Look away! Eyes and arrows engage oculomotor responses automatically

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The present study investigates how people's voluntary saccades are influenced by where another person is looking, even when this is counterpredictive of the intended saccade direction. The color of a fixation point instructed participants to make saccades either to the left or right. These saccade directions were either congruent or incongruent with the eye gaze of a centrally presented schematic face. Participants were asked to ignore the eyes, which were congruent only 20% of the time. At short gaze–fixation-cue stimulus onset asynchronies (SOAs; 0 and 100 msec), participants made more directional errors on incongruent than on congruent trials. At a longer SOA (900 msec), the pattern tended to reverse. We demonstrate that a perceived eye gaze results in an automatic saccade following the gaze and that the gaze cue cannot be ignored, even when attending to it is detrimental to the task. Similar results were found for centrally presented arrow cues, suggesting that this interference is not unique to gazes.

At any given moment, our senses are bombarded with vast amounts of sensory information, from which the perceptual system must select relevant information for further processing. This selection process is largely determined by attentional orienting, whereby we attend to certain aspects of the environment that may be of importance, while ignoring others. Researchers generally distinguish between two types of attentional orienting: overt and covert attention. In most situations, we tend to look at objects to which we attend by means of saccadic eye movements. These visible *overt* eye movements rapidly move the fovea, the region of the retina with a high spatial acuity, onto the stimulus of interest, thus enhancing visual processing at that location. However, it is possible to improve spatial detection and discrimination of stimuli at a particular location, even in the absence of an eye movement. This *covert* attentional orienting is frequently investigated using a cuing paradigm (Posner, 1980), in which participants are asked to maintain fixation and respond as quickly as possible to a target that can be preceded by a spatial cue. Because attention benefits the processing of stimulus information, when attention is oriented covertly to the location signaled by a spatial cue, the typical finding is that reaction times (RTs) to targets occurring at the cued location are shorter than those to targets appearing at an uncued location.

A further distinction is made between reflexive (exogenous) and volitional (endogenous) attentional orienting (Jonides, 1981). Reflexive orienting is driven by external stimulation, such as an abrupt peripheral onset cue. Because one can observe orienting to an onset location even when participants are instructed to ignore the cue (Jonides, 1981) and/or when the onset cue is counterpredictive of the target location (see, e.g., Warner, Juola, & Koshino, 1990), reflexive orienting is considered to be automatic and involuntary (Posner, Cohen, & Rafal, 1982; Yantis & Jonides, 1990). Traditionally, it was assumed that reflexive covert spatial orienting was only possible in response to sudden stimulus changes, such as when a cue appears abruptly in the periphery. However, recently it has become apparent that centrally presented cues, such as those provided by the eye gaze direction of a face, result in sudden shifts in attention (see Frischen, Bayliss, & Tipper, 2007, for a review). These shifts of attention to central directional cues share many of the features usually associated with reflexive orienting to peripheral abrupt onsets. For example, Friesen and Kingstone (1998) used a modified cuing task (Posner, 1980) in which participants were asked to detect a target that appeared either on the left or the right of a centrally presented face. Before a target appeared, the eyes in the face would look to either the left or the right of fixation. Friesen and Kingstone's results showed that participants' RTs were faster if the target appeared at the location looked at by the central face. What made this finding noteworthy was that RTs were facilitated at a gazed-at (cued) location even when participants

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were informed that they should ignore the gaze direction, since it did not predict where a target would appear. That gaze direction triggers attentional orienting even when it is spatially nonpredictive, and when participants are aware of that fact, is one key characteristic that gaze direction shares with more traditional nonsocial reflexive cues. Another is that the attention effects for the social cues emerge very quickly, within 100 msec after a gaze cue is presented (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999), and that these cues are hard to ignore (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004; Tipples, 2008).

There are, however, some apparent differences. Gaze direction alone does not yield any RT delay at the cued position, an effect commonly referred to as *inhibition of return* (IOR; Posner & Cohen, 1984). Indeed, the facilitation effect at a gazed-at location can persist for up to a second or more (see, e.g., Friesen & Kingstone, 1998; Frischen, Smilek, Eastwood, & Tipper, 2007; Langton & Bruce, 1999). This stands in marked contrast to abrupt onsets, which routinely yield IOR when the cue–target delay exceeds half a second. Nevertheless, it has been demonstrated recently that if attention is drawn away from a gazed-at location by an abrupt onset, an RT delay can then be observed at the previously gazed-at location (Frischen, Smilek, et al., 2007). Thus, gaze cues can be associated with inhibitory effects that are normally linked with reflexive onset cues.

A further characteristic of reflexive attention is its resistance to top-down control. Several studies have shown that the effects of orienting by reflexive cues are relatively insensitive to participants' intentions. For instance, when participants are explicitly instructed that onset cues predict that a target is likely to occur elsewhere, attention effects to the onset location are still observed (see, e.g., Warner et al., 1990). Similarly, Driver et al. (1999) suggested that gaze cues may be similarly resistant to top-down control, with attention being committed to a gazed-at location even when the gaze direction was made counterpredictive. To summarize, covert spatial orienting in response to eye gaze fulfills the main characteristics usually associated with reflexive spatial orienting: It occurs with a spatially nonpredictive cue, occurs rapidly, can be associated with RT delays, and is resistant to strategic control.

To what extent are these conclusions specific to the biologically relevant cue of eye gaze? This issue has been the focus of a flurry of research recently, stemming largely from a series of reports showing that a central, biologically irrelevant *arrow cue* may also trigger reflexive orienting (Eimer, 1997; Hommel, Pratt, Colzato, & Godijn, 2001; Tipples, 2002; see Gibson & Bryant, 2005; Tipples, 2008; and Vecera & Rizzo, 2004, for a different interpretation). Ristic, Friesen, and Kingstone (2002) directly compared the effects of gaze and arrow cues in preschool children and in adult populations and found that the two cues produced behaviorally equivalent orienting effects at short (<200-msec) and long (>1,000-msec) cue–target delays. Collectively, these data suggested that eyes and arrows have equivalent effects on reflexive covert spatial attention.

More recently, however, differences between these cues have emerged. Friesen et al. (2004) reported that when gaze and arrow cues are made *counterpredictive*, gaze cues, but *not* arrow cues, trigger an initial attention effect to the cued (congruent but not predictive) location. Friesen et al. suggested that, as cues, eyes are more strongly reflexive than arrows, which might reflect the fact that a neural architecture is specialized for processing eyes. This finding, and its interpretation, dovetails with the results of recent behavioral (Ristic, Wright, & Kingstone, 2007) and functional neuroimaging (Hietanen, Nummenmaa, Nyman, Parkkola, & Hämäläinen, 2006; Tipper, Handy, Giesbrecht, & Kingstone, 2008) studies. However, Tipples (2008) reported involuntary orienting to counterpredictive arrow cues, thus questioning the unique status of eye gaze as a biologically distinctive directional cue.

To what extent is this conclusion—that eyes and arrows have similar but dissociable attention effects—specific to reflexive *covert* spatial orienting? In other words, are the different attention effects for biologically relevant and irrelevant stimuli a general principle of attentional orienting, or are they limited to the specific, and relatively narrow, laboratory-based situations that are used to study covert attention (e.g., in which participants fixate a central point while making manual responses to stimuli appearing in their peripheral vision)? On this fundamental issue, the extant data are equivocal.

It is well understood that spatially nonpredictive gaze direction can have an impact on overt eye movement responses. For instance, Deaner and Platt (2003) had humans and monkeys perform a peripheral target detection task while viewing pictures of a rhesus monkey whose gaze was either congruent or incongruent with the target location. The results showed that both monkeys and humans responded faster to targets appearing in the gazed-at location than to those appearing on the other side. Although they were not supposed to move their eyes, humans and monkeys also tended to make more erroneous saccades in the direction indicated by the monkey's gaze. Finally, even when overt errors were not executed, small and consistent microsaccades were recorded in the direction of the gaze of the image. Thus, biologically relevant gaze cues can activate the oculomotor system and lead to the execution of overt eye movement errors when eye movement responses are not permitted. Gaze cues also impact oculomotor responses when eye movements are permitted and/or required. Mansfield, Farroni, and Johnson (2003) demonstrated that when participants are asked to saccade to a left- or right-appearing target, saccade latencies to a target at a gazed-at location are significantly faster than those to targets at the non-gazed-at location. Mansfield et al. also found a tendency to execute erroneous saccades in the direction indicated by a nonpredictive gaze cue, echoing the conclusion of Deaner and Platt.

When the effect of biologically relevant gaze cues and biologically irrelevant arrow cues are compared, however, the results are less clear cut. Like gaze cues, arrow cues can facilitate saccadic latencies to the congruent relative to the incongruent location (Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). Moreover, Ricciardelli et al. found that

correct RTs were equivalent for gaze and arrow cues. However, there was an RT difference for erroneous eye movements. Specifically, errors to the cued location were much more likely to occur for gaze than for arrow cues, suggesting that overt orienting, like covert orienting, may be more strongly reflexive for eyes than for arrows, although this effect appears to be limited to response accuracy.

Importantly, a recent article by Kuhn and Benson (2007) failed to replicate this key result of Ricciardelli et al. (2002). That is, although Kuhn and Benson found that correct RTs were equivalent for eyes and arrows, they also found a highly significant, and equal, tendency for participants to make erroneous eye movements to the cued location for both eyes and arrows. Thus, the effects of eyes and arrows appear to be identical for both correct RTs and error rates. The only difference Kuhn and Benson found between the two cues was in error RTs, with shorter latencies for gaze than for arrow cues.

In summary, there is little doubt that biologically relevant cues, such as eyes, and biologically irrelevant cues, such as arrows, can reflexively engage the covert as well as the overt attention system. Moreover, there is good evidence of a preferential bias for biologically relevant stimuli to reflexively engage the covert attention system more than stimuli such as arrows do. However, a similar state of affairs does not seem to hold for the overt attention system. At present, the only evidence of a difference between the two types of cues appears to be in erroneous eye movements, and this may be limited solely to error latencies rather than error rates. Thus, although some evidence does exist that eyes engage the overt system more than arrows do, there is far more evidence that the two types of cues engage the overt attention system with equal efficacy.

It was originally believed that eyes and arrows were equivalent in their abilities to reflexively engage the *covert* attention system, until researchers placed reflexive and volitional attentional control in competition by making eyes and arrow cues counterpredictive. Such manipulations revealed that eyes, but not arrows, trigger a covert shift of reflexive attention to the cued (congruent) location, even when volitional covert orienting is being committed to the noncued (incongruent) location—where the target is likely to appear (Friesen et al., 2004; but see also Tipples, 2008). The aim of the present study was to test whether reflexive *overt* orienting to counterpredictive gaze cues is more reflexive than is orienting to counterpredictive arrow cues.

Our line of investigation was accomplished in three stages. In Experiment 1, we investigated the time course of the effect that nonpredictive gaze cues have on the dynamics of overt orienting, over a time range of approximately 1 sec (0 to 900 msec). Although investigations of covert orienting over such a range have been performed extensively, similar investigations have never been performed for overt orienting. In Experiment 1, as well as in previous reports (Kuhn & Benson, 2007; Ricciardelli et al., 2002), the gaze cue was both nonpredictive of participants' saccade direction and task irrelevant. In Experiment 2, we investigated the time course of the effect that counterpredictive gaze cues have on the dynamics of overt

orienting over the same time range as in Experiment 1. Thus, rather than being asked to ignore the eyes (making the cues task irrelevant), participants were encouraged to make eye movements in the direction opposite to the distractor gaze. On the basis of the findings, in Experiment 3 we restricted our comparison of gaze and arrow cues to the interval that would provide the largest reflexive attention effect for counterpredictive cues, and in so doing, maximized our power to uncover differences between the abilities of biologically relevant and irrelevant cues to engage overt attention reflexively.

EXPERIMENT 1

The aim of Experiment 1 was to investigate the time course of the effect of nonpredictive eye gaze on voluntary saccades. It should be noted that although Ricciardelli et al. (2002) investigated this issue, they employed a rather small (±150 msec) time window. In their task, participants were presented with an image of a real face, which was flanked by two target points. The color of the fixation point signaled a volitional eye movement to the left or to the right target. This saccade instruction was presented 150 msec or 75 msec prior to the irrelevant gaze stimulus, simultaneously with the gaze stimulus, or 75 msec or 150 msec after the gaze stimulus. The results showed that when the distractor gaze direction was congruent with the target location, participants' correct-saccade RTs were facilitated, and this benefit was relatively consistent across all SOAs. In addition, more directional errors were executed when gaze direction was incongruent with the target location, suggesting that, at least on a small proportion of trials, participants initiated erroneous saccades toward the gazed-at direction. However, this effect of eye gaze on the accuracy of volitional saccades was only observed within a very narrow time window. Participants made significantly more saccade errors when the distractor gaze was presented either simultaneously with or 75 msec after the target, but gaze direction had no impact on volitional saccade accuracy when the cue was presented 150 msec after the target. Gaze direction also had no effect when the cue preceded the target signal. Interestingly, the skew of this distractor effect contrasts with a previous report (Mansfield et al., 2003) that an irrelevant gaze direction had an impact on *reflexive* saccades when the gaze *preceded* a target signal by 300 msec. In sum, the data suggest that the interference effect of a gaze cue on a volitional saccade may be very different from its effect on a reflexive saccade, with the distractor effects for volitional saccades existing within a smaller time window and being limited to distractor faces that occur simultaneous with, or very shortly after, a target signal.

Yet Kuhn and Benson (2007) recently failed to replicate Ricciardelli et al.'s (2002) results, which brings into question their time course data. Moreover, because Kuhn and Benson only tested one SOA (distractor and saccade direction cues presented simultaneously), we thought it prudent to begin the present study by examining the time course of gaze direction's effect on voluntary saccades using Ricciardelli et al.'s paradigm, but applying it over a much longer time range (nearly 1 sec).
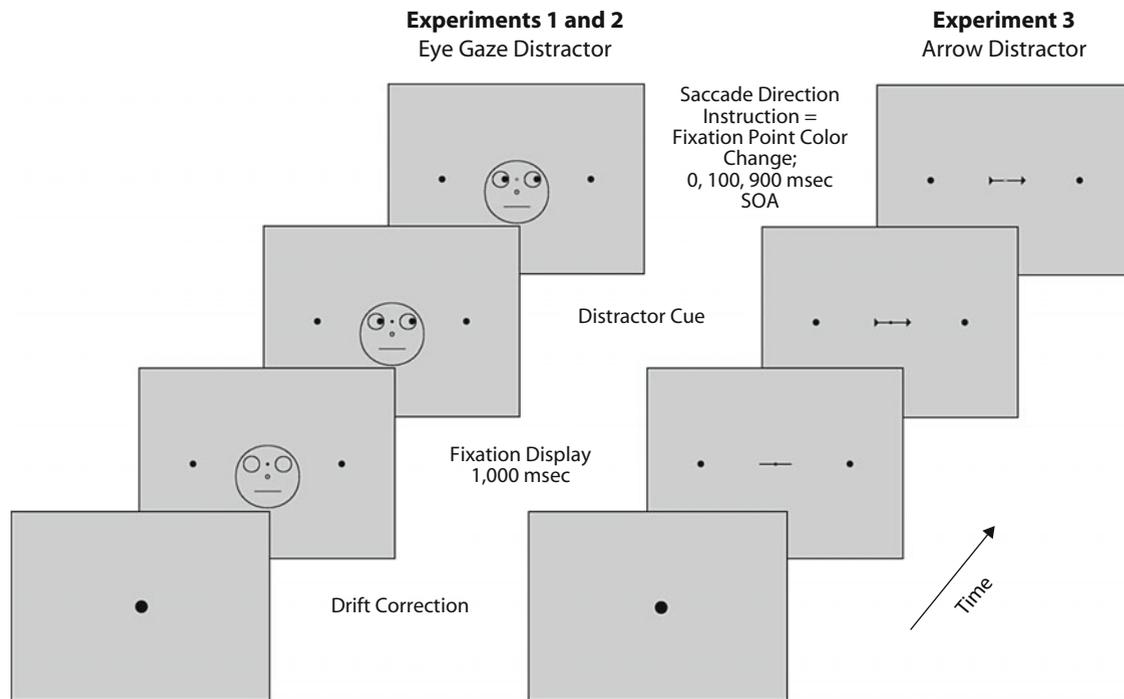
Figure 1. Sequence of events for each of the experiments.

Method

Participants. A total of 12 undergraduate students (9 female, 3 male) were paid £5 each to participate in the study. All participants had normal or corrected-to-normal vision and were naive to the purpose of the experiment.

Materials and Procedure. Eye movements were monitored using an Eyelink2 eyetracker (SR Research Ltd, Osgoode, Canada), and eye movements were recorded monocularly at 500 Hz. The experiment was run on a Pentium D computer and displayed on a 20-in. CRT monitor (viewing distance was 63 cm). The experiment was compiled and run using Experiment Builder (SR Research Ltd, Osgoode, Canada). Each trial began with a central black fixation point (0.63° in diameter) on a gray background (see Figure 1). Participants were asked to fixate on this central spot and press the space bar once they had achieved fixation. This procedure allowed us to perform a drift correction and ensured that participants fixated the center of the screen. The keypress initiated the remaining trial sequence, which comprised a schematic face (8.57° in diameter) with two eyes (2.27° in diameter) flanked by two solid black target circles (0.91° in diameter, 10° from fixation). Between the eyes, a small black spot acted as a fixation point (0.45° in diameter). After 1,000 msec, pupils (0.45° in diameter) appeared inside the eyes that could look either to the left or to the right. After a distractor cue SOA of 0, 100, or 900 msec, the black fixation point turned either red or green. Half of the participants were instructed to move their eyes to the right when the fixation point turned red and to the left when it turned green, and for the other half the color commands were reversed. The color change of the fixation spot therefore informed each participant as to which target they had to saccade to. Congruent trials were those in which the saccade target direction and the eye gaze direction were the same; incongruent trials were those in which the target and eye gaze directions were opposite. After 1,000 msec, the display was replaced with a blank screen for 1,500 msec. There were 432 trials in total, with trials equally and randomly divided between the three SOA conditions and the congruent/incongruent conditions. Trials were presented in three blocks of 144 trials apiece.

Prior to each experimental block, participants performed a nine-point calibration, followed by a validation procedure. The calibration was accepted if the average error was below 0.5°. Participants were then asked to fixate on the central fixation point at the beginning of each trial and to press the space bar when they had done so. Once the trial was initiated, they were asked to saccade to the left or the right target, as indicated by the color switch of the fixation point, and to ignore the distractor cues. Participants were instructed to move their eyes as quickly as possible to the target and to avoid making any mistakes. Moreover, they were asked to ignore the eyes, because the eyes would point to the correct target location on only 50% of the trials. The participants were given 16 practice trials prior to the experiment.

Results

The dependent variables were eye movement onset latencies and directional errors. It was predicted that if gaze-following is automatic, saccade latencies should be shorter on congruent than on incongruent trials. Moreover, participants should make more directional errors on incongruent than on congruent trials.

Eye movement onset latency was measured as the time that elapsed from the fixation point color change (direction cue) to the initiation of the first saccade. The first saccade was defined as the first eye movement with a velocity and acceleration exceeding 30°/sec and 8,000°/sec², respectively. Only saccades greater than 1° were analyzed; each record was inspected individually. All saccades that went in the intended direction were defined as correct saccades. Those that went in the opposite direction were defined as error saccades. Trials on which tracker loss occurred were excluded from the analysis, as were those on which participants failed to move their eyes. These errors accounted for a total of 0.2% of all trials. Saccade laten-
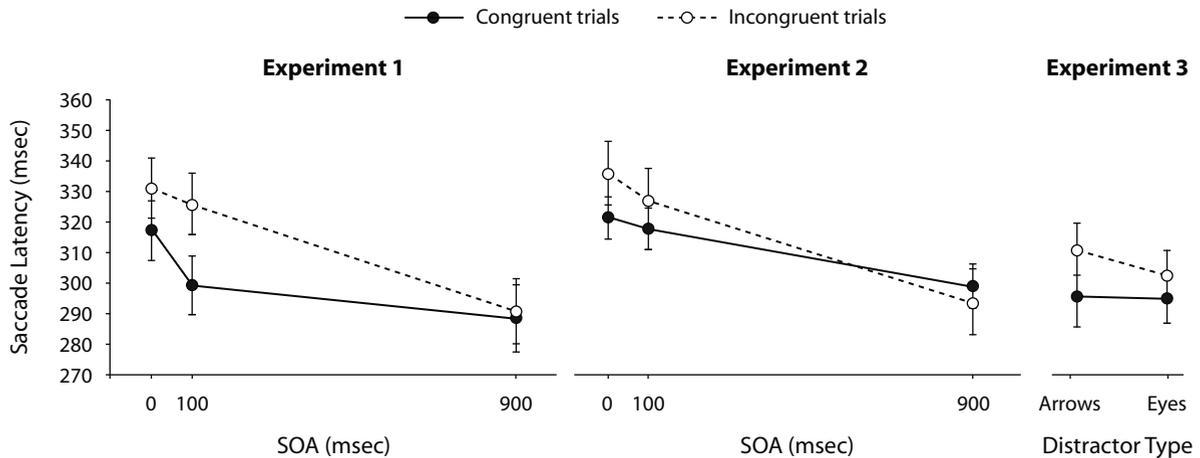
● Congruent trials   - - ○ - - Incongruent trials

Figure 2. Mean saccade latencies for congruent and incongruent trials for Experiments 1, 2, and 3. Error bars represent standard errors.

cies less than 80 msec (anticipatory saccades) or greater than 550 msec were classified as outliers and were also removed prior to analysis (3.2% of trials). All p values are two-tailed unless stated otherwise.

Saccade latencies. Figure 2 shows the mean latencies for saccades that went in the correct direction on congruent and incongruent trials as a function of SOA. An ANOVA with trial type (congruent vs. incongruent) and SOA (0, 100, or 900 msec) as within-subjects factors showed a significant main effect of trial type [$F(1,11) = 66.1, p < .0001$], which resulted from shorter saccade latencies on congruent ($M = 301$ msec, $SE = 9.56$) than on incongruent ($M = 316$, $SE = 9.59$) trials. Furthermore, there was a significant main effect of SOA [$F(2,22) = 19.7, p < .0001$], demonstrating a reduction in saccade latencies as the SOA increased, an effect typically found in RT tasks. Moreover, there was a significant trial type × SOA interaction [$F(2,22) = 9.41, p = .001$]. Figure 2 suggests that this interaction reflects a reduction in the gaze distractor's interference as SOAs increased.

Indeed, planned comparisons showed that participants' saccade latencies were faster on congruent than on incongruent trials at the 0-msec [$t(11) = 3.39 \ p = .006$] and 100-msec [$t(11) = 6.04, p < .0001$] SOAs. However, this effect disappeared at the 900-msec SOA [$t(11) = 1.25, p = .24$]. These results suggest that, insofar as saccadic latency is concerned, eye gaze interfered with saccadic preparation and/or execution at the two shorter SOAs but not at the longer SOA.

Saccade errors. Errors were trials on which the first saccade was contrary to the saccade instruction. If the direction of the distractor cue influenced volitional saccades, one would expect more directional errors to occur on incongruent than on congruent trials. Figure 3 shows the percentage of errors for congruent and incongruent trials for each of the three distractor–fixation-cue SOAs. An ANOVA with trial type (congruent vs. incongruent) and SOA (0, 100, or 900 msec) as within-subjects factors found a significant main effect of trial type [$F(1,11) = 22.01, p = .001$] that resulted from higher error rates on

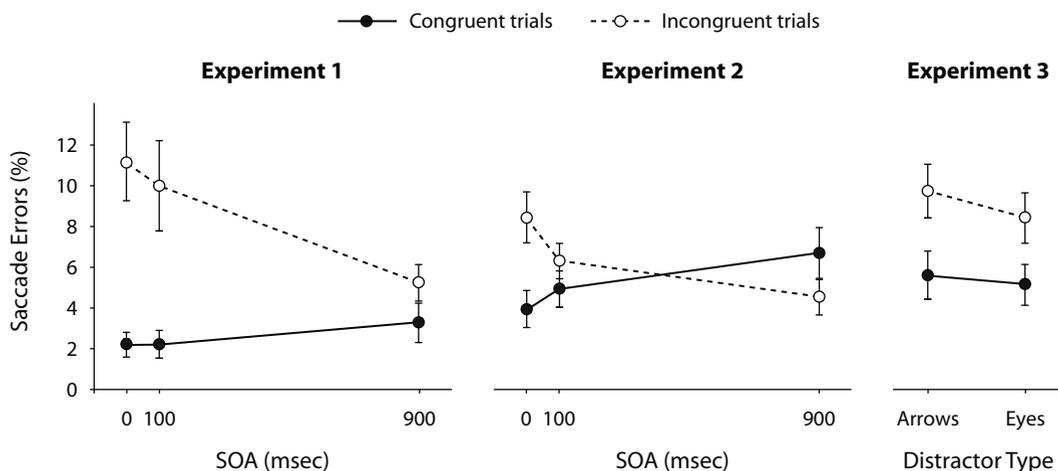● Congruent trials   - - ○ - - Incongruent trials

Figure 3. Percentages of errors made on congruent and incongruent trials for Experiments 1, 2, and 3. Error bars represent standard errors.

incongruent ($M = 7.77$, $SE = 1.25$) than on congruent ($M = 3.56$, $SE = 0.66$) trials. Moreover, there was a significant main effect of SOA [$F(2,22) = 3.97$, $p = .034$], showing that participants made fewer errors as SOA increased. Finally, there was a significant trial type × SOA interaction [$F(2,22) = 7.82$, $p = .003$]. Planned comparisons revealed that participants made significantly more errors on incongruent than on congruent trials at the 0-msec [$t(11) = 4.52$, $p = .001$] and 100-msec [$t(11) = 3.83$, $p = .003$] SOAs; the effect approached significance at the 900-msec SOA [$t(11) = 2.18$, $p = .052$]. However, in Figure 3, it can be seen that this effect decreased over time, which was supported by the linear within-subjects contrasts [$F(1,11) = 17.50$, $p = .002$].

Reflexive nature of saccades. If gaze-following is truly reflexive, we would expect saccades elicited by the distractor cue to be faster than volitional saccades (Kuhn & Benson, 2007; Theeuwes, Kramer, Hahn, Irwin, & Zelinsky, 1999). This means that on incongruent trials, error saccades should be faster than correct saccades. Table 1 shows the latencies for correct and incorrect saccades. Indeed, on incongruent trials, an ANOVA with saccade type (correct vs. error) and SOA (0, 100, or 900 msec) as within-subjects factors revealed a significant main effect of saccade type [$F(1,9) = 5.58$, $p = .042$] and a significant main effect of SOA [$F(2,18) = 4.06$, $p = .035$], but no significant SOA × saccade type interaction [$F(2,18) = 1.19$, $p = .33$]. As predicted on incongruent trials, error saccades were faster than correct saccades. Participants' errors on congruent trials would have resulted from executing a saccade in the nonintended direction, opposite the direction in which the eyes were pointing. Errors on congruent trials therefore did not result from following the gaze distractor, and thus are not considered to be reflexive. We would therefore expect to find no difference in saccade latencies between correct and error saccades. And indeed, on congruent trials, the same analysis revealed no significant main effect of saccade type [$F(1,5) < 1$], nor of SOA [$F(2,10) < 1$], nor a significant SOA × saccade type interaction [$F(2,5) = 3.49$, $p = .07$]. Errors that did not result from the gaze interference therefore did not result in faster saccade latencies.[1]

If participants' gaze-following is purely reflexive, we would expect them to execute saccades in the same di-

rection in which the eyes are pointing, even before the saccade instruction has been received. To investigate this issue, we calculated the number of saccades that were executed after the gaze cue but prior to the saccade instruction in the 900-msec SOA condition. Participants moved their eyes in the direction in which the eyes were pointing on 0.34% ($SD = 0.54$) of the trials, as compared with in the opposite direction on 0.23% ($SD = 0.63$) of the trials. Since these saccades occurred on a rather low proportion of trials and the means did not differ significantly [$t(11) = 1.0$, $p = .34$], we can conclude that the distractor gaze influenced oculomotor behavior once a saccade was executed but not prior to its execution.

Discussion

Experiment 1 investigated the time course of the effect that nonpredictive eye gaze has on voluntary saccades. Even though gaze direction did not predict where the target would occur, and was therefore irrelevant to the task, participants' saccade latencies were significantly shorter on congruent than on incongruent trials. Moreover, participants made more directional errors on incongruent than on congruent trials, demonstrating that at least on a small proportion of trials, they followed the irrelevant gaze rather than moving their eyes in the direction of the target. The interference effects were sampled at three different distractor–fixation-cue SOAs, thus allowing insight into the time course of this effect. In target detection tasks involving covert, rather than overt, attention (see, e.g., Friesen & Kingstone, 1998), RT facilitation resulting from the targets appearing at the gazed-at location emerges relatively soon after the eye gaze cue has been presented (cue–target SOA of about 100 msec) and is long lived, dissipating at an SOA of around 1,000 msec. In the present study, eye gaze affected participants' saccade latencies at very short SOAs (0 and 100 msec), but this effect disappeared at the 900-msec SOA. Ricciardelli et al. (2002) used a larger number of SOAs (−150, −75, 0, 75, and 150 msec; note that in their study, negative values indicated that the saccade instruction cue preceded the distractor cue) but over a smaller range. Ricciardelli et al. found significant differences between the congruent and incongruent conditions at all SOAs but the longest (150 msec), a pattern of results that is somewhat reflected in our own. How-

Table 1
Mean Saccade Latencies for Error and Correct Saccades on Incongruent and Congruent Trials, for Experiments 1, 2, and 3

| | | Incongruent | | | | | | Congruent | | | | | |
| | | Error Saccades | | | Correct Saccades | | | Error Saccades | | | Correct Saccades | | |
	SOA	M	SD	n	M	SD	n	M	SD	n	M	SD	n
Exp. 1	0	320	73.3	12	339	36.5	12	299	102.0	9	327	35.5	12
	100	285	76.0	11	331	32.8	12	297	79.9	8	307	33.0	12
	900	279	34.4	10	295	38.1	12	298	64.0	8	299	41.2	12
Exp. 2	0	317	48.5	30	342	41.2	30	343	56.2	17	333	35.2	30
	100	307	49.9	30	333	38.3	30	310	69.7	20	325	38.1	30
	900	296	46.2	23	302	38.7	30	291	52.9	21	308	37.8	30
Exp. 3 Eyes	0	287	42.3	28	312	40.4	28	308	56.4	21	306	40.8	28
Exp. 3 Arrow	0	289	48.1	28	320	44.1	28	341	62.5	20	309	48.1	28

ever, in terms of saccade errors, Ricciardelli et al. only found significant differences between the congruent and incongruent conditions at SOAs of −75 and 0 msec, not at any of the others. Our results, on the other hand, revealed that the interfering effect of the distractor gaze is much longer lasting than was previously claimed. Although the effect did reduce over time, it was still present at the 900-msec SOA, suggesting that, contrary to Ricciardelli et al.'s claim, these effects are very long lasting.

Two of the hallmarks of reflexive attentional orienting are that the effect must occur *rapidly* and in response to a *nonpredictive* cue (see, e.g., Müller & Rabbitt, 1989). The fact that our effect occurred at very short SOAs and in response to a nonpredictive stimulus suggests that these effects are indeed reflexive. Some neurophysiological evidence suggests that different neurological structures are responsible for voluntary and reflexive saccades (Mort et al., 2003), and behavioral evidence also supports this proposition. For example, Theeuwes et al. (1999) investigated the effects of abrupt onsets on oculomotor behavior and showed that the planning and execution of a saccade toward a target was disrupted by the onset of a task-irrelevant abrupt onset. In several instances, participants' eyes moved toward the task-irrelevant onset, even when this was in the direction opposite to the intended saccade. Moreover, saccade latencies for eye movements in the direction of the abrupt onset were significantly faster than latencies for goal-directed eye movements, suggesting that these two types of saccades are qualitatively distinct (see, e.g., van Zoest, Donk, & Theeuwes, 2004). In the present study, we compared the latencies for saccades in the intended direction (correct saccades) with those for saccades in the unintended, but cued, direction (error saccades on incongruent trials). As in the previous study, we found that error saccades were executed significantly faster than correct saccades. If these error saccades are truly reflexive and distinct from the volitional saccades, we would expect latencies to be shorter for the latter saccades than for the former. Indeed, our results showed this to be the case. Moreover, the fact that this effect did not interact with SOA suggests that the error saccades at each of the three SOAs were reflexive. Interestingly, on congruent trials, error saccades did not result from gaze-following, and on those trials, no difference was found between RTs for the correct and the error saccades, suggesting that the latency difference we found was due not merely to making an error, but to reflexively following the gaze cue. However, interestingly, the gaze cue only interfered with participants' oculomotor behavior once the saccade instruction was presented. Prior to the saccade execution cue, the gaze distractor had little effect on participants' oculomotor behavior, suggesting that the distractor interfered with the planning and execution of saccades, and thus the gaze-following was not simply arbitrary.

EXPERIMENT 2

In Experiment 1, we showed that nonpredictive gaze interfered with the planning and execution of volitional saccades when participants had no particular motiva-tion to follow the distractor gaze. In Experiment 2, we investigated whether this effect of eye gaze is automatic in the stronger sense—that is, whether it arises even when participants are asked to move their eyes in the direction *opposite* the one in which the stimulus eyes are looking. We investigated the time course of counterpredictive gaze cues on overt orienting over the same time range as in Experiment 1.

Previous studies have tested the reflexive nature of covert attentional orienting to gaze direction by using counterpredictive gaze cues (Driver et al., 1999; Friesen et al., 2004; Tipples, 2008). In the typical study of this kind, participants are informed that when the eyes look to the left, the target is much more likely (e.g., four times) to appear on the right; when the eyes look right, the target is more likely to appear on the left. This research has shown that at short cue–target SOAs (e.g., 100 msec—Friesen et al., 2004; 300 msec—Driver et al., 1999), attention is committed to the gazed-at/congruent location, even though a target is unlikely to appear there and is much more likely to appear at the incongruent location. Over time, attention tends to be allocated to the incongruent location. However, as found by both Driver et al. and Friesen et al., the power of the gaze stimulus can be so strong that even at cue–target SOAs that approach a full second, the difference between congruent and incongruent locations is not significant; although there may be a small numerical trend for RTs to reverse and be shorter at the incongruent than at the congruent location (Driver et al., 1999; Friesen et al., 2004).

The aim of Experiment 2 was to test whether the cue-following effect, as demonstrated in Experiment 1, is automatic in the strong sense. This was achieved by altering the ratio of congruent and incongruent trials so as to discourage participants from following the eye gaze distractor. It was predicted that if gaze-following is automatic, congruent trials should produce shorter saccade latencies at short SOAs (0 and 100 msec) than do incongruent trials. Similarly, in accordance with the results of Experiment 1, short SOAs should also yield more directional saccade errors on incongruent than on congruent trials. In light of the past findings that gaze direction can still impact performance at SOAs approaching 1 sec, which dovetails with the error data in our Experiment 1, it is very possible that significant differences between congruent and incongruent locations may still be in evidence even at 900 msec. However, given that the effect of gaze direction on RTs declined toward zero in Experiment 1, it is possible that at least a numerical trend toward a crossover effect would emerge in this new experiment, with RTs now being shorter at the incongruent location.

One final and important point: The predictions above in many ways mirror the performance patterns that we obtained in Experiment 1. Specifically, we predict that RTs will be faster at congruent than at incongruent locations at the shortest SOAs and that this difference will move toward zero (with a possible trend toward a crossover effect) at the longest SOA. This trial type × SOA interaction is pretty much exactly what we found in Experiment 1. In light of this duplication, one might very reasonably ask how we would know if participants were actually mak-

ing use of the fact that the target response was four times more likely to be incongruent with the direction of gaze? Without such evidence, Experiment 2 would not provide a strong test of automaticity (we thank Bernhard Hommel for making this critical point to us). The answer is that the evidence that participants are using the cue would not be found in a trial type × SOA interaction, but in a significant difference between the magnitudes of the congruency effect in the two experiments. We expect that participants will actively attempt to avoid committing attention to the congruent (unlikely) location and to commit it instead to the incongruent (likely) location. This active top-down effort to inhibit the reflexive attention effect of gaze direction should reduce the difference between congruent and incongruent responses. If some part of the gaze effect is strongly automatic, we would still expect RTs to the congruent location to be faster at the short SOAs, but the congruency effect should be significantly smaller in Experiment 2 than in Experiment 1, at least at those short SOAs.

Method

Participants. A total of 30 undergraduate students (21 female, 9 male), none of whom took part in any of the other experiments, either were paid £5 apiece to participate or were given course credits. All participants had normal or corrected-to-normal vision and were naive to the purpose of the experiment.

Materials and Procedure. This experiment was identical to Experiment 1, with the exception that the proportions of congruent and incongruent trials were manipulated so that 20% of the trials were congruent and 80% were incongruent. A total of 450 trials were presented, in three blocks containing 150 trials each. There were equal numbers of trials in all of the SOA conditions.

Prior to the experiment, participants were informed that the gaze direction on the stimulus face would correctly indicate the intended saccade direction on only 20% of the trials. They were urged to move their eyes as quickly as possible and to avoid making any mistakes. The participants were given 16 practice trials before the experiment.

Results

The eye movement analysis was identical to that in Experiment 1. Because of difficulties with the eyetracker, 2 participants completed only two of the three blocks. Any trials in which tracker loss occurred or participants failed to move their eyes were excluded from the analysis (1.37% of trials). Saccade latencies smaller than 80 msec or greater than 550 msec were classified as outliers and were also removed prior to analysis (2.6% of trials).

Saccade latencies. Figure 2 shows the mean correct latencies for saccades on congruent and incongruent trials as a function of SOA. An ANOVA with trial type (congruent vs. incongruent) and SOA (0, 100, or 900 msec) as within-subjects factors showed no effect of trial type $[F(1,29) = 2.96, p = .10]$ but a significant main effect of SOA $[F(2,58) = 82.0, p < .0001]$. The trial type × SOA interaction was also significant $[F(2,58) = 9.16, p < .0001]$. Saccade latencies were significantly faster on congruent than on incongruent trials at the 0-msec $[t(29) = 3.09, p = .004]$ and the 100-msec $[t(29) = 3.00, p = .005]$ SOAs. At the 900-msec SOA, this difference went numerically in the opposite direction, so that saccade latency trials were longer on congruent than on incongruent trials.

However, this difference was not statistically significant $[t(29) = -1.73, p = .096]$. These results demonstrate that at shorter SOAs, saccade latencies remained faster on congruent than on incongruent trials, even though the gaze cues were counterpredictive of the intended saccade direction. However, at the longest SOA, we observed the expected crossover effect.

Saccade errors. Error saccades were defined as in Experiment 1. Figure 3 shows the percentages of errors for the congruent and incongruent conditions at each SOA. For incongruent trials, an ANOVA with saccade type (congruent vs. incongruent) and SOA (0, 100, or 900 msec) as within-subjects factors found no main effect of SOA $[F(2,58) = 0.60, p = .56]$, but did find a significant main effect of saccade type $[F(1,29) = 4.37, p = .045]$ and a significant interaction $[F(2,50) = 11.30, p < .0001]$. At the 0-msec SOA, participants made significantly more directional errors on incongruent than on congruent trials $[t(29) = 4.32, p < .0001]$. At the 100-msec SOA, this difference went in the same direction but was not statistically significant $[t(29) = 1.77, p = .088]$. At the 900-msec SOA, the participants made numerically more errors on congruent than on incongruent trials, but this effect was not statistically significant $[t(29) = -1.83, p = .076]$.

Reflexive nature of saccades. The saccade latencies for correct and error saccades were analyzed as in Experiment 1. Table 1 shows the latencies for correct and error saccades on congruent and incongruent trials. An ANOVA for saccade latencies on incongruent trials, with SOA (0, 100, or 900 msec) and saccade direction (correct vs. incorrect) as within-subjects factors, showed significant main effects of saccade type $[F(1,22) = 8.42, p = .008]$ and SOA $[F(2,44) = 29.2, p < .0001]$ and a significant interaction $[F(2,44) = 4.97, p = .011]$. Paired-sample t tests showed that error saccades were significantly faster than correct saccades at the 0-msec $[t(29) = 2.65, p = .013]$ and 100-msec $[t(29) = 3.644, p = .001]$ SOAs. However, no such difference was found for the 900-msec SOA $[t(22) < 1]$. Only at the shorter SOAs (0 and 100 msec) did directional saccade errors reveal their reflexive nature.

On congruent trials, the same analysis revealed a significant main effect of SOA $[F(2,18) = 5.25, p = .018]$ but no effect of saccade type $[F(1,9) < 1]$. The saccade type × SOA interaction was not significant $[F(2,18) = 2.13, p = .15]$,[2] indicating that the difference in saccade latencies was not due to making an error saccade per se, but rather to automatic cue-following.

As in Experiment 1, we calculated the number of saccades after the gaze distractor but prior to the saccade distractor in the 900-msec SOA condition. Participants made numerically more saccade errors in the same direction as the gaze cue ($M = 1.98\%$, $SD = 3.6$) than in the other direction ($M = 1.58\%$, $SD = 2.9$), but this difference was not significant $[t(27) < 1]$.

Comparison Between Experiments 1 and 2

Experiments 1 and 2 had identical methods, except for the change in the relation between the target response and gaze cue direction: In Experiment 1 these were unrelated, and in Experiment 2 they were related, with the target

response four times more likely to be incongruent than to be congruent with the gaze direction. This data pattern was very similar between the experiments, consistent with the idea that attention is biased toward the congruent gaze direction, even when participants actively try to attend elsewhere. To ensure that this similarity in results occurred despite participants' attempts to attend the incongruent location, we conducted a between-experiment analysis. For the purposes of this analysis, and to ensure that we controlled for possible speed–accuracy differences related to the differences in error rates between experiments (see Figure 4), we calculated RT efficiency scores. Efficiency scores are a standard way to combine RTs and accuracy by dividing RT by the proportion of correct responses for a given condition (Townsend & Ashby, 1983). Lower values on this measure indicate more efficient performance.

Accordingly, RT and accuracy were converted to efficiency scores for each participant in each condition. These data were entered into a two-way mixed ANOVA, with experiment (1 vs. 2) as a between-subjects factor and trial type (congruent vs. incongruent) and SOA (0, 100, or 900 msec) as within-subjects factors. In this analysis, we found no main effect of experiment ($F < 1$), demonstrating that the participants in the two studies were matched, but significant effects for both trial type [$F(1,40) = 36.64, p = .0001$] and SOA [$F(2,80) = 88.57, p = .001$]. There was also a significant trial type $\times$ SOA interaction [$F(2,80) = 20.97, p = .0001$], consistent with the facts that performance in both experiments was enhanced for congruent relative to incongruent trials and that this difference was eliminated at the longest SOA. More importantly, there was also a highly reliable interaction between experiment and trial type [$F(1,40) = 14.27, p = .0005$], confirming that the congruency effect was substantially smaller in Experiment 2 than in Experiment 1. Planned comparisons

showed that this difference in congruency effect magnitude was significant at both the 0-msec [$F(1,40) = 4.6, p = .038$] and 100-msec [$F(1,40) = 18.87, p = .0002$] SOAs, but not at the 900-msec SOA [$F(1,40) = 1.70, p = .20$]. Thus, this analysis shows that the change in event probabilities between Experiments 1 and 2 significantly altered the magnitude of the congruency effect induced by gaze at the 0- and 100-msec SOAs, with the predicted smaller congruency effects at these SOAs occurring in Experiment 2. However, by 900 msec after presentation of the gaze cue, the congruency effect induced by gaze was significantly reduced in both experiments, and even reversed in sign in Experiment 2, when participants could develop the expectancy that the target response was most likely to be incongruent with the direction of gaze.

Discussion

In Experiment 2, we investigated the time course of the effect of counterpredictive gaze cues on the dynamics of overt orienting over the same time range as in Experiment 1. This investigation was operationalized by having congruency on only 20% of the trials, meaning that the gaze cues were counterpredictive of the target's true location. Even under these conditions, saccade latencies were still shorter on congruent trials than on incongruent trials at short SOAs (0 and 100 msec). In terms of saccade errors, participants made more errors on incongruent than on congruent trials at the shortest SOA (0 msec). Although the pattern of errors was similar at the 100-msec SOA, there the difference was not significant. Together, these results demonstrate that the eye gaze cues could not be ignored, even when observers were encouraged to do so. At the longest SOA (900 msec), this effect disappeared and error rates were somewhat greater on congruent rather than incongruent trials, thus demonstrating a crossover effect. This pattern of results is strong evidence for the
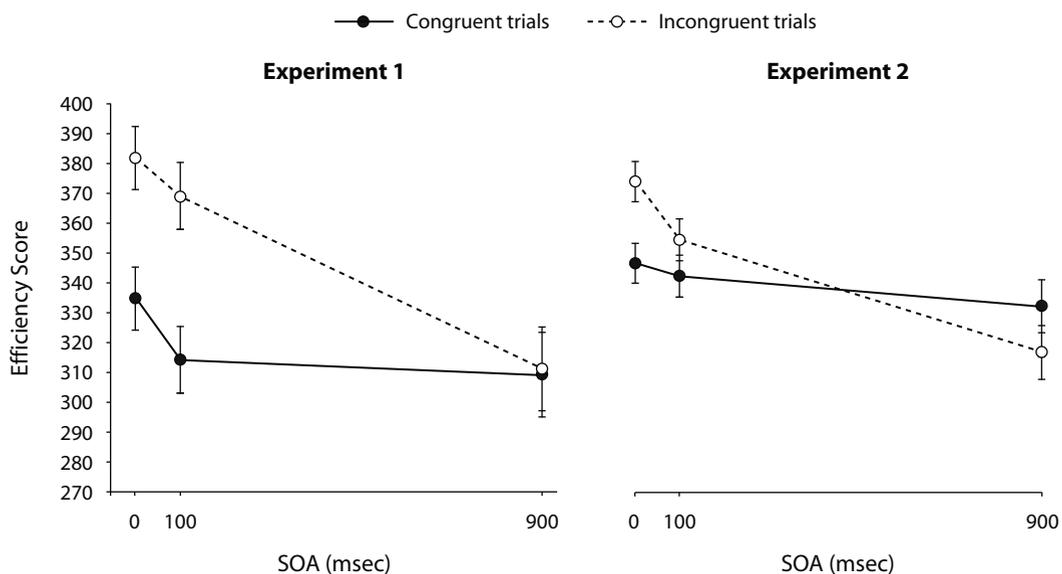

Figure 4. Efficiency scores for Experiments 1 and 2. These scores were calculated by dividing the mean RT by the proportion of correct responses for a given condition.

automatic nature of the interference effect of gaze cues on volitional saccades. This claim can be further supported by the analysis of error saccades. Directional error saccades exhibited shorter latencies on incongruent trials than did correct saccades, but only at the two shortest SOAs (0 and 100 msec). However, as in Experiment 1, the gaze cue did not affect participants' oculomotor responses prior to the saccade instruction, thus suggesting that gaze cues interfered with the planning or execution of the saccade. These findings replicate those from the corresponding analysis in Experiment 1, and as such strengthen our argument that eye gaze automatically interferes with volitional saccades at short SOAs. However, the frequency manipulation significantly reduced the magnitude of the cuing effect, thus demonstrating that this effect is not immune to top-down control.

Ricciardelli et al. (2002) claimed that gaze-following is unique to biologically relevant stimuli by demonstrating that whereas both eye gaze distractors and symbolic arrow cues have similar effects on participants' saccade latencies, only eye gaze distractors elicit saccade errors. However, in a recent, more controlled study using arrow as well as gaze distractors, Kuhn and Benson (2007) showed that both types were equivalent in their abilities to interfere with volitional saccades, thus undermining the claim that gaze distractors are more biologically relevant. However, Kuhn and Benson also provided some evidence that the error saccades elicited by eye gaze cues were more reflexive than those elicited by arrow cues. In the eye gaze condition, error latencies were significantly shorter than correct latencies on incongruent trials, thus demonstrating their reflexive nature. However, no such difference was found in the arrow condition, suggesting that eye gaze distractors may elicit errors more reflexively than do arrow distractors. These results concur with those from a study by Friesen et al. (2004), who used counterpredictive cues to examine covert reflexive and volitional orienting to eyes and arrows. These authors showed that although both eye gaze and arrow cues can lead to either reflexive or volitional orienting of covert attention (see also Ristic et al., 2002), only eye gaze cues elicited reflexive gaze shifts in the cued direction, thus suggesting that orienting in response to gaze cues may be harder to ignore than in response to arrow cues, and thus may be more reflexive.

In light of this evidence, it seems imperative to investigate whether the reflexive shift in overt attention demonstrated in the previous experiments is unique to biologically relevant directional cues, such as eye gaze, or also applies to more symbolic, nonbiological cues, such as arrows.

EXPERIMENT 3

The aim of Experiment 3 was to test whether automatic gaze-following occurs for both eyes and arrow cues, or just for eyes. Experiment 3 was identical to Experiment 2, with two exceptions. To investigate whether reflexive orienting is unique to biologically relevant stimuli, we compared gaze and arrow cues in their abilities to elicit interference effects. Both cue types were closely matched in terms of appearance and salience and were modeled on those in the Kuhn and Benson (2007) study. Moreover, to gain statistical power, we only used the SOA at which the largest and most reliable cuing effects were found, in terms of both saccade latencies and errors—namely, the 0-msec condition.

Method

Participants. A total of 28 undergraduate students (15 female, 13 male), none of whom participated in any of the other experiments, were paid £5 apiece to participate in the study. All had normal or corrected-to-normal vision and were naive to the purpose of the experiment.

Materials and Procedure. The stimuli used in Experiment 3 were identical to those in Experiment 2, with the exception that an additional condition was created in which the directional eye gaze was replaced by a directional arrow. For this condition, the face was replaced with a horizontal line (3.8º in length; see Figure 1). The fixation point was positioned at the center of the line, and arrow heads appeared at either end. As in Experiment 2, 80% of the trials were incongruent and 20% were congruent. The trials were blocked according to cue type, and each block contained 200 trials.

The procedure was identical to that of Experiment 2, and the block order and directional instructions were counterbalanced across participants.

Results

Trials on which tracker loss occurred or on which participants failed to move their eyes accounted for 0.2% of the data and were excluded from the analysis. Saccade latencies below 80 msec or above 550 msec were classified as outliers and were also removed prior to analysis (2.51% of trials).

Saccade latencies. Figure 2 shows the mean correct latencies for saccades on congruent and incongruent trials for both distractor types. An ANOVA on saccade latencies with trial type (congruent vs. incongruent) and distractor type (eye vs. arrow) as within-subjects factors found a significant main effect of trial type [$F(1,27) = 14.1$, $p = .001$] and a marginal interaction [$F(1,27) = 4.14, p = .052$]. Saccade latencies on congruent trials were significantly faster than those on incongruent trials in the eye gaze [$t(27) = 2.44$, $p = .022$] and arrow [$t(27) = 3.83$, $p = .001$] conditions. Rather surprisingly, the cuing effect was slightly larger for arrows ($M = 10.9$ msec) than for eye gaze cues ($M = 5.5$ msec). There was, however, no significant main effect of distractor type [$F(1,27) = 1.86$, $p = .184$].

Saccade errors. Saccade errors were analyzed in the same way as in Experiments 1 and 2. Figure 3 shows the percentages of errors made on congruent and incongruent trials for both eye gaze and arrow distractors. A two-way ANOVA with distractor type (eye vs. arrow) and trial type (congruent vs. incongruent) as factors found a significant main effect of trial type [$F(1,27) = 6.28, p = .018$]. Participants made significantly more errors on incongruent than on congruent trials, in both the eye gaze [$t(27) = 2.24$, $p = .033$] and arrow [$t(27) = 2.50$, $p = .019$] conditions. Neither the main effect of distractor type [$F(1,27) = 2.00$, $p = .17$] nor its interaction with trial type [$F(1,27) < 1$] reached significance.

Reflexive nature of saccades. Table 1 shows the mean latencies for correct and incorrect saccades on incongruent and congruent trials. For saccade RTs on incongruent trials, an ANOVA with saccade type (correct vs. incorrect) and distractor type (eyes vs. arrows) as within-subjects factors found a significant main effect of saccade type [$F(1,27) = 70.2, p < .0001$], demonstrating that, overall, error saccades were significantly faster than correct saccades. There was no significant main effect of distractor type [$F(1,27) = 1.56, p = .22$], nor was its interaction with saccade type significant [$F(1,27) = 1.21, p = .28$]. Thus, no evidence suggests that the error saccades elicited by eye gaze cues were more reflexive than those for arrow cues.

On congruent trials, the same analysis revealed no significant main effects of saccade type [$F(1,27) = 1.28, p = .28$] or distractor type [$F(1,27) = 3.39, p = .089$], nor a significant interaction [$F(1,27) = 2.13, p = .17$]. In fact, latencies were somewhat shorter overall for correct saccades ($M = 313.0$) than for error saccades ($M = 322.8$ msec), which is again consistent with our general finding that both eyes and arrows reflexively activate an oculomotor response.

Discussion

The aim of Experiment 3 was to investigate whether the cuing effects previously found with eye gaze cues are unique to biologically relevant stimuli, or whether a more general mechanism is applicable to both forms of symbolic cue. Our results show that even when participants were encouraged to move their eyes in the direction opposite where the eye gaze pointed, saccade latencies on congruent target trials (which were relatively improbable) were still shorter than those on incongruent target trials (probable), and directional saccade errors were also more frequent on the latter trial type, indicating automatic cue-following. Moreover, as in the previous experiments, on incongruent trials latencies were significantly shorter for error than for correct saccades, thus further suggesting the reflexive nature of this effect. No differences between eye and arrow cues, however, were observable for any of these effects, which does not support the notion that eye gaze cues lead to more reflexive shifts in overt attention than do arrow cues.

GENERAL DISCUSSION

In a series of three experiments, we investigated whether gaze cues produce automatic shifts in overt attention and whether these shifts are specific to biologically relevant cues. In Experiment 1, participants were instructed to make voluntary saccades to a target on either the left or the right of fixation. These volitional saccades could be either in the same direction as a centrally presented distractor gaze (congruent) or in the opposite direction (incongruent). The distractor gaze was nonpredictive of the saccade response, yet saccade latencies were significantly faster on congruent than on incongruent trials. In addition, a greater number of saccade errors were made on incongruent than on congruent trials. These results concur with previous findings demonstrating that nonpredictive (task-irrelevant) gaze

cues interfere with volitional saccades (Kuhn & Benson, 2007; Ricciardelli et al., 2002) and add to a growing body of evidence suggesting that eye gaze leads to reflexive orienting of both overt (Deaner & Platt, 2003; Koval, Thomas, & Everling, 2005; Nummenmaa & Hietanen, 2006) and covert (see, e.g., Driver et al., 1999; Friesen & Kingstone, 1998) attention. Our results also demonstrate that on a significant proportion of trials, participants moved their eyes in the direction the distractor eyes were looking, even when saccades in the opposite direction were required. This finding suggests that gaze-following occurs automatically, and it is further supported by the finding that error saccades were significantly faster than correct, volitional saccades. However, the distractor gaze only interfered with participants' covert attention when a saccade was being initiated. Prior to execution of the saccade, the distractor gaze had little effect on overt attention.

The main aim of Experiment 1 was to investigate the time course of the gaze cue interference. Three gaze–fixation-cue SOAs were used (0, 100, and 900 msec). The gaze cue only affected saccade latencies at the two shortest SOAs, thus suggesting that the facilitation elicited by gaze cues is short lived. However, the same pattern of directional errors was found at all three SOAs, suggesting that the interference effect is much longer lived than has previously been thought (Ricciardelli et al., 2002). However, a reduction in the interference as SOA increased suggests that the strength of the cue's effect decreases over time.

When peripheral cues are used to orient attention, the initial facilitatory effect of the cue usually turns to IOR at longer SOAs. Traditionally, IOR has been taken as one of the hallmarks of reflexive attentional orienting, because it reliably emerges at SOAs of around 500 msec (Posner & Cohen, 1984). Until recently, it was thought that gaze cues are unique, in that they result in reflexive orienting of attention in the absence of IOR. Facilitation effects in response to gaze cues are usually maintained across intervals of up to 700 msec and decay around 1,000–1,500 msec (see, e.g., Friesen & Kingstone, 1998). Although it may be difficult to directly compare studies using gaze-cue–stimulus SOAs with the present study using gaze-cue–direction-cue SOAs, all of the former studies suggest that the facilitation effects from eye gaze cues are long lasting, and thus concur with our results. It has recently been shown that if attention is drawn away from the gazed-at location, inhibitory processes are observed at long stimulus–target SOAs (Frischen, Smilek, et al., 2007). However, this effect occurs around 2.4 sec, and is therefore well beyond the maximum duration used in the present experiment.

To what extent did participants employ truly automatic gaze-following? Even peripheral cues such as onsets of new objects, which have traditionally been viewed as resulting in automatic attentional capture, are influenced by volitional control (Folk, Remington, & Johnston, 1992). The nature of this volitional control can be very subtle, and participants are often unaware of its influence. For example, the propensity for onset cues to capture people's attention increases as the similarity of the target and cue increases, which is referred to as *attentional control setting* (Folk et al., 1992). One way to demonstrate automa-

ticity in a strong sense is to show that spatial orienting occurs in one direction, despite participants' attempts to control volitional orienting by deploying it elsewhere (see, e.g., Driver et al., 1999).

Experiment 2 adopted precisely this approach: The direction of a central eye gaze stimulus was counterpredictive of the direction of a targeted volitional saccade. The time course of a counterpredictive gaze cue on voluntary saccades was examined in order to determine the dynamics of this relationship. Congruency was manipulated by instructing participants to move their eyes in the direction opposite the one indicated by the gaze stimulus on 80% of the trials. Even under these conditions, interference effects on saccade latencies were found at both of the two shortest distractor–fixation-cue SOAs (0 and 100 msec). In terms of saccade errors, a significant interference effect was found at the 0-msec SOA but failed to reach significance at the 100-msec SOA. At the longest SOA (900 msec), we found a reversal of this effect, suggesting that interference from a gaze cue can be overcome with sufficient time. As in Experiment 1, saccade latencies were shorter for these erroneous saccades than for correct saccades. However, there was a crucial difference between the two experiments, in that faster saccades only occurred for directional errors at the two shortest SOAs, thus further demonstrating the reflexive nature of these saccades. Taken together, the results demonstrate that overt attentional orienting in response to eye gaze is automatic, in line with the findings reported in other studies of covert attentional orienting (Driver et al., 1999; Friesen et al., 2004; Senju, Tojo, Dairoku, & Hasegawa, 2004; Tipples, 2008). However, we should note that the alteration in cue predictability significantly reduced the magnitude of the cuing effect at our two shortest SOAs. These results thus demonstrate that although the cuing effects are reflexive, the magnitude of the effect is influenced by participants' volitional control.

Via changing the spatial validity of the eye gaze cue, the previously spatially uninformative cue now becomes informative. Since the cue now carries strategic value, participants may choose to attend to the gaze, rather than ignoring it. Indeed, when participants had sufficient time between the change in eye gaze and the saccade instruction (at the 900-msec SOA), they utilized the predictability of the eye cues. One could suggest that, by actively inhibiting participants' tendency to move their eyes to the gazed-at location, this controlled orienting slowed down the overall RTs and reduced the overall errors. However, contrary to this prediction, participants' RTs in Experiment 2 ($M = 323$, $SE = 6.56$) were not significantly slower than those in Experiment 1 ($M = 316$, $SE = 10.4$) [$F(1,40) < 1$], and error rates also did not vary between experiments (Experiment 1, $M = 5.66$, $SE = 1.22$; Experiment 2, $M = 5.79$, $SE = 0.77$) [$F(1,40) < 40$], indicating that the additional information did not result in any overall cost.

Evidence from both neurological and behavioral studies has suggested that attentional orienting in response to eye gaze cues is qualitatively different from the orienting resulting from symbolic cues, such as arrows. For example, by examining a split-brain patient, Kingstone, Friesen, and Gazzaniga (2000) showed that reflexive orienting to eye gaze was lateralized to the right hemisphere, whereas no such effect was found using arrows (Ristic et al., 2002). This finding suggests that orienting in response to these different stimulus types is subserved by different brain areas. Further support for this hypothesis comes from recent neuroimaging studies showing that shifts of attention triggered by either gaze or biologically irrelevant arrow cues relied on different neurological structures (Hietanen et al., 2006), or at least engaged the same areas differentially (Tipper et al., 2008). In particular, researchers have claimed that attentional orienting in response to symbolic arrows involves cortical areas that are typically associated with voluntary shifts of attention. Behaviorally nonpredictive arrow and gaze cues have been shown to have similar effects on covert attentional orienting (Tipples, 2002).

However, different results have been obtained with counterpredictive cues. Friesen et al. (2004) examined the reflexive nature of attentional orienting to eyes and to arrows with a novel design in which performance to both the cued and the predicted target locations was compared with a performance baseline to locations that were neither cued nor predicted. Their results showed that attentional shifts in response to arrow cues only occurred volitionally to the predicted location, not to the cued, nonpredicted location. Gaze cues, on the other hand, resulted in shifts of attention to the cued location even when this location was not predicted, thus suggesting that reflexive orienting in response to gaze cues is more strongly reflexive than orienting by arrow cues. Moreover, Kuhn and Benson (2007) provided some evidence to suggest that error saccades elicited by eye gaze distractors are more reflexive than those elicited by arrow distractors. The aim of Experiment 3 was to further investigate whether eye gaze cues result in more reflexive attentional orienting than do arrow cues.

Contrary to Friesen et al.'s (2004) finding for covert attention, we showed that both counterpredictive eye gaze and arrow cues produced the same reflexive shifts in overt attention. Interference effects were inferred on the basis of both saccade latencies and errors and were found to be the same for both types of distractors. In fact, contrary to any preferential bias for greater reflexive orienting to eye stimuli, the arrow effects were slightly (but nonsignificantly) larger than those found for eye gazes. Moreover, with regard to the reflexive nature of the error saccades, no difference was found between the errors elicited by arrow and gaze stimuli, a finding that conflicts with the previous findings of Kuhn and Benson (2007). In this previous report, the analysis of the latencies of error saccades was post hoc and relied on a much smaller sample than did the present experiment ($n = 9$ vs. $n = 28$). The interpretation that error saccades are more reflexive when elicited by gaze rather than arrow cues may therefore be premature; at least in terms of overt attentional orienting, our results challenge the suggestion that attentional orienting by gaze cues is more reflexive than orienting due to symbolic cues (Friesen et al., 2004; Ristic et al., 2007; but see Tipples, 2008). This point is most important, because it undermines the view that gaze-following is unique to biologically relevant stimuli (but see Kuhn &

Benson, 2007) and coincides with the findings of Hommel et al. (2001), who were the first to challenge the view that covert attentional orienting in response to gaze cues is unique (see also Ristic et al., 2002; Tipples, 2002, and 2008, Experiment 3).

In keeping with the methods used by other researchers (e.g., Friesen & Kingstone, 1998; Friesen et al., 2004; Hietanen et al., 2006), we used schematic gazes rather than images of real faces. This was done primarily to ensure that we could match the arrow and eye gaze cues on some of their lower-level features. This does, however, raise the question of whether these results would generalize to more realistic-looking faces. Hietanen and Leppänen (2003) directly compared the cuing effects elicited by schematic and real faces showing various emotional expressions. Their results showed that cuing effects were not modulated by the facial expression but that larger cuing effects were associated with schematic rather than real faces. It therefore seems unlikely that we would have found a different pattern of results using real rather than schematic faces. Moreover, several of the studies that have demonstrated qualitative differences between eye gaze and symbolic attentional orienting have also used schematic faces (Friesen et al., 2004; Hietanen et al., 2006; Kuhn & Benson, 2007), which suggests that symbolic faces may be processed differently than symbolic arrow cues, and thus may be more biologically relevant than arrows.

It is conceivable that an innate "eye direction detector" enables people to detect the direction of another person's gaze (Baron-Cohen, 1995). Such a detector could be used to orient spatial attention from an early age. The idea that we are born with an equivalent "arrow direction detector," on the other hand, is less likely, and attentional orienting by arrow cues may well be acquired through experience. Young infants would have less experience than adults with arrows, suggesting that nonpredictive gaze cues should have greater effects on children's attention than biologically irrelevant stimuli such as arrows. Surprisingly, Ristic et al. (2002) showed that both nonpredictive gaze cues and arrow cues produced orienting effects in preschool children (3–5 years) and that these effects were indistinguishable from each other.

Recent research, including the present study, has demonstrated that nonpredictive cues lead to reflexive shifts in attention. Moreover, the magnitude of the orienting effects are similar, irrespective of whether the cue comprises a biologically relevant stimulus. All of these studies have involved the presentation of stimuli in relatively impoverished displays, in which the only stimulus feature to change across trials is the directional cue. In the real world, we are rarely presented with such simple displays. In most real-world situations, directional cues are embedded in some context, and the motivation for selecting and responding to these cues depends greatly on the context in which they occur. Our results show that saccades tend to follow both gaze cues and arrow cues, even when participants are encouraged to move their eyes in the opposite direction. This suggests that cue-following occurs independent of participants' motivation and intention. However, it remains to be seen whether this behavior can be generalized to the real

world. Studying attentional orienting in response to eye gaze has already brought researchers some way toward understanding spatial attention in the real world. However, the displays used in such studies are still a long way from the types of situations faced in the real world (see Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003; Kuhn & Land, 2006; Kuhn & Tatler, 2005). Thus, although arrows and eye gazes may be of equal relevance when they are presented to the participant in isolation, key differences between social and nonsocial cues may only become apparent when they are embedded within a richer environment. In these richer contexts, attention must select some stimuli for further processing and discard others. It may be that when this selection process occurs, key differences do occur between stimuli that are and are not biologically relevant (Birmingham, Bischof, & Kingstone, 2008a, 2008b). In other words, one might discover that participants prefer to look at eyes rather than arrows when they are provided with the opportunity to make that selection. However, in most lab-based studies this opportunity is not provided, and participants are essentially "force-fed" one stimulus or another. In such situations, it appears that any differences between eyes and arrows on attentional orienting are very minor indeed, if they exist at all.

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NOTES

1. Errors on congruent trials were rare, and since only 6 participants made errors in each of the three SOA conditio)ns, these results need to be treated with some care.

2. Errors on congruent trials were rare, and only 9 participants made errors in all three SOA conditions. These results therefore must also be treated with caution.