Peripheral Cues and Gaze Direction Jointly Focus Attention and Inhibition of Return

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Short Title: PERIPHERAL GAZE CUES

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Abstract

Centrally presented gaze cues typically elicit a delayed inhibition of return (IOR) effect compared to peripheral exogenous cues. We investigated whether gaze cues elicit early onset IOR when presented peripherally. Faces were presented in the left or right peripheral hemifields, which then gazed upward or downward. A target appeared in one of four oblique spatial locations giving the cue and target horizontal or vertical congruency, both, or neither. After establishing that peripheral movement and gaze direction jointly facilitate target processing at short durations (200 ms: Experiment 1), IOR was evident for peripheral motion at longer time courses (800 and 2400 ms: Experiment 2). Only after 2400 ms did gaze direction additionally contribute to IOR for the specific gazed at location, showing the inverse pattern of response times to Experiment 1. The onset of IOR for gaze cues is independent from peripheral exogenous cueing but nevertheless contributes to the allocation of attention.

Keywords: Gaze direction; attention; facilitation; inhibition of return; peripheral vision.

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Attentional mechanisms are reflexively aligned with the location of changing peripheral stimuli in order to rapidly and accurately process potentially beneficial or threatening stimuli. However, such changes may occur outside one's own visual field. In these cases the direction of another person's visual attention, which can be coded from the direction of their eyes and / or head (hereafter referred to as *social attention* or *gaze direction cues*), may provide important information about our dynamic environment. Social cueing experiments have reliably demonstrated the effectiveness of another person's gaze direction in directing our own attentional resources. In the paradigm experiment, a stimulus face is presented centrally but indicates a potential target location by turning its head or averting the eyes (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999, see Frischen, Bayliss, & Tipper, 2007 for a review). A target appearing in the gazed-at location is processed more quickly than targets appearing in the location opposite, demonstrating a mirroring of the observer's attention, even when the cue is non-predictive of target location.

The effects of social cueing emerge quickly, with facilitation evident after 100 ms from cue onset (Friesen & Kingstone, 1998). In this respect, social cueing is highly similar to that of exogenous cueing, in which targets appearing in the periphery enjoy facilitated processing when they are preceded by a transient cue stimulus in the same spatial location (Posner, 1980; Posner & Petersen, 1990). However, at longer time courses the facilitation effect of exogenous cues diminishes after 300 ms, after which a reverse cueing effect is evident, in which responses to cued targets become slower (Posner & Cohen, 1984; Samuel & Kat, 2003). This latter effect is termed inhibition of return (IOR), and is said to reflect a bias against redeploying attentional and motor resources toward recently attended locations. In contrast, social attention shows no such inhibitory effect at comparable time courses (Friesen & Kingstone, 1998; Friesen & Kingstone, 2003a; Langton & Bruce, 1999; Ristic et

al., 2005; Tipples, 2008), and the facilitation effect may even persist at these longer intervals (700 ms: Driver et al., 1999; 1005 ms: Friesen & Kingstone, 1998). Only a handful of studies have demonstrated an inhibitory effect for social cueing (Frischen, Smilek, Eastwood, & Tipper, 2007; Frischen & Tipper, 2004; Marotta et al., 2013), but reveal that it emerges only under highly specific methodological circumstances. Firstly, its emergence is considerably delayed, evident after an SOA of 2400 ms. Secondly, the eyes revert back to a forward facing position and a global visual transient is necessary to divert attention away from the cued location prior to target onset.

An outstanding question is therefore why orienting to exogenous cues and gaze cues shows such differing characteristics. One answer may lie in the fact that the conditions under which IOR has been examined for social cues differ fundamentally from those which have proved to elicit IOR for exogenous cues. IOR is typically observed in response to peripherally presented transient cues, and there is close spatial proximity between cue placeholder and target location. Furthermore, the cue generates a transient that is salient enough to attract attention to that location via bottom-up stimulus driven mechanisms. In contrast, social cues are typically presented at fixation, and as such there is only a generic correspondence between the direction of gaze and the target location. Such a discrepancy may explain why IOR for social attention has proved so elusive, yet is observed so robustly for peripheral transient cues.

The aim of the present study was to investigate whether social cues can elicit a more traditional IOR response under conditions that have proven effective in yielding robust IOR for exogenous cues, namely as a peripherally presented transient cue. We employed a face cue in the left or right visual hemifield, which oriented its head up or down, after which a target letter appeared in one of the four corners of the display. The movement of the face acted as an exogenous peripheral transient cue that would engage bottom-up attentional

allocation horizontally, while its direction of gaze ought to cue the observer's attention along the vertical axis. Cue-target congruency therefore occurred along two partially overlapping dimensions: Horizontal congruency caused by peripheral cueing (whether the target appeared in the same or opposite visual hemifield), and vertical congruency caused by gaze cueing (whether the target appeared in the upper or lower portion of the display attended to by the face). The design of the experiment served to maximise the potential for gaze cues to orient attention by the same means as exogenous cues, and elicit IOR.

Experiment 1 first sought to establish whether a peripheral face cue can orient attention under these conditions, and whether the resulting effect would be localised to the gazed-at location. Peripheral cueing will be evident as facilitated processing when targets share the same visual hemifield as the face cue. Moreover, if the direction of gaze can be interpreted as referring to a specific part of the display, response times will be enhanced further when sharing vertical congruency with the gaze direction, such that the two cue-types have an additive or interactive effect on target processing. Experiment 2 examined whether the two cue components could jointly elicit an IOR effect with the same spatial characteristics as the preceding facilitation effect, and at what time course it follows. If the mechanisms underlying IOR are indeed sensitive to a peripheral social attention we expect to observe the reverse pattern of *longer* RTs when targets were horizontally and vertically congruent with their preceding cues. Two SOAs of 800 ms and 2400 ms were employed to reflect the durations when IOR occurs in response to peripheral exogenous cues and central gaze cues respectively. These manipulations will therefore establish the relative importance of gaze cue location and gaze cue direction in eliciting IOR, and whether these two cue types reveal IOR to have different temporal characteristics.

General Method

Participants

All participants (Experiment 1: N = 36, 30 females, mean age = 24.3 years, *SD* = 5.5; Experiment 2: N = 41, 30 females, mean age = 20.6 years, *SD* = 5.0), had normal or corrected-to-normal vision, and gave written informed consent prior to taking part.

Stimuli and Apparatus

Experiments were conducted using E-Prime (Psychology Software Tools, Inc., Sharpsburg, PA) on a Pentium PC linked to an 85-Hz colour monitor. The face cues were created using Poser 6 (Curious Labs, Inc., Santa Cruz, CA and e-frontier, Inc., Scotts valley, CA). Two identities were used (one female, one male). The centre of the cue subtended 12.3^{o} from the centre of the screen. The female cue measured $12.7^{o} \times 9.9^{o}$ in height and width, and the male $12.6^{o} \times 9.3^{o}$. The target consisted of an H or an S (width and height of 1.8^{o}) that was low contrast (RGB = 205, 205, 205) compared to the background colour (RGB: 217, 217, 217). The centre of the target was 13.0^{o} from the centre of the screen.

Design and Procedure

Experiment 1. The experiment was a 2×2 within-subjects design, with horizontal and vertical congruency as factors (congruent or incongruent, in both cases). After completing 8 practice trials, participants completed two blocks of 64 trials, each consisting of iterating the horizontal location of the cue (left, right), the vertical direction of gaze (up, down), the target location (top left, top right, bottom left, bottom right), the target (H, S) and the cue identity (male, female). Cue-target congruency was 50% along both the horizontal and the vertical axes, producing four cue-target contingencies with the target appearing in the specific gazed at location on 25% of trials (32 trials).

Each trial (Figure 1) began with a black fixation cross (width and height of 0.3º) that remained on screen throughout the trial, and to which participants remained fixated.   A face oriented forwards was presented in the left or right visual hemifield for 1500 ms (sufficiently long for attention to be reoriented to the central fixation following onset of the face). The face then cued a location by looking upward or downward and, after an SOA of 200 ms, a target appeared in one of the four corners of the display (3000 ms or until response). Participants responded whether the target was an H or S by pressing the Z or M keys on a standard keyboard (labelled accordingly, counterbalanced across participants).

Experiment 2. The design was the same as for Experiment 1, but with SOA (2400 ms vs. 800 ms) as an additional within-participants factor, producing 256 trials. Within this extended SOA, a re-orientation cue intervened (200 or 1800 ms) between the cue and target, following standard IOR methodology (Pratt & Fischer, 2002). The central fixation cross changed to white and increased in size (height and width of 1.1º) and the face oriented to its original forward position, after which the fixation returned to its initial state for 400 ms, before the target appeared.
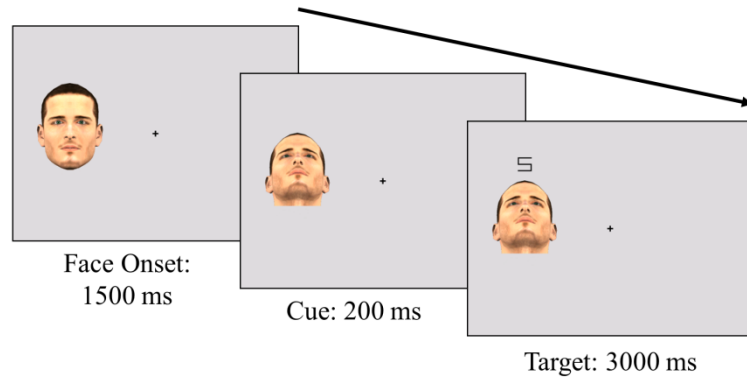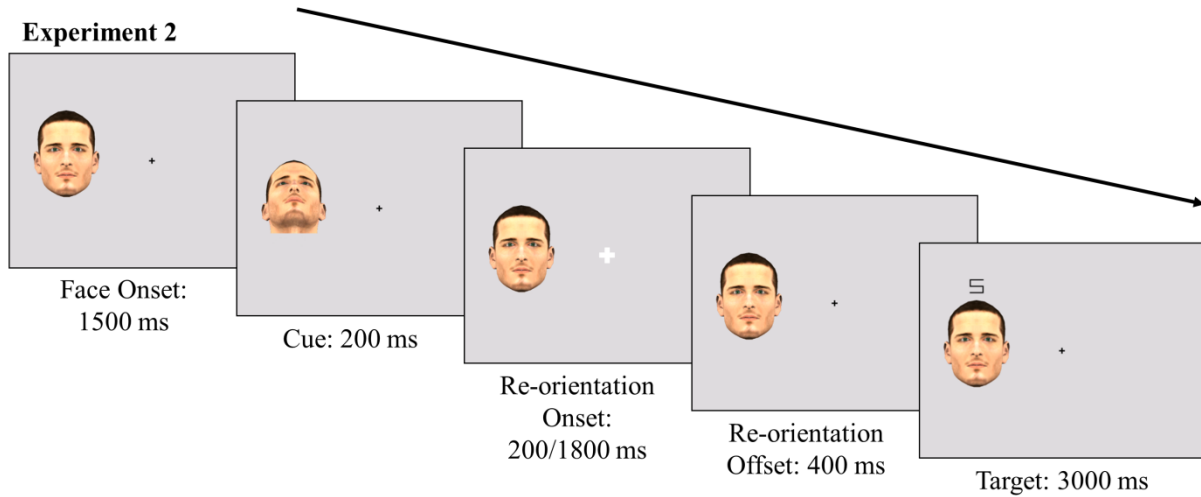
[Insert Figure 1 about here]

Experiment 1

Face Onset:
1500 ms

Cue: 200 ms

Target: 3000 ms

Experiment 2

Face Onset:
1500 ms

Cue: 200 ms

Re-orientation
Onset:
200/1800 ms

Re-orientation
Offset: 400 ms

Target: 3000 ms

Figure 1. Trial sequence for Experiments 1 and 2. The cue-target congruency depicted here is congruent on both the horizontal axis and vertical axis. The target is presented as black for illustrative purposes, and stimuli are not drawn to scale.

Results

Experiment 1

Incorrect trials ($M = 3.9\%$, $SD = 2.9$) were removed from the analysis, as were RT outliers ($> 2SD$ of the condition mean for each participant, 4.9% of trials). The data were entered into a 2×2 ANOVA with peripheral congruency (congruent vs. incongruent) and gaze congruency (congruent vs. incongruent) as within-participant factors. There was an effect of peripheral cueing, $F(1, 35) = 6.99$, $p = .012$, $\eta_p^2 = .166$, with shorter RTs when the target appeared in the congruent ($M = 560$ ms, $SD = 76$) rather than incongruent hemifield ($M = 580$ ms, $SD = 98$ ms). There was an effect of gaze cueing, $F(1, 35) = 7.40$, $p = .01$, $\eta_p^2 = .175$, with shorter RTs when the target appeared in the gazed-at location ($M = 562$ ms, $SD = 76$ ms), rather than the opposite location ($M = 578$ ms, $SD = 98$ ms). The interaction between peripheral and gaze cueing was not significant, $F(1, 35) = 1.18$, $p = .286$, $\eta_p^2 = .033$.

The effects of peripheral and gaze cueing and the null interaction suggest that both cue types contribute equally to target processing. Simple effects analysis confirmed that the gaze cueing effect was significant both when horizontally congruent, $t(35) = 2.07$, $p = .046$, $d = .15$, ($M = 551$ ms, $SD = 71$ ms vs. $M = 566$ ms, $SD = 81$ ms), and incongruent with face location $t(35) = 2.45$, $p = .02$, $d = .21$, ($M = 570$ ms, $SD = 80$ ms vs. $M = 590$ ms, $SD = 112$ ms). The two conditions in which the cue and target were congruent on just one axis did not differ from each other, $t(35) = .736$, $p = .467$, $d = .04$. Thus, target processing was equally facilitated by the cue transient and the gaze direction.

Experiment 2

Incorrect trials (M = 3.1%, SD = 2.4%) and RT outliers (4.8%) were removed from the analysis. At an SOA of 800 ms, there was a peripheral cueing effect with RTs slower when cue and target appeared in the same hemifield (M = 736 ms, SD = 207 ms), than when in opposite hemifields, (M = 704 ms, SD = 161 ms), $F(1, 40)$ = 9.34, p = .004, η_p^2 = .194. The gaze cueing effect was not significant, $F(1, 40)$ = .115, p = .736, η_p^2 = .003, nor was the interaction, $F(1, 40)$ = 1.97, p = .168, η_p^2 = .048.

At an SOA of 2400 ms, there was again a significant inhibitory effect due to peripheral cueing, as horizontally congruent trials elicited slower RTs (M = 698 ms, SD = 171 ms) than horizontally incongruent trials, (M = 681 ms, SD = 157 ms), $F(1, 40)$ = 6.5, p = .015, η_p^2 = .143. There was a marginally significant inhibitory effect of gaze cueing, $F(1, 40)$ = 3.79, p = .059, η_p^2 = .089, with gaze congruent targets eliciting slower RTs (M = 697 ms, SD = 175 ms) than gaze incongruent targets , (M = 683 ms, SD = 153 ms). There was no interaction, $F(1, 40)$ = .022, p = .882, η_p^2 = .001.
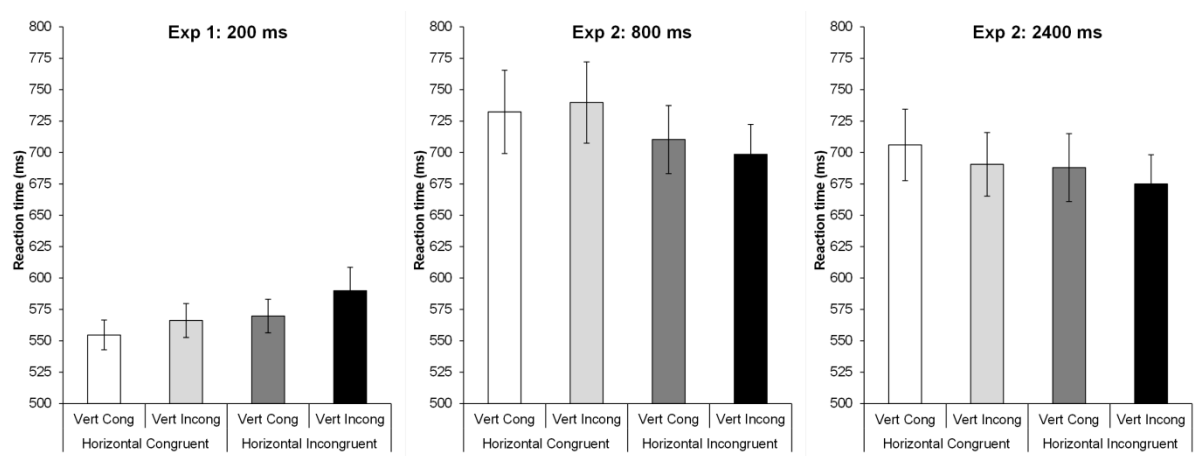
[Insert Figure 2 about here]

Figure 2. The effects of horizontal and vertical congruence on target discrimination times in Experiments 1 and 2. Mean reaction times are shown when the target was horizontally congruent or incongruent with the visual hemifield in which the cue appeared in (peripheral cueing) and vertically congruent or incongruent with the half of the screen gazed at by the cue (gaze cueing). Error bars represent standard error of the mean.

Discussion

Experiment 1 demonstrated that peripheral and gaze cues combine to facilitate specific regions of space. Attention is attracted to the hemifield occupied by the face cue on the basis of its transient movement as its gaze shifts upward or downward. Moreover, attention is then shifted to the location indicated by the direction in gaze. The net result is an additive facilitatory effect in which the two cue types combine to orient attention to specific regions of space. Both of these effects can be considered reflexive as the SOA between cue and target was 200 ms, each aspect of the cue was non-predictive, and participants were instructed to ignore the face. Most importantly, target processing was fastest when the target appeared in the specific corner of the screen that was looked at by the cue, demonstrating that the two components of the cue were cueing a common spatial location that resulted in an enhanced spatial resolution of the orienting effect. The attention system can indeed extract directional information from peripheral gaze cues. Furthermore, it seems that each source of information contributed equally and independently to the spatial refinement of the facilitation effect. This is confirmed by the observation that target processing was no better when the target was congruent with just the horizontal location of the cue than when it was congruent with just the vertical direction of gaze. Experiment 2 demonstrated that peripheral movement and gaze cues elicit a similar pattern of IOR but only after the target appears 2400 ms after onset of the cue, with RTs slowest when targets had both horizontal and vertical congruency

with the two cue types. At 800 ms SOA, IOR was insensitive to gaze direction, occurring only in response to cue movement, and affecting target responses in the entire hemifield.

The rationale for this methodology is predicated on the notion that IOR is consistently a product of peripherally presented transient cues at short SOAs, and that the typical central presentation of gaze cues do not replicate the conditions necessary for IOR processes to be engaged at these early time courses. Thus, the peripheral presentation of gaze cues would require the engagement of such processes to exogenously orient to the cue prior to orienting in response to the gaze direction, thus requiring a conjoint processing of the two facets of the cue. However, despite Experiment 1 demonstrating that the exogenous orienting worked in tandem with the gaze cue to enhance the facilitation effect, this combination was insufficient to elicit IOR in response to the gaze cue after 800 ms. Therefore, at time courses in which IOR for peripheral cues is reliably observed, once IOR had been established to the location of the cue it was not further engaged by the directional information conveyed by the cue itself. However, at an SOA of 2400 ms, which typically elicits IOR for centrally presented gaze cues, a marginal IOR effect of gaze direction was observed, that was concurrent but independent of the IOR effect caused by the transient movement of the cue itself. Our data unambiguously argue against the hypothesis that the very different characteristics of IOR elicited for peripheral exogenous cues and central gaze cues observed in previous studies can be attributed to the differing locations of the cues, but are very much due to the different time courses of the respective IOR effects.

Despite these differing temporal onsets, the cueing effects observed for exogenous movement and gaze direction are independent and additive, both when facilitating and inhibiting the allocation of attention. These results build on previous demonstrations of the independence of gaze cueing from exogenous cueing. For example, gaze cues continue to facilitate target processing in the presence of inhibitory exogenous cueing to a different

spatial location (Friesen & Kingstone, 2003b; Martin-Arevalo, Kingstone, & Lupianez, 2013). By having the cue types indicate a common spatial location at an extended time course, we show that this combined effect is evident for inhibitory mechanisms as well.

A crucial difference between the current study and those to have demonstrated IOR for gaze cues is that social cueing was here conveyed by head movements rather than by eye moments. As such, eye direction was not directly observable and was inferred from the head orientation, which provides a less spatially specific directional cue of social attention (Perrett & Emery, 1994). This may explain why gaze cueing, both facilitative and inhibitory, was generalised to the vertical half of the screen cued by head orientation, even if the target appeared in the opposite visual hemifield to the location of the cue. This is surprising given the accuracy with which observers can specify someone´s focus of attention (Bock, Dicke & Their, 2008), and how gaze typically cues a specific spatial location (Marotta, Lupiáñez, Martella & Casagrande, 2012). This lack of spatial specificity may also account for why IOR for social attention was statically marginal, despite being of comparable size (19 ms) to previous studies.

The question remains as to why gaze cues elicit IOR only after a prolonged time course, despite producing comparable early facilitation effects to peripheral cues. Given the automaticity of social cueing and its superficial similarity to the early orienting to salient environmental stimuli, it is surprising that the mechanisms underpinning them are so disparate. Ristic and Kingstone (2012) have suggested that at the beginning of development, social attention (along with other directional cues of high ecological relevance such as arrows), command volitional top-down orienting of attention. Through repeated exposure, social attention is associated with the location of important stimuli and becomes an overlearned directional cue (automatic symbolic cueing, see also Hommel, Pratt, Colzato, & Godijn, 2001). Therefore, social attention exploits an orienting mechanism that is separable

from both exogenous cues and non-familiar endogenous cues. The result of which is that automatic symbolic cues act in an additive but independent manner to exogenous cues, exactly as found in Experiment 1.

Extending this line of reasoning to IOR, it is equally plausible that environmental contingencies would delay the onset of IOR in response to social attention.   Gaze cueing is mediated by social factors, such as the identity of the gazer (e.g. Hudson, Nijboer, & Jellema, 2012), necessitating more complex and prolonged processing involving cortical regions such as the Superior Temporal Sulcus and Fusiform Gyrus. Furthermore, social attention is implicated in more complex social interactions such as language acquisition and theory of mind (Charman et al., 2000), and understanding the goals of others actions (Hudson, Liu, & Jellema, 2009). These situations necessitate prolonged monitoring of gaze direction. Therefore, at early stages of processing, the function of gaze direction overlaps with that of exogenous cues, whereas at later processing stages the function of the two cue types diverges. As gaze direction is pivotal in more complex and sophisticated socio-cognitive abilities, the onset of IOR is delayed and the characteristics of the respective inhibition effects are very different. The dissociable developmental trajectories may explain why neurodevelopmental disorders differentially affect cueing in response to different cue types, such as those with Asperger´s syndrome who show no IOR in response to gaze direction despite intact IOR in response to peripheral exogenous cues (Marotta et al., 2013). It may also account for why cueing in response to gaze is also different from that in response to other symbolic endogenous cues, such as arrows, which elicit both early facilitation and later inhibitory effects, but which appear to be specific to objects rather than specific spatial locations (Marotta et al., 2012; Weger, Abrams, Law & Pratt, 2008).

Conclusion

Attentional allocation is jointly oriented by a peripheral face by virtue of both its horizontal location and it´s social attention. Despite early enhancement of facilitation effects, the relative inhibitory effects depend very much on the different time courses and not the location of the cues themselves. IOR in response to gaze direction is not evident at time courses in which IOR for exogenous peripheral cues is evident, despite the cue being presented in the periphery and eliciting IOR for the location of the cue itself. As IOR mechanisms were evidently engaged by the stimulus, this presents a more emphatic demonstration of the failure of social attention to inhibit attentional allocation under the same conditions as observed for peripheral exogenous cues. Only after the very late onset of IOR for gaze direction are inhibitory effects enhanced in a similar way as early facilitation effects. This places in starker contrast the relative discrepancies in IOR for the two cue types. It is likely that attention orienting mechanisms developed to automatically orient in response to social gaze, but delay the inhibition of such orienting. Thus, attention orienting proceeds via several separable pathways that govern not only the type of orienting (facilitation or IOR) but also the stimulus which elicits these two effects (exogenous, endogenous, automated symbolic cues).

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Figure Captions

Figure 1. Trial sequence for Experiments 1 and 2. The cue-target congruency depicted here is congruent on both the horizontal axis and vertical axis. The target is presented as black for illustrative purposes, and stimuli are not drawn to scale.

Figure 2. The effects of horizontal and vertical congruence on target discrimination times in Experiments 1 and 2. Mean reaction times are shown when the target was horizontally congruent or incongruent with the visual hemifield in which the cue appeared in (peripheral cueing) and vertically congruent or incongruent with the half of the screen gazed at by the cue (gaze cueing). Error bars represent standard error of the mean.