gradual build-up in the activation of a proactive eye movement. Recall that this attentional bias comes from the observation of the reaching action and the reflexive activation of a predictive eye movement to the reach-goal. Based on our results, this activation peaks at around 250ms and then decreases due to competition from the intentional inhibition of an eye movement. When the reach ends at 1000ms the activation associated with the predictive eye movement ends, but the inhibition remains resulting in an inhibitory rebound.

The results of Experiment 1 are consistent with this explanation. In the 250 ms SOA, congruent responses are facilitated relative to incongruent responses. Then, the saccadic response times in congruent trials consistently
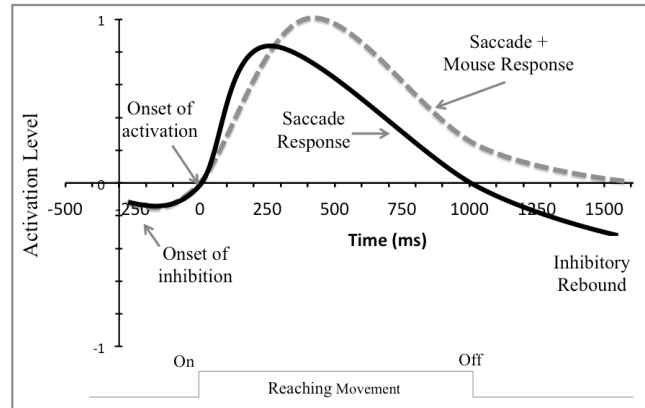

Figure 3. The proposed model of activation and inhibition of eye movements toward the reach-goal that explains the reverse-congruence at long SOAs in saccade response times (E1; solid line) but not saccadic responses in conjunction with mouse movements (E3; dashed line)

increase from 250 ms to 1250 ms SOA while the saccadic response times in incongruent trials remains relatively flat (Figure 2). This is because the predictive eye movement to the reach-goal is being inhibited which slows responses in the same direction. This inhibition does not affect responses in the incongruent trials. Furthermore, this inhibition is not evident in the key-press responses. Instead, the congruent responses are consistently facilitated relative to the incongruent responses. We suggest that this is because the inhibition of the key press response does not increase over the course of the trial and is applied equally to congruent and incongruent responses.

To test our hypothesis about selective inhibition of the predictive saccade, we modified the task to include a mouse movement response and measured how this multi-modal response affected saccadic response times. Note that mouse movements, like goal-directed reaches, are visually guided actions. Therefore, the eyes are activated in this task to both proactively move in the direction of the actor's reach, and to guide the mouse movements to the target in response to the cue. We expected that the additional activation associated with preparing a mouse movement that would not subside until the response was completed would offset the inhibition of the predictive saccade at the completion of the reach by the actor.

Experiment 3: Mouse Movement + Saccade Response

Methods

Participants Twenty-seven students participated in this experiment (Mean age: 19.5 years, SD: 0.9 years; Left handed: n=7; Male: 12), three participants were tested and excluded from analysis due to noncompliance with task instructions.
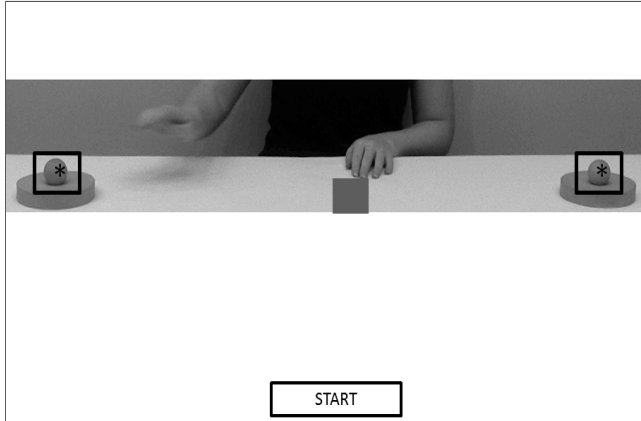
Figure 4. Still frame from Experiment 3 immediately following the color change of the cue in the 500ms SOA condition.

Stimuli and Apparatus Video stimuli from Experiment 1 was cropped to include only the reaching action and presented in the top third of the screen. Additionally, text-box centered at the bottom of the screen with the word 'START' and an asterisk was centered within the response rectangles over each of the objects. The following SOAs were used in this experiment: 250, 500, 750, 1000, 1250, and 1600ms.

Design Participants were instructed to initiate each trial by clicking the mouse on the 'START' box, then remaining on box until the cue changed. They then moved the cursor and clicked on the asterisk in the right box if the cue was red and clicked the asterisk in the left box if the cue was blue.
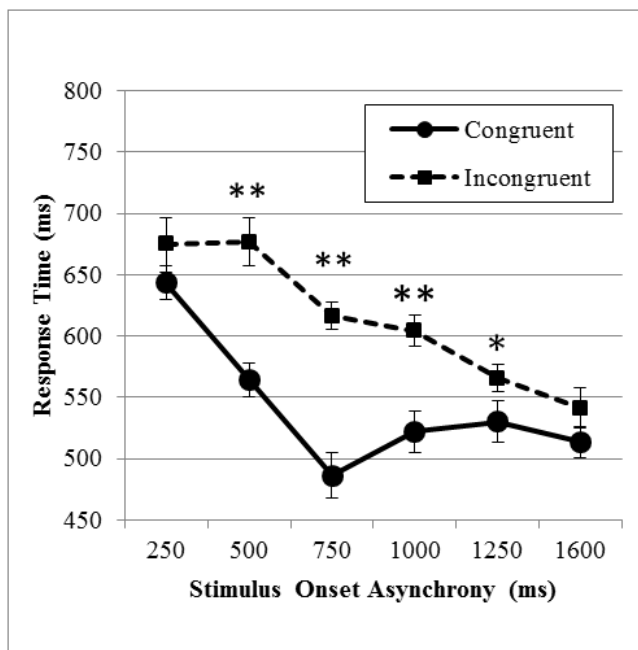

Figure 5. Saccadic response time in Experiment 3. Error bars represent ± standard error of the mean. * p<0.05; ** p<.001.

Results and Discussion

Response Time Analysis of saccadic response times revealed significant main effects of both SOA ($F(5,22)=11.99$, $p<0.001$, $\eta^2=.73$) and congruence ($F(1,26)=29.58$, $p<0.001$, $\eta^2=.53$) as well as a significant interaction between SOA and congruence, ($F(5,22)=3.20$, $p=.025$, $\eta^2=.42$). Planned comparisons revealed significantly faster congruent responses at the 500, 750, 1000, and 1250 ms SOAs (all $t's(26)> 2.18$, all $p's<.04$). Critically, there was no evidence of a reverse-congruence effect at 1250 or 1600ms.

An analysis of the mouse response times revealed only a main effect of SOA ($F(5,22)=4.28$, $p=.007$, $\eta^2=.49$) due to faster response times at the longer SOAs. Neither the main effect of congruence ($F(1,26)=2.64$, $p=.116$, $\eta^2=.09$) nor the interaction between SOA and congruence ($F(5,22)=0.51$, $p=.77$, $\eta^2=.10$) were significant.

Discussion As predicted saccadic response times continued to show an early congruence effect, albeit delayed relative to Experiments 1 and 2, but no reverse-congruence effect as seen in Experiment 1. This is consistent with our hypothesis for the reverse-congruence effect, because, in this case, the eye movement continues to be facilitated as it is needed to guide the mouse movements. Note that there was no evidence of response times in the congruent condition increasing as SOAs increased beyond 250ms. This is because the build-up of an inhibitory response to prevent a premature eye movement was offset by the preparation to move the mouse in the congruent direction. Unlike the activation of a proactive eye movement which was stimulated from observing the actor's reach, the activation of the eye movement associated with the mouse movement continued until the completion of the response.

Interestingly, the mouse response times did not reveal either a congruency or reverse-congruency effect, and, in fact, showed no consistent differences between congruent and incongruent responses. This result underscores the importance of using multiple response measures as the mouse response-time alone may have lead one to conclude that there was no effect of action observation on attention distribution.

General Discussion

Taken together the results of these three experiments demonstrate that attention is automatically captured by the observation of dynamic reaching actions. In all three experiments participant's responses are faster when the response direction is congruent with the direction of the reach, but only when the cue to respond occurs shortly after the onset of the reach stimulus. This only tells part of the story however, because the time course of the reach's influence is not the same across all responses. The eye movement response in Experiment 1 showed a significant reverse-congruence effect, where the responses to cues at long SOAs were slower in the direction congruent with the reach. We suggest that this reverse-congruence reflects a

steady build-up of inhibition in order to ensure that the eye does not move from the fixation square until cued. We tested this hypothesis by adding a visually-guided response in Experiment 3, and the results revealed that the activation associated with preparing a mouse movement overcame the inhibition of the saccadic response..

These results contribute to our understanding of reflexive shifts in attention to observed actions in three ways:. First, we used a dynamic stimulus. By presenting videos of a reaching action, as opposed to still images of a grasp, we were able to examine the role of ongoing actions in a more ecologically valid way. While this opens up the possibility that any dynamic motion stimulus would similarly drive attention, we predict that this would not be the case. Recall that we presented both ipsilateral and contralateral actions. Contralateral actions start on the side opposite from the eventual reach-goal, and would therefore initially facilitate incongruent responses if shifts in attention were driven only by movement. Critically, the congruence effect was consistently present in the 250ms SOA despite the fact that 250ms into a contralateral reach the hand had just reached the midline of the actor (Figure 1) and therefore the perceived direction of the hand movement was still somewhat ambiguous.

Second, presenting a dynamic reaching action helps to clarify an apparent inconsistency in the literature where some studies are reporting no spatial orienting following a grasp (Fischer & Szymkowiak, 2004; Mazzarella et al., 2012) and others are reporting that an incomplete grasp does automatically drive attention (Fischer et al., 2008, Daum & Gredebäck, 2011). By studying the effects of an ongoing reaching action on automatic spatial orienting we observed results that are consistent with both results. Attention is automatically oriented in the direction of the reach while the reach is ongoing. This facilitation ends when the reach is complete, supporting Fischer & Szymkowiak (2004) explanation that completed actions do not drive attention.

Finally, the use of multiple response measures revealed that automatic spatial orienting affected responses differently depending on the response modality. Taken together the results of these experiments support a hypothesis that could not be tested by one experiment alone. The reverse-congruence effect observed in Experiment 1 appears very similar to inhibition of return despite evidence that social cues do not elicit IOR. Increasing the activation of the eye movements in the direction of the reach by adding the mouse movement response eliminated the reverse-congruence effect and allowed us to reject the IOR explanation while providing support for our hypothesis of specific saccade inhibition.

References

Bertenthal, B. I., Boyer, T. W., & Harding, S. (2014). When do infants begin to follow a point? *Developmental Psychology*, *50*(8), 2036–2048.

Crostella, F., Carducci, F., & Aglioti, S. M. (2009). Reflexive social attention is mapped according to effector-specific reference systems. *Experimental Brain Research*, *197*(2), 143–151.

Daum, M. M., & Gredebäck, G. (2011). The development of grasping comprehension in infancy: covert shifts of attention caused by referential actions. *Experimental Brain Research*, *208*(2), 297–307.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509–540.

Eshuis, R., Coventry, K. R., & Vulchanova, M. (2009). Predictive eye movements are driven by goals, not by the mirror neuron system. *Psychological Science*, *20*(4), 438-440.

Fischer, M. H., Prinz, J., & Lotz, K. (2008). Grasp cueing shows obligatory attention to action goals. *The Quarterly Journal of Experimental Psychology*, *61*(6), 860–868.

Fischer, M. H., & Szymkowiak, A. (2004). Joint Attention for Pointing but not Grasping Postures. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *40*(1), 168–170.

Flanagan, J. R. R., & Johansson, R. S. (2003). Action plans used in action observation. *Nature*, *424*(6950), 769–771.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*(3), 490–495.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze Cueing of Attention: Visual Attention, Social Cognition, and Individual Differences. *Psychological Bulletin*, *133*(4), 694–724.

Klein, R. M. (2000). Inhibition of return. *Trends in cognitive sciences*, *4*(4), 138-147.

Langton, S. R. H., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in Cognitive Sciences*, *4*(2), 50–59.

Mazzarella, E., Hamilton, A., Trojano, L., Mastromauro, B., & Conson, M. (2012). Observation of another's action but not eye gaze triggers allocentric visual perspective. *The Quarterly Journal of Experimental Psychology*, *65*(12), 2447–2460.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*(1), 3–25.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and Performance X* (pp. 531–556). Hillsdale, NJ: Erlbaum

Rizzolatti, G., Riggio, L., & Sheliga, B. M. (1994). Space and selective attention. In C. Umilta & M. Moscovitch (Eds.), *Attention and performance XV*, *15*, 231-265.

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