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How Attentional Systems Process Conflicting Cues. The Superiority of Social Over Symbolic Orienting Revisited

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We investigated orienting of attention by social and symbolic cues presented inside/outside the locus of attention. Participants responded to laterally presented targets preceded by simultaneously presented gaze and arrow cues. Participants' attention was allocated to either of the cues and the other cue served as a distractor. In Experiments 1–4 nonpredictive cues were employed. The validity of the attended cue and distractor were varied orthogonally. Valid cues and distractors produced additive facilitation to reaction times when compared to invalid cues and distractors. The effects of gaze and arrow distractors were similar. When the cue was 100% valid and the distractor 50% valid (Experiment 5), distractor validity had no effect on reaction times. When realistic gaze and arrow cues were employed (Experiment 6), arrow but not gaze distractors influenced the reaction times. The results suggest that social and symbolic directional information can be integrated for attention orienting. The processing of social and symbolic directional information can be modulated by top-down control, but the efficiency of the control depends on the visual saliency of the cues.

Keywords: gaze, attention, orienting, cueing

Our environment is crowded with objects that potentially need further scrutiny, and on many occasions attending to the task-relevant features of the environment is an essential prerequisite for effective functioning. Hence, people use various directional cues to orient other individuals' attention to important events in the world. These directional cues can be symbolic, such as pointing arrows or words with directional meaning, as well as social, such as gaze direction, head orientation, and pointing gestures. However, not all the directional cues surrounding us are relevant to the tasks we are currently performing. For example, while driving downtown, a traffic sign of a crosswalk should cue our attention to the possible pedestrians ahead of us, whereas the gaze direction of a fashion model in a roadside advertisement provides no relevant information for the driving task. Nevertheless, both these cues can be perceived simultaneously, but attention should be oriented only according to the traffic sign.

But does the directional information mediated by the gaze of the model in the advertisement interfere with attentional orienting to the traffic sign? Interestingly, both centrally presented social (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999; Langton & Bruce, 1999) and symbolic (Hommel, Pratt, Colzato, & Godijn, 2001; Ristic, Friesen, & Kingstone, 2002; Tipples, 2002) directional cues have been demonstrated to trigger what seems to be reflexive orienting of spatial attention to the cued location. These findings prompt one to ask what would happen if social and symbolic cues indicate opposite directions—would the attentional systems prioritize the processing of either of the cues? In the present studies we investigate how the perceptual and attentional systems process competing, simultaneously presented gaze and arrow cues in a situation where only one of the cues (gaze or arrow) is task-relevant and deliberately attended to. Our paradigm will enable us to investigate the (a) perceptual and attentional interference of the social and symbolic cues, and (b) the automaticity of processing of these two types of cues. For example, if the gaze cues trigger more reflexive shifts of attention, as has been suggested (see below), we should find the gaze cues resulting in more interference as compared to the arrow cues.

Attentional Effects of Eye Gaze and Learned Symbols: Are There Reliable Differences?

Directional information mediated by the eyes has a special role in the orienting of spatial attention as eyes are both an important medium for conveying social information (Emery, 2000; Kleinke, 1986) and also an overt manifestation of the locus of other individuals' visual attention (Findlay & Gilchrist, 2003). Given this importance, it comes as no surprise that recent neuroimaging studies have revealed that specialized brain networks, mainly in the superior temporal sulcus and intraparietal sulcus, are involved in encoding of gaze direction (Calder et al., 2007; George, Driver, & Dolan, 2001; Hoffman & Haxby, 2000; Hooker et al., 2003; Pelphrey, Singerman, Allison, & McCarthy, 2003; Pelphrey, Viola, & McCarthy, 2004). As noted above, it has also been shown that perceiving another person's averted gaze orients perceiver's attention reflexively to the direction of the gaze. This conclusion is

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based on studies showing that participants respond more quickly to targets presented at the location where a centrally presented face was previously gazing at than to targets the face was not gazing at (Driver et al., 1999; Friesen & Kingstone, 1998; Friesen, Moore, & Kingstone, 2005; Hietanen, 1999; Hietanen & Leppänen, 2003; Langton & Bruce, 1999). This gaze-cued orienting is argued to be reflexive in nature for two reasons: First, the reaction time (RT) benefits can occur when the time interval between the presentation of the gaze cue and target is short (e.g., 100 ms) and, second, the cueing effect occurs even when the participants know that the gaze cues are nonpredictive or even counterpredictive (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004).

Though symbolic directional cues such as arrows were for a long time considered as capable of triggering only volitional shifts of attention (Jonides, 1981; Müller & Rabbitt, 1989), recent studies have demonstrated that biologically irrelevant but widely used symbols with learned directional meaning such as arrows (Hommel et al., 2001; Experiments 1a–4a; Ristic et al., 2002; Tipples, 2002) and directional words ("left" and "right"; Hommel et al., 2001; Experiments 1b–4b) may also result in reflexive shifts of covert spatial attention. However, there seem to be three important differences between orienting of attention by social versus symbolic cues. First, both nonpredictive and counterpredictive gaze cues trigger attention reflexively to the gazed-at location, whereas recent evidence suggests that counterpredictive arrow cues do not cause reflexive shifts of visual attention (Friesen et al., 2004, but see Hommel et al., 2001 for conflicting results for counterpredictive arrows). Thus, Friesen et al. interpreted these findings as suggesting that orienting of attention by gaze is "more reflexive," i.e., less susceptible to top-down control of attention orienting (cf. attentional control setting). Second, it has been argued that gaze direction cues result in both facilitatory and inhibitory attentional effects, whereas arrow cues result in inhibition-less, nonattentional priming effects (Langdon & Smith, 2005; see Posner, Nissen, & Odgen, 1978, for discussion of attended and unattended processing modes). And third, a recent neuroimaging study by Hietanen, Nummenmaa, Nyman, Parkkola, & Hämäläinen (2006) provided direct evidence that gaze- and arrow-cued attentional orienting are subserved by different neural networks. Crucially, the arrow cues activated the voluntary attention orienting network more than the gaze cues, suggesting that orienting of attention by arrows may actually be more voluntary in nature.

One of the traditional criteria for automaticity is that an automatic process should not be affected by allocating attention towards/away from the stimulus causing the reaction (Kahneman & Treisman, 1984; see also Moors & De Houwer, 2006, for a recent review). In the attentional cueing studies reviewed above the participants were typically presented with non- or counterpredictive cue stimuli at the fixation. Though in such a paradigm participants are typically instructed to ignore the cues, it can be questioned how effective this instruction actually is as (a) the cues are presented at the fixation, thus being very likely under the spotlight of attention, and (b) the cues nevertheless provide directional information, thus participants may infer that the cues might, after all, provide information about the target location, and use them accordingly. Thus, an alternative paradigm would be needed to test whether the arrow- and gaze-triggered orienting fulfill the unintentionality criterion of automatic processing.

Processing Conflicting Attentional Cues

As our attentional systems are constantly bombarded with both social and symbolic directional cues potentially interfering with attending to the goal-relevant elements in the scene, it is necessary to maintain attentional control over orienting by different directional cues. Dual-process theories of attention (see Barrett, Tugade, & Engle, 2004; Corbetta & Shulman, 2002; Egeth & Yantis, 1997) distinguish between goal-driven (voluntary) and stimulus-driven (reflexive) mechanisms of attention orienting. When participants are presented with highly predictive central arrow cues and nonpredictive peripheral abrupt onset cues, the peripheral cues interfere with orienting by the arrow cues (Thomsen, Specht, Ersland, & Hugdahl, 2005) even when the peripheral cues are presented 500 ms after the arrow cues (Berger, Henik, & Rafal, 2005). This has been explained by the notion that the peripheral cues engage the automatic attention orienting system which, in turn, dominates over the voluntary orienting by the predictive arrows. Even when participants are told that the arrow cues are highly predictive and will benefit their performance on the task, the peripheral cues (or distractors) interfere with the orienting by the arrow cues (Müller & Rabbitt, 1989). Nevertheless, the reflexive and voluntary systems can be active at the same time. Müller and Rabbitt noted that participants' performance was best (i.e., they made least errors in a target discrimination task) when the peripheral and central cues pointed at the same direction. Thus, attentional systems seem to *combine* the information provided by these two cue types and the attention is oriented by the summated attentional effects set off by the cues. However, the information conveyed by the peripheral cue is weighted more, at least in the early stages of processing.

Though orienting of attention by abrupt luminance onset cues is on many occasions highly automatic (Jonides, 1981; Müller & Rabbitt, 1989; Posner, 1980), attentional control setting can exert an influence on the reflexive attention orienting system (Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994). Under certain conditions, peripheral luminosity onsets orient attention reflexively only when they are consistent with task goals, that is, when they share a task-relevant feature, such as color, with the target demanding a response. Thus, Folk et al. have suggested that the reflexive attention orienting system can be configured to respond only to a certain subset of stimulus properties that are relevant to the currently performed task.

Similarly, attentional control settings can modulate orienting by centrally presented symbolic cues. Pratt and Hommel (2003) employed a spatial cueing paradigm in which the target was preceded by four arrows pointing to different peripheral locations in which the target could be presented. One of the arrows matched with a previously defined task-relevant feature (color) of the target. Faster RTs were observed when the target occurred at a location that was cued by an arrow with matching task-relevant feature than when the target appeared at other locations, suggesting that the potency for symbols to influence attentional orienting depends on their task-relevancy. In similar fashion, Gibson and Bryant (2005) tested whether voluntary control processes can influence orienting by symbols. They employed a simple cue discrimination manipulation (i.e., respond only to predefined cue shapes) in a standard endogenous cueing task. The results showed that when compared to "no discrimination" condition, the cue discrimination task increased the magnitude of the cueing effect, especially at short (50 ms) stimulus onset asynchrony (SOA). Together these findings thus suggest that both reflexive and voluntary attention orienting mechanisms are adaptive, in the sense that they do not function in simplistic and deterministic manner, but instead are influenced by environmental and task demands.

Against this background, an interesting issue is how the attentional systems solve the potential conflict resulting from two *centrally presented* attentional cues (eye gaze and arrow) that are presumed to engage two different attention orienting systems. Faces are known to attract attention reflexively (Langton, Law, Burton, & Schweinberger, 2008; Theeuwes & Van der Stigchel, 2006) and as discussed above, the averted gaze of a face is a highly salient social signal that directs attention reflexively. Thus, if we return to our initial example of driving a car downtown, it could be hypothesized that it would be difficult or even impossible to maintain attentional control setting for orienting only by task-relevant traffic signs when faces and gaze direction cues are present in street-side advertisements. Instead, while having a discussion with a friend standing at a crossroads, maintaining attentional set for orienting by the eye gaze direction of our friend but not to the traffic signs would be much easier. Consequently, manipulation of participants' attentional control setting towards or away from faces/arrows can provide us with an interesting paradigm to compare the attentional effects of eye gaze and arrow cues. A robust way to test whether there is a difference in the automaticity of orienting triggered by gaze and arrow cues would be to present these two types of cues simultaneously, define only one of them as task-relevant (i.e., define attentional control setting for that particular cue), and assess the attentional effects set off by attended, task-relevant, and unattended, task-irrelevant cues.

The Current Study

The current study aimed at making a contribution to the literature by assessing how attended and unattended social and symbolic cues are processed for orienting of visual attention. To this end, our study involved three methodological advances. First, participants were presented with combined gaze and arrow cues followed by a laterally presented target that participants had to detect. Second, we employed an attentional control setting manipulation. The participants were instructed to attend only to one of the cues (hereafter simply referred to as cue) while the unattended cue served as a distractor. It has been shown (Gibson & Bryant, 2005) that asking participants to perform perceptual discrimination tasks for the cue will facilitate the processing of and subsequent orienting of attention by centrally presented cues. Thus, a load task related to the physical characteristics of the cue was employed to ensure that the participants were attending to the stimulus as instructed. Third, in Experiments 1–4, the cues and distractors were nonpredictive (and both the cue and the distractor could be either congruent or incongruent with respect to the location of the target stimulus), whereas in Experiments 5–6 the cues were always 100% valid while the distractors were nonpredictive.

We were especially interested in whether the distractor effects resulting from the unattended gaze and arrow cues were similar. We hypothesized that if only orienting of attention by eye gaze is truly automatic as it has been suggested (Friesen et al., 2004; Ristic & Kingstone, 2005), we should observe an interaction between the attended cue type and distractor validity. That is, the gaze distractors should exert greater influence on orienting of attention than the arrow distractors. On the contrary, if attentional orienting by gaze and arrow is equally automatic, we should observe only a main effect of the distractor validity or, in the case that the distractors can be completely suppressed, no effect of distractor validity at all.

Experiment 1

In Experiment 1 we examined whether unattended gaze and arrow cues exert an influence on covert orienting of attention by using a central cueing paradigm with a localization task. On each trial, participants were presented with combined gaze and arrow cues at fixation. Depending on the experimental block, they were given the instruction to attend only to the gaze (attend-to-gaze condition) or the arrow (attend-to-arrow condition) cues, and the unattended directional cue served as a distractor. Presentation of the cues was followed by a laterally presented target with SOA of 200 ms or 600 ms. Independently of each other, the cue and the distractor could be either valid or invalid with respect to the target. To validate that we get the traditional reflexive gaze- and arrow-cueing effects with the present experimental setup, the aforementioned trial types were intermixed with "no distractor" trials in which only the attended cue was presented. These were analyzed separately from the rest of the trials, as they did not include any distractor and, consequently, were not comparable with such trials. A similar approach was used also in Experiments 2–4.

Participants

Fifteen graduate and undergraduate students (6 men, 9 women; mean age 28 years) with normal or corrected-to-normal vision volunteered to participate in the experiment.

Apparatus

Stimuli were presented on a 17-inch monitor with a 1-GHz Pentium 2 computer. The E-prime software controlled stimulus presentation and response acquisition. Participants sat on a comfortable chair with their head position stabilized on a chin rest located at a distance of 52 cm from the screen.

Stimuli

The stimuli (see Figure 1) consisted of a fixation point, a face display, an arrow display with head and tail, and an asterisk (the target stimulus to be detected). The fixation point was a central cross subtending 0.5°. The face display consisted of a black line drawing of a round schematic face subtending 8.5° and centered in the middle of the screen. The eyes subtending 1.3° were located on the central horizontal axis at the distance of 2° from the central vertical axis. Black-filled circles inside the eyes represented pupils. They subtended 0.7°, were centered vertically to the eyes, and were just touching right or left of the eyes. For the attend-to-gaze catch trials (see below), the pupils were filled with white. The arrow stimulus subtended horizontally 1.6°, vertically 1.3° and was centered on the screen. For the attend-to-arrow catch trials, the arrow stimulus was filled with white. The target stimulus to be

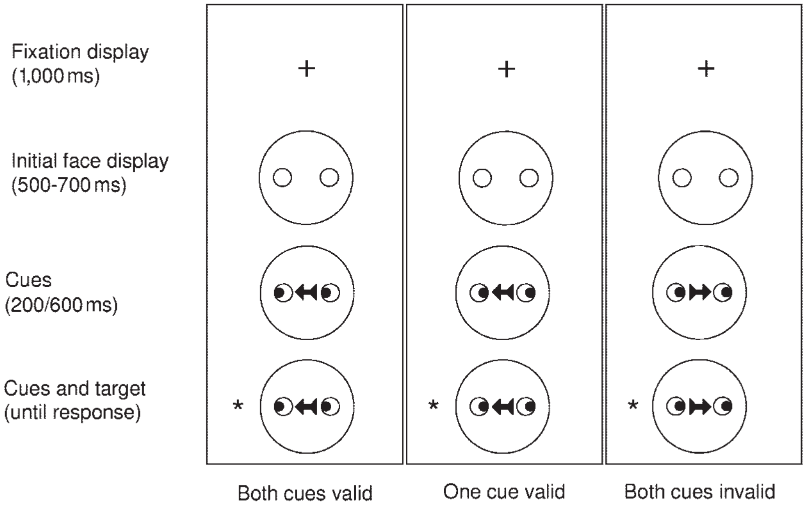

Figure 1. Illustration of stimuli and examples of trials with two, one, and no valid cues in Experiment 1. Depending on the experimental condition, either the gaze or the arrow cue served as a distractor.

responded to was an asterisk subtending 0.5° presented 6° to the left or right of the center of the screen.

Design

The experimental design involved four within-subjects factors: Attended cue type (gaze vs. arrow), Cue validity (valid vs. invalid), Distractor validity (valid vs. no distractor vs. invalid), and SOA (200 ms vs. 600 ms). On validly cued trials, the target appeared to the same side as the attended cue was pointing to and on invalidly cued trials it appeared to the opposite side. Similarly, the distractor could point either to the same or the opposite side where the target would appear. In no-distractor trials, the distractor (i.e., pupils or arrow) was simply not presented. The dependent measure was the participants' manual RT to the target. We used catch trials (17% of total trial count) to ensure that participants allocated attention only to the desired stimulus property, that is, the pupils or the arrow. In these trials, the attended cue appeared filled with white instead of black and no response was to be made.

Procedure

Participants were tested in groups of one to three, and testing time totaled approximately 35 min per participant. Upon arriving to the laboratory, participants gave an informed consent and were explained that the study concerned visual perception. Participants were seated in front of the monitor in a cubicle and given instructions on how to perform the experimental trials. They were instructed to fixate at the center of the screen throughout the trials, respond as fast and accurately as possible, pay careful attention to the attended cues, and respond only on trials when the cue was black. It was also stressed to the participants that neither the cue nor the distractor predicted the location of the target.

On each trial (see Figure 1) the fixation cross appeared at the center of the screen. After 1,000 ms, the initial face display without the pupils was presented for a random time between 500–700 ms. Next, the cue and distractor stimuli (pupils/arrow) were presented, and after 200 or 600 ms the target stimulus appeared to the left or to the right of the face display. Participants responded by pressing the left response pad button (using left index finger) for a target on the left or the right button (using the right index finger) for a target on the right. On catch trials no response was required. The cue, distractor, and target remained visible until response or until 1,500 ms had elapsed.

Each participant performed 10 blocks of the experimental task. Either the first or the last half of blocks was performed with the instruction to allocate attention to the gaze stimulus and the other half with the instruction to allocate attention to the arrow stimulus, with order of tasks counterbalanced across participants. Before the first and sixth block, participants performed 12 practice trials representing the forthcoming experimental condition. Each block consisted of 58 trials (4 trials of each type + 10 catch trials) totaling 20 trials of each type in the whole experiment, and a grand total of 580 trials. On completion of all experimental blocks, participants were thanked and debriefed about the purposes of the experiment.

Results

On average, participants made errors on 3% of the catch trials (i.e., pressed the button when they should not have pressed it), suggesting that the load task was successful in orienting of participants' attention as intended. Prior to analyses, incorrect responses as well as anticipations and retardations (response times < 100 or $> 1,000$ ms) were filtered. Next, RTs 2 standard deviations (*SD*) above and below each participant's mean were excluded. These accounted for 2.5% of the trials. RT data for correct trials were treated similarly in all the subsequent experiments.

Mean RTs were computed for each condition (see Table 1). First, we analyzed the RTs for the no-distractor condition to validate that we get the cueing effect. These RTs were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures analysis of variance

Table 1
Reaction Times by Stimulus Onset Asynchrony, Cue Validity, Distractor Validity, and Attended Cue Type in Experiment 1

	200 ms				600 ms			
	Valid cue		Invalid cue		Valid cue		Invalid cue	
Distractor	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attend arrow cue								
Valid	325	38	346	41	276	25	284	31
Invalid	333	42	357	44	284	27	292	33
None	334	34	361	41	281	26	296	38
Attend gaze cue								
Valid	319	30	341	34	277	22	285	22
Invalid	337	40	353	38	291	23	291	22
None	336	35	354	31	290	24	296	21

(ANOVA). This resulted in the main effects of cue validity, $F(1, 14) = 30.41$, $p < .01$, $\eta^2 = .69$, and SOA, $F(1, 14) = 138.16$, $p < .01$, $\eta^2 = .91$, with faster RTs on validly than on invalidly cued trials (RTs 310 vs. 326 ms, respectively) and on 600-ms than on 200-ms SOA (RTs 290 vs. 346 ms, respectively). The shortening of the reaction times as a function of the SOA is a typical result reflecting the effects of several factors (e.g., arousal and subjective expectancy) on RTs after any cue event (for a review, see Niemi & Näätänen, 1981). The cue validity × SOA interaction was also significant, $F(1, 14) = 8.71$, $p = .01$, $\eta^2 = .38$. This resulted from the fact that the cueing effect ($\text{RT}_{\text{invalid}} - \text{RT}_{\text{valid}}$) was larger at the 200-ms than 600-ms SOA (22 ms vs. 11 ms).

Next, we analyzed the data for trials with the cues and distractors. The analysis, a 2 (Cue type: gaze, arrow) × 2 (Cue validity: valid, invalid) × 2 (Distractor validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA, yielded significant main effects for cue validity, $F(1, 14) = 71.11$, $p < .01$, $\eta^2 = .84$; distractor validity, $F(1, 14) = 43.29$, $p < .01$, $\eta^2 = .76$; and SOA, $F(1, 14) = 120.18$, $p < .01$, $\eta^2 = .90$ (see Figure 2). RTs were faster on validly than on invalidly cued trials (305 vs. 318 ms), on trials with valid than with invalid distractors (306 vs. 317 ms) and on trials with 600-ms SOA than on trials with 200-ms SOA (272 vs. 338 ms). Additionally, the cue validity × SOA interaction reached significance, $F(1, 14) = 17.08$, $p < .01$, $\eta^2 = .55$. This resulted from larger cueing effect at the 200-ms than 600-ms SOA (21 vs. 6 ms, respectively). No other second- or higher-order interactions proved significant.

Discussion

The results demonstrated clear cueing effects for both the cue and the distractor suggesting that the directional information mediated by the unattended (to-be-ignored) distractors reflexively exerted an influence on attentional orienting. However, contrary to our predictions the Cue type × Distractor validity interaction was not statistically significant. In other words, both gaze and arrow distractors resulted in similar attentional cueing effects and, consequently, the results did not support our hypothesis that it is easier to voluntarily suppress orienting by arrow than by gaze cues.

We found it interesting that the cueing effect was additive for cues and distractors, that is, fastest RTs were observed when both the cue and distractor validly pointed to the target and slowest when they both invalidly pointed away from the target. It should also be noted that the cueing effect ($\text{RT}_{\text{invalid}} - \text{RT}_{\text{valid}}$, pooled across SOAs) was highly similar for the cues and the distractors (13 vs. 14 ms, respectively). These findings suggest that the directional information provided by the cues and the distractors had actually been processed, and subsequently additively combined for attentional orienting. Taken together, the results seem to support the notion that the directional meaning of both arrow and gaze cues is encoded equally automatically, and that the subsequent orienting responses resulting from gaze/arrows are equally automatic as well.

Ristic and Kingstone (2005) have shown that an ambiguous figure that can be perceived as a face with averted eyes or as a car with eccentric wheels triggers automatic shifts of attention only when it is perceived as a face. This study also showed that once participants perceive the stimulus as a face, the automatic cueing

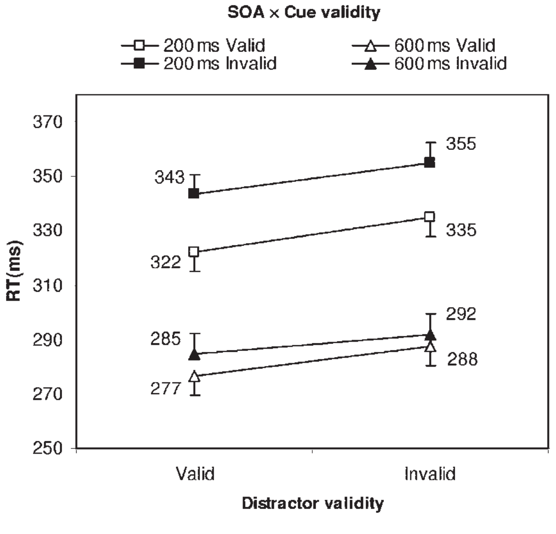

Figure 2. Mean reaction times (RT) and 95% contrast-wise confidence intervals as a function of stimulus onset asynchrony (SOA), cue validity, and distractor validity in Experiment 1.

effect carries on even if participants are actively trying to perceive the stimulus as a car. Thus, it is possible that in the current experiment, the distractor effect of the eyes would be larger for those participants who initially attended to the eyes (and tried to ignore arrows). We thus verified this by reanalyzing the data with Order (Attend to gaze first vs. Attend to arrows first) as an additional between-subjects factor. Order did not have a main effect, $F < 1$, $p = .73$, and its second- or higher-order interactions with other factors (Cue type, Cue validity, SOA) did not reach significance, $F\text{s} < 2.7$, $p\text{s} > .10$, which further supports our hypothesis regarding symmetric distractor effects for gaze vs. arrow cues.

Though the arrow and gaze distractors resulted in similar interference effects, the experimental stimulus displays contained a possible confound. The arrow cues were presented at the fixation point and the gaze cues (i.e., pupils) were located 2° from the central vertical axis. At the beginning of each trial, participants had to fixate at the centre of the screen. The zoom lens model of the visual attention (Eriksen & St. James, 1986) would predict that the attend-to-arrow condition could have restricted the area covered by the attentional zoom lens to only the very central part of the screen where the fixation cross and the subsequent arrow cue were presented. On the contrary, when attending to the gaze cues, the participants would have had to widen the attentional zoom lens to cover the whole face display, including both the gaze cue and the arrow distractor. Accordingly, one could argue that the distractor effect resulting from the to-be-ignored arrows (i.e., when participants are attending the gaze cue) would have been inflated when compared to the distractor effect for the to-be-ignored gaze (i.e., when participants are attending the arrow cue), and more asymmetric effects for arrow and gaze distractors could emerge if the different types of cues would be presented in comparable spatial locations. Therefore, we conducted Experiment 2 to control for this potential confound.

Experiment 2

Experiment 2 replicated Experiment 1 in every other aspect except for the location of the cue and distractor stimuli in the face display. To make the arrow and gaze cues more comparable in salience, we used two unidirectional arrow cues placed right below or above the eyes of the schematic face stimulus. The eyes were no longer aligned at the central horizontal axis of the face display, but were located slightly above/below the midline according to the placement (above/below) of the arrows to make the stimulus displays symmetric. Therefore, neither the gaze nor the arrow stimuli were displayed at the fixation.

Participants

Fifteen volunteer graduate and undergraduate students (6 men and 9 women, mean age 28 years) with normal or corrected-to-normal vision volunteered to participate in the experiment.

Stimuli, Procedure, and Design

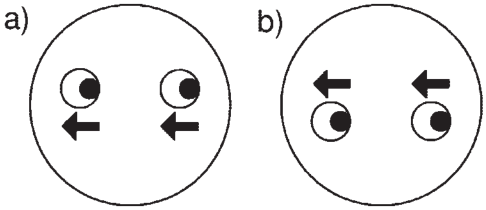

Figure 3. Examples of stimuli with gaze (a) and arrow (b) cues in upper position in Experiments 2 and 4.

The stimuli were similar to those in Experiment 1 with the following exceptions (see Figure 3 for examples). The eyes were located 0.5° either above or below the central horizontal axis. The arrows had only one head, measured 2°, were located 0.5° above or below the central horizontal axis, and located 2° from the central vertical axis. The procedure of Experiment 2 was similar to that in Experiment 1 with the following exceptions. The initial face display did not contain the pupils, only the outline circle was presented. On half of the blocks the arrows were located above the eyes and on the other half below the eyes. The logic behind blocking and not randomizing the location of the cue/distractor location across the trials was that when the spatial location of the cue to be attended remained constant throughout each block, participants did not have to search for attended (instructed) cue, which would make ignoring the distractors easier. This resulted in a fully within-subjects design involving five factors: Cue type (gaze vs. arrow), Cue location (above vs. below), Cue validity (valid vs. invalid), Distractor validity (valid vs. invalid vs. no distractor), and SOA (200 ms vs. 600 ms).

Results

On average, participants made errors on 2.5% of the catch trials. First, the mean RTs for the no-distractor trials (see Table 2) were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue location: above, below) × 2 (Cue validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. This yielded main effects of cue location, $F(1, 14) = 40.70$, $p < .01$, $\eta^2 = .74$; cue validity, $F(1, 14) = 11.23$, $p < .01$, $\eta^2 = .45$; and SOA, $F(1, 14) = 170.84$, $p < .01$, $\eta^2 = .91$. RTs were faster when the cues were presented in the upper than in the lower position (306 vs. 324 ms), when the cue vas valid than when it was invalid (309 vs. 321 ms), and when the SOA was 600 than when it was 200 ms (300 vs. 330 ms). Moreover, the cue validity × SOA interaction proved significant, $F(1, 14) = 5.07$, $p = .04$, $\eta^2 = .27$. The interaction resulted from larger cueing effect on 200-ms than on 600-ms SOA (14 vs. 7 ms, respectively).

Next, the mean RTs for the trials with cues and distractors were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue location: above, below) × 2 (Cue validity: valid, invalid) × 2 (Distractor validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. There were main effects for cue location, $F(1, 14) = 9.01$, $p < .01$, $\eta^2 = .39$; cue validity, $F(1, 14) = 28.99$, $p < .01$, $\eta^2 = .67$; distractor validity, $F(1, 14) = 16.10$, $p < .01$, $\eta^2 = .54$; and SOA, $F(1, 14) = 116.84$, $p < .01$, $\eta^2 = .89$ (see Figure 4). RTs were faster for trials in which the cue was in the upper position than in the lower position (300 vs. 308 ms), for validly than for invalidly cued trials (298 vs. 309 ms), for trials with valid than with invalid distractors (300 vs. 308 ms), and for the trials at the 600-ms than 200-ms SOA (285 vs. 323 ms). The cue type × distractor validity, $F(1, 14) = 10.00$, $p < .01$, $\eta^2 = .42$; and cue

Table 2
Reaction Times by Stimulus Onset Asynchrony, Cue Validity, Distractor Validity, Attended Cue Type, and Cue Location in Experiment 2

	200 ms				600 ms			
	Valid cue		Invalid cue		Valid cue		Invalid cue	
Distractor	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attend upper arrow cue								
Valid	314	30	323	35	275	19	286	28
Invalid	320	33	336	31	285	26	293	23
None	317	29	332	33	299	36	288	25
Attend lower arrow cue								
Valid	322	31	336	37	287	23	298	37
Invalid	325	33	338	34	280	24	295	34
None	337	27	352	32	306	28	313	31
Attend upper gaze cue								
Valid	301	21	316	26	272	17	283	17
Invalid	316	39	328	29	279	16	287	20
None	311	20	322	23	290	28	290	29
Attend lower gaze cue								
Valid	316	25	322	31	283	18	281	18
Invalid	327	26	337	31	290	21	298	28
None	326	21	346	25	303	19	314	21

type × cue location × distractor validity interaction, $F(1, 14) = 10.00$, $p < .01$, $\eta^2 = .42$, also proved significant. The cue type × distractor validity resulted from the fact that the distractor effect ($RT_{invalid} - RT_{valid}$ for distractors) was larger for arrow than for gaze distractors (9 vs. 3 ms, respectively). However, analysis of the three-way interaction of cue type × cue location × distractor validity revealed that this was true only when participants were attending cues in upper position, $F(1, 14) = 6.0$, $p = .02$, $\eta^2 = .30$, but not when they were attending cues in lower position, $F < 1$.

Discussion

When gaze and arrow distractors (and cues) were presented in comparable spatial locations, the arrow distractors seemed to result in slightly but reliably greater interference effect than the gaze distractors (a difference of 6 ms). However, inspection of the RTs in Table 2 reveals that the greater distractor effect for arrow than gaze cues seems to result from the fact that when the attended arrow cues were presented at the lower location, the validity effect for the gaze distractors was for some reason reversed. In other words, in this particular condition, the RTs were shorter for invalid than valid gaze distractors. We are inclined to interpret this result as anomalous and, thus, the interaction of cue type × distractor validity probably reflects the effects of this one anomalous condition. Accordingly, Experiment 2 essentially replicated the results obtained in Experiment 1, and suggested, therefore, that the similar effect for gaze and arrow distractors found in Experiment 1 was not due to the central presentation of the arrow cues. Both gaze and arrow distractors exerted an influence on covert orienting of attention when participants were trying to allocate their attention away from them. Thus, the present results further supported the notion that the directional meaning of both gaze and arrow cues is prone to be processed unintentionally and that the subsequent orienting triggered by these two types of cues is equally automatic.

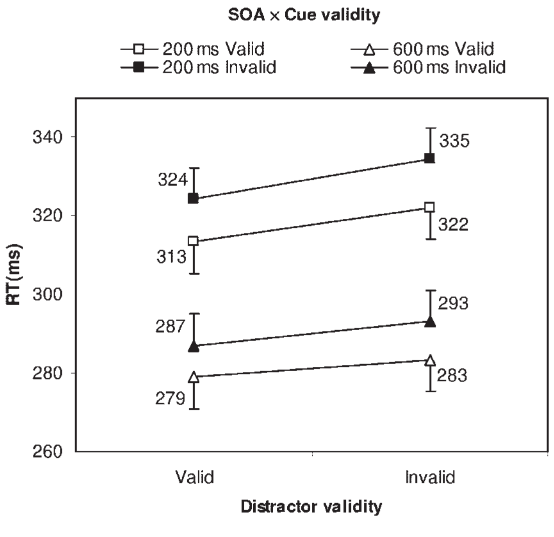

Figure 4. Mean reaction times (RT) and 95% contrast-wise confidence intervals as a function of stimulus onset asynchrony (SOA), cue validity, and distractor validity in Experiment 2.

The results of Experiments 1 and 2 indicate that (a) the unattended gaze and arrow distractors interfere with orienting by the attended cues, and (b) that the cues and distractors have relatively symmetric effects on RTs. However, the results from Experiments 1 and 2 do not conclusively demonstrate at which level the interference occurs. It would be tempting to argue that the effects are due to additive effects of simultaneous workings of two separate attentional systems—one for gaze and one for arrow cues (c.f. Hietanen, Nummenmaa, Nyman, Parkkola, & Hämäläinen, 2006; Ristic et al., 2002), but the stimulus layout employed in Experiments 1 and 2 prevents us from making such conclusions. Namely, it has been suggested that the purpose of allocating attentional resources onto an object is to generate an object file that stores information about all feature dimensions of the object (e.g., Kahneman & Treisman, 1984). Now, as both the gaze and arrow cues were line drawings presented inside a circle that depicted a schematic face, it may be that the participants perceived the eye and arrow cues as one object (e.g., a face with two arrows painted on it) instead of two distinct objects (a face plus two arrows), and generated a single object file consisting of gaze and arrows. Therefore, it is possible that the results observed in Experiments 1 and 2 did not reflect the workings of two separate attentional systems, but reflected some sort of pooling of the directional meaning of gaze and arrow cues/distractors. Experiment 3 was conducted to test this alternative hypothesis.

Experiment 3

The specific contribution of Experiment 3 was testing of whether the cueing effects for gaze and arrow distractors observed in Experiments 1 and 2 resulted from perceiving the cue and the distractor as a single object. This was accomplished by presenting the cues and distractors as clearly separable stimuli. Again, both the arrow and gaze cues were presented on each trial, but this time the directional eye gaze and arrow cues were presented inside separate, nonoverlapping circles. In the paradigm, the cues were presented centrally but the distractors were presented to the visual periphery (over 5° away from foveal fixation of the eyes; see Wandell, 1995). If the interference between the cues and distractors occurred due to merging them into a single object file, no distractor effects were to be expected in Experiment 3.

Participants

Participants were 18 volunteer female students (mean age 24 years) from the University of Tampere. All had normal or corrected-to-normal vision.

Stimuli, Procedure, and Design

The stimuli, procedure, and design were similar to those in previous experiments with the following exceptions. The initial display consisted of three circles aligned above each other. The timing of these circles was like that of the initial empty faces in Experiment 1. The gaze stimuli were similar to those in Experiment 1 (i.e., the eyes located on the central horizontal axis of the face) and the arrow stimuli were similar to those in Experiment 2, with the exception that this time the two arrows were centered on the central horizontal axis. Stimulus displays (see Figure 5) consisted of the arrow and gaze cues presented above each other, as well as one empty circle. The attended cue was always presented at the center of the screen, whereas the distractor could be presented either above or below the cue, with a distance of 8.7° between the horizontal axes of the central cue and the distractor. On half of the trials, the cue appeared at the upper location and on half of the trials at the lower location. On the no-distractor trial, the eyes/arrow were not presented inside the distractor stimulus circle. The target was presented similarly as in Experiments 1 and 2.

Results

On average, participants made errors on 3.7% of catch trials. First, mean RTs (see Table 3) for the no-distractor trials were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. The analysis yielded significant main effects of cue validity, $F(1, 17) = 4.33$, $p = .05$, $\eta_p^2 = .20$, and SOA, $F(1, 17) = 194.00$, $p < .01$, $\eta_p^2 = .92$. Again, RTs were faster for validly than for invalidly cued trials (329 vs 337 ms), and for trials at the 600-ms than 200-ms SOA (306 vs. 360 ms).

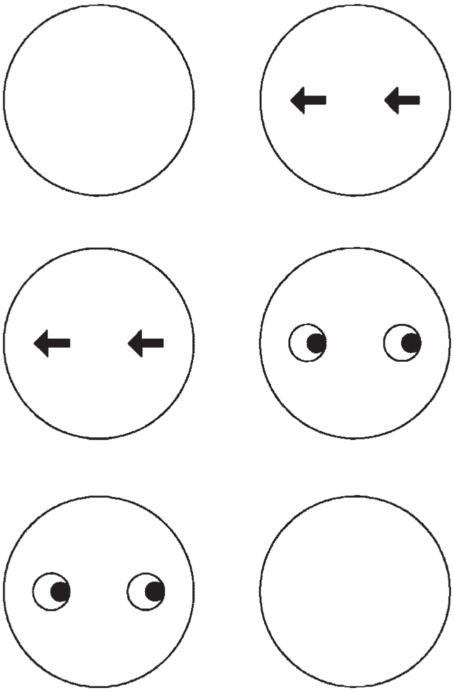

Figure 5. Examples of stimuli used in Experiment 3. The cue was always presented at fixation, and the distractor was presented either below (left panel: gaze distractor) or above (right panel: arrow distractor) the attended cue.

Next, mean RTs for the trials with cues and distractors were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue validity: valid, invalid) × 2 (Distractor validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. See Figure 6 for results. The analysis yielded significant main effects of cue validity, $F(1, 17) = 6.36$, $p = .02$, $\eta_p^2 = .27$; distractor validity, $F(1, 17) = 21.02$, $p < .01$, $\eta_p^2 = .55$; and SOA, $F(1, 17) = 125.64$, $p < .01$, $\eta_p^2 = .88$. RTs were faster for validly than for invalidly cued trials (325 vs. 332 ms), for trials with valid than with invalid distractors (325 vs. 332 ms), and for 600-ms than for 200-ms SOA (303 vs. 355 ms). There were no other statistically significant effects, Fs < 1.

Discussion

Experiment 3 essentially replicated the results of Experiments 1 and 2. Again, RTs were faster for trials with valid than with invalid cues and for trials with valid than with invalid distractors. We found noteworthy that gaze and arrow distractors resulted in similar, symmetric distractor effects. Experiment 3 also indicated that the distractor effect occurred even when the cues and distractors constituted of visually separable stimuli. Thus, the interference effect by the gaze and arrows observed in the previous experiments was not likely to result from perceptual binding of the cue and the

Table 3

Reaction Times by Stimulus Onset Asynchrony, Cue Validity, Distractor Validity, and Attended Cue Type in Experiment 3

	200 ms				600 ms			
	Valid cue		Invalid cue		Valid cue		Invalid cue	
Distractor	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attend arrow cue								
Valid	340	40	353	36	292	34	299	33
Invalid	350	36	356	36	300	37	305	37
None	353	39	361	43	299	42	308	35
Attend gaze cue								
Valid	352	41	364	40	300	28	304	31
Invalid	360	38	368	40	313	34	311	36
None	359	38	370	38	306	28	314	37

distractor as one object. Instead, it is more likely that the influence of the cues and distractors on performance occurred at later, postperceptual processing stages. The gaze and arrow cues were presented at an eccentricity of 8.7°; thus, they could not be simultaneously foveated. Therefore, Experiment 3 also corroborated the previous findings that gaze direction cues can exert influence on orienting of attention even when they are presented to the parafoveal (Friesen & Kingstone, 2003) or peripheral (Holmes, Richards, & Green, 2006) vision. As a new finding, the present results showed that peripherally presented, endogenous arrow cues can also automatically reorient attention in the direction indicated by the arrow head.

Experiment 4

All the previous experiments relied on a localization task. Although this task is known to be sensitive in detecting small cueing effects, it also provides a possible confound. As participants perform left/right localization task and the cues also point to the left and right, it is possible that the observed facilitatory effects are not due to orienting of attention by the cues and distractors, but due to spatial stimulus-response compatibility, similar to that observed in the Simon tasks (see Lu & Proctor, 1995). It must be emphasized that previous studies have repeatedly shown gaze cueing (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen & Leppänen, 2003) and arrow cueing (e.g., Hommel et al., 2001; Ristic et al., 2002; Tipples, 2002) with paradigms requiring target *detection* or target *discrimination*, thus circumventing the possibility of stimulus-response compatibility explaining the observed results. Nevertheless, as our experimental setup involved two separate cue types that could interfere with each other, we wanted to make sure that the interference we observed in Experiments 1–3 is attentional and not related to any kind of stimulus-response compatibility effects.

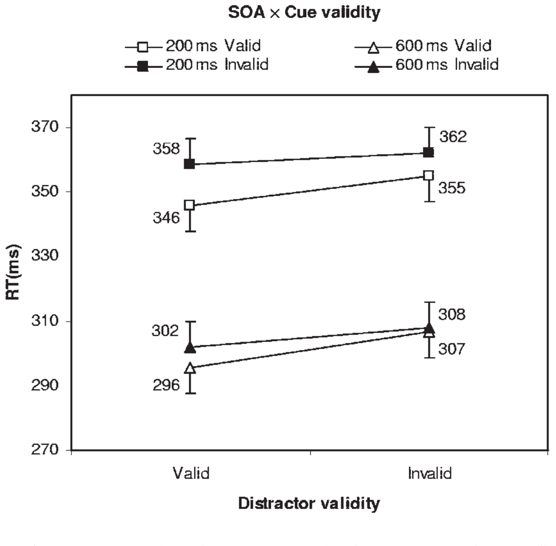

Figure 6. Mean reaction times (RT) and 95% contrast-wise confidence intervals as a function of stimulus onset asynchrony (SOA), cue validity, and distractor validity in Experiment 3.

We felt that this was particularly important because there is evidence that irrelevant directional information provided by both gaze (Langton, 2000; Langton & Bruce, 2000; Zorzi, Mapelli, Rusconi, & Umiltà, 2003; Ricciardelli, Bonfiglioli, Iani, Rubichi, & Nicoletti, 2005) and arrow (Ricciardelli et al., 2005) cues is automatically processed resulting in Simon effects. Accordingly, the results of Experiments 1–3 could also be explained in terms of automatic spatial response coding of the cues and distractors, and the interference would occur at the stage of response programming and execution and not at the earlier stage of attention orienting. Namely, when both the cue and distractor point at the target location they yield the maximum spatial compatibility with the response to be made, whereas when they both point away from the target they yield minimal compatibility. Accordingly, it is possible that encoding of directional information as well as response determination are carried out in parallel for the gaze and arrow cues, and the interference occurs at the stage of response programming and execution. Such a model would be totally compatible with the pattern of reaction times observed in Experiments 1–3. Thus, to test whether the results of these experiments were really due to *attentional* interference between the cues and distractors, we replicated Experiment 2 with a detection task that is not confounded with stimulus-response compatibility effects. We decided to replicate the paradigm we used in Experiment 2 in order to check whether the slight deviance in the results we observed the first time (see Discussion of Experiment 2) was an anomaly, as we suggested, or persisted.

Participants, Stimuli, Procedure, and Design

Participants were 17 volunteer students (all females, mean age 23 years) from the University of Tampere. All had normal or corrected-to-normal vision. Of the 19 persons originally participating in the study, 2 had to be dropped from the analysis due to high number (>50%) of anticipatory responses, resulting in nearly zero valid measurements on some cells of the experimental design. The stimuli, procedure, and design were similar to those in Experiment 2 with the exception that instead of a localization task, participants were instructed to press a single response button as soon as they detected the target.

Results and Discussion

On average, participants made errors on 3.4% of catch trials. Mean RTs (see Table 4) for the no-distractor condition were analyzed with a 2 (Cue type: gaze, arrow) × 2 (Cue location: above, below) × 2 (Cue validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. There were main effects for cue validity, $F(1, 16) = 7.64, p < .01, \eta^2 = .45$, and SOA, $F(1, 16) = 199.00, p < .01, \eta^2 = .76$. RTs were faster for validly than for invalidly cued trials (330 vs. 337 ms), and for the trials at the 600-ms than 200-ms SOA (299 vs. 369 ms).

Next, mean RTs for the trials with cues and distractors were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue location: above, below) × 2 (Cue validity: valid, invalid) × 3 (Distractor validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. See Figure 7 for a summary of the results. There were main effects for cue validity, $F(1, 16) = 14.09, p < .01, \eta^2 = .48$; distractor validity, $F(1, 16) = 7.95, p < .01, \eta^2 = .35$; and SOA, $F(1, 16) = 237.61, p < .01, \eta^2 = .94$. The Cue type × SOA interaction also proved significant, $F(1, 16) = 8.39, p < .01, \eta^2 = .36$. Reaction times were faster for trials with valid than with invalid cues (316 vs. 322 ms), for trials with valid than with invalid distractors (316 vs. 322 ms), and for trials with 600-ms than with 200-ms SOA (286 vs. 352 ms). The Cue type × SOA interaction resulted from the fact that the foreperiod effect was larger for gaze than for arrow cues (70 vs. 62 ms). All in all, Experiment 4 essentially replicated the results of Experiments 1–3 with a detection task. Accordingly, it corroborated the hypothesis that the results from experiments 1–3 were due to attentional orienting triggered by the cues and distractors instead of stimulus-response compatibility effects.

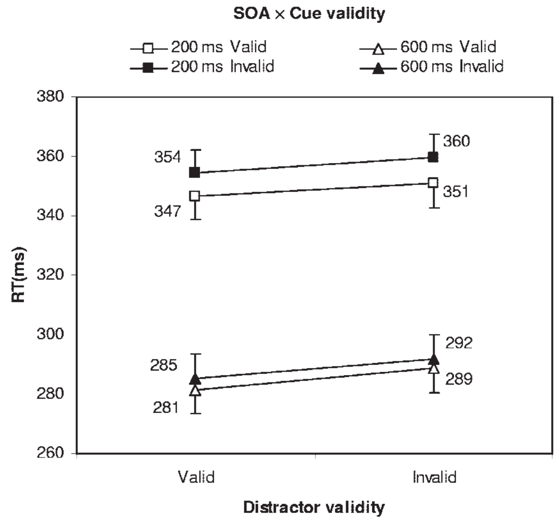

Figure 7. Mean reaction times (RT) and 95% contrast-wise confidence intervals as a function of stimulus onset asynchrony (SOA), cue validity, and distractor validity in Experiment 4.

Table 4
Reaction Times by Stimulus Onset Asynchrony, Cue Validity, Distractor Validity, Attended Cue Type, and Cue Location in Experiment 4

	200 ms				600 ms			
	Valid cue		Invalid cue		Valid cue		Invalid cue	
Distractor	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attend upper arrow cue								
Valid	344	61	350	69	286	63	286	78
Invalid	346	60	355	71	290	72	272	72
None	357	57	365	64	289	72	288	78
Attend lower arrow cue								
Valid	339	54	351	60	282	50	276	56
Invalid	347	59	354	63	292	64	297	57
None	366	54	362	58	285	64	300	60
Attend upper gaze cue								
Valid	341	59	347	50	271	52	275	61
Invalid	342	51	351	53	274	55	287	47
None	363	58	371	55	288	68	301	70
Attend lower gaze cue								
Valid	345	62	352	55	273	60	282	63
Invalid	354	55	361	56	277	58	294	57
None	366	54	372	53	301	59	300	71

Experiment 5

In all the previous experiments, we provided participants with two sources of equally unreliable (i.e., 50% valid) information about the target location, and manipulated which source (gaze vs. arrow cue) the participants were attending to by means of a secondary color detection task. Although the participants performed the secondary task highly accurately (an average of 3.15% errors in Experiments 1–4), it is still possible that the secondary task did not fully inhibit the processing of the distractors. As both cues and distractors were 50% valid, no reliable information about the upcoming target location was available. It is thus possible that the attentional systems were automatically integrating all the information provided by the two unreliable sources (cue and distractor) in order to resolve the ambiguity about the upcoming target location. Accordingly, this would suggest that the attentional control system would be "leaky" if the attended cues are nonpredictive, and it could be questioned whether the distractors were actually unattended. To test this hypothesis, we ran an experiment with 100% valid cues and 50% valid (nonpredictive) distractors. The predictive validity of a cue should be a strong motive for the participants to attend to the cue and ignore the distractors (see Yantis & Jonides, 1990). If the distractors are always processed automatically and in parallel with the attended cues, we expected that the main effect of distractor validity would also be replicated in Experiment 5, where the cues were relevant to the primary target detection task (c.f. the effects of peripheral cues in the Müller & Rabbitt, 1989 study). On the contrary, if the directional information conveyed by the cues and distractors is integrated only when neither the cues nor the distractors provide reliable information about the target location, we expected the main effect of distractor validity to disappear in Experiment 5. In Experiment 5, the cues and distractors were presented inside two separate, nonoverlapping circles.

Participants, Stimuli, Procedure, and Design

Participants were 19 volunteer students (5 males, mean age 23 years) from the University of Tampere. Two people originally participating in the experiment were removed from the analysis due to high (>25%) frequency of responses on catch trials. The procedure and design were similar to those in Experiment 3 with the following exceptions. The size of the cue and distractor stimuli was scaled down with a factor of [1/2] to make Experiment 5 comparable with the subsequent Experiment 6. The cue and distractor were presented above each other, slightly above and below the fixation point centered on the vertical axis of the screen, thus neither of them was under foveal attention. The inner edges of the cue and distractor were 1.3 degrees apart. The attended cues were 100% valid, whereas the distractors were 50% valid. This was explained to the participants, and it was stressed that they should try to use the information conveyed by the attended cue when localizing the target as the cue provided reliable information of the upcoming target location. Like in Experiment 4, the task was a target detection task. The no-distractor condition was removed from the experiment, as it would have been meaningless with 100% valid cues. Additionally, in this experiment we presented two types of catch trials. Half of the catch trials were like in the previous experiments, and the other half were catch trials where the target did not appear at all. The total number of catch trials was the same as in the previous experiments.

Results

On average, participants made errors on 3.4% of catch trials. Mean RTs (see Table 5) were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue location: above, below) × 2 (Distractor validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. See Figure 8 for a summary of the results. There was a main effect for SOA, $F(1, 18) = 175.00$, $p < .01$, $\eta^2 = .90$, resulting from faster RTs for trials with 600-ms than with 200-ms SOA (280 vs. 339 ms). The four-way interaction Cue type × Cue location × Distractor validity × SOA also reached significance, $F(1, 18) = 6.85$, $p = .02$, $\eta^2 = .27$, but planned contrasts following simple effects tests did not reach significance. All other main effects and interactions were nonsignificant, Fs < 1.5.

Discussion

Experiment 5 demonstrated that when attended cues provide 100% valid, directional information for the attentional task the participants are performing, the distractors are not processed in parallel with the attended cues. This supports our hypothesis that the parallel processing of irrelevant spatial distractors can be inhibited, but only when the attended cues provide reliable information for attentional orienting. In other words, the top-down control exerted over attentional orienting must exceed a certain threshold before the parallel processing of the distractor is inhibited. Although this argument is based on a null effect, we are confident about the validity of this conclusion. Namely, the main effect of distractor validity had a large effect size in Experiments 1–4 (an average η^2 of .55), whereas here the corresponding effect size was nearly zero. Again, there were no differences between the processing of gaze and arrow distractors, which further supports our argument that gaze and arrow cues result in equally automatic orienting responses.

Experiment 6

The cue stimuli used in Experiments 1–5 were extremely impoverished—instead of realistic eye gaze stimuli and "traffic sign" arrows that people typically encounter in daily life, we used

Table 5
Reaction Times by Stimulus Onset Asynchrony, Distractor Validity, Cue Type, and Cue Position in Experiment 5

	200 ms				600 ms			
	Valid distractor		Invalid distractor		Valid distractor		Invalid distractor	
Cue type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Cue above								
Gaze	336	91	346	84	284	76	283	69
Arrow	335	77	331	72	268	59	268	54
Cue below								
Gaze	347	77	347	82	286	75	291	77
Arrow	334	73	338	73	282	68	281	64

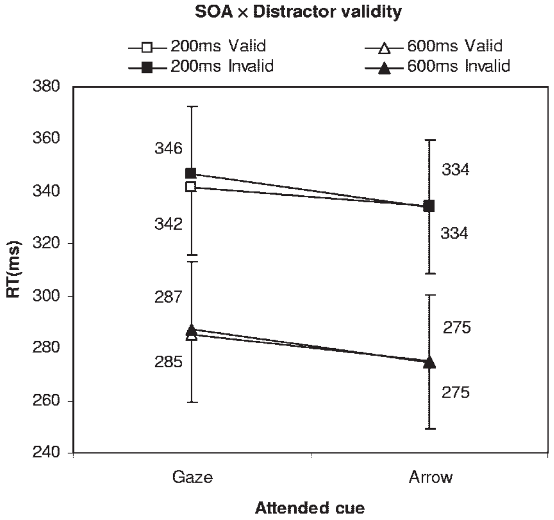

Figure 8. Mean reaction times (RT) and 95% contrast-wise confidence intervals as a function of stimulus onset asynchrony (SOA), distractor validity, and attended cue type in Experiment 5.

schematic faces and simplistic arrows. There were two reasons for this. First, a bulk of previous studies (see Introduction) has demonstrated that such cues reliably trigger reflexive shifts of visual attention. Second, such gaze and arrow stimuli are visually similar and, therefore, it is unlikely that the results are biased by differences in visual conspicuity of the different (i.e., gaze vs. arrow) cue types. This makes comparison of their attentional effects straightforward.

However, the schematic faces and simplistic arrows are not totally unproblematic stimuli. Although such face stimuli are indeed perceived and processed as faces (see e.g., Hietanen et al., 2006), one could question whether the arrow cues employed in Experiments 2–5 could be perceived as faces as well. Indeed, the placement of the arrows within the circle resembles the respective placement of the eyes within our face stimuli, and it is known that two small shapes within an outline can be primed to be perceived as a face (Bentin & Golland, 2002). If this applies to our stimuli as well, Experiments 2–5 would have only provided data regarding the processing of two conflicting gaze cues. Although Experiment 1 which employed a single arrow cue (that could not be confused with the eyes) provided essentially the same results as Experiments 2–4 and thus provided data against the "arrows as eyes" argument, we had also another reason for testing the cueing effect with more realistic stimuli. Namely, we were concerned about the ecological validity of the simplistic eye stimuli. It is possible that "the eyes have it" in the sense that unattended, realistic eyes would have greater distracting effects than the eyes of the schematic stimuli, when the eyes have to compete for attentional resources with symbolic arrow cues. This is indeed a serious threat to our previous findings, given that realistic faces are known to attract attention in a reflexive manner (Langton et al., 2008; Theeuwes & Van der Stigchel, 2006). We thus decided to remove these potential confounds by employing more realistic and ecologically valid face and arrow stimuli in the cueing task.

Participants, Stimuli, Procedure, and Design

Participants were 22 volunteer students (3 males, mean age 23 years) from the University of Tampere. The procedure and design were similar to those in Experiment 5 with the following exceptions. First, instead of schematic gaze and arrow stimuli, photorealistic grayscale eye and arrow ("traffic sign") stimuli were employed. See Figure 9 for illustrations. The size of the stimuli was 8° × 3°. A total of 10 different face and arrow identities were generated and paired randomly on experimental trials; as we aimed at assessing the effects of realistic gaze and arrow cues on attention orienting, we felt that it was important that the eye and arrow stimuli were variable and representative of the arrows and eyes we typically encounter. The gaze and arrow stimuli were matched with respect to average size of the eyes within the face vs. size of the arrow within the surrounding "traffic sign box," mean luminosity, kurtosis of luminosity distribution, and global energy, $Fs < 3.30$. The inner edges of the cue and distractor stimuli were 2.8° apart. Before each trial 8° × 3° placeholder boxes with a black outline were presented at the upcoming cue and distractor locations. As the arrow and eye stimuli now varied in size and shape within the outline, we either presented red pupils (attend-to-gaze condition) or red pupil-size circles within the arrow (attend-to-arrow condition) on the cue catch trials. Like in Experiment 5, half of the catch trials were no-target catch trials.

We also wanted to validate that we get the standard reflexive cueing effect with the realistic stimuli. To that end, the experiment begun with a cueing task involving singly presented, 50% valid gaze or arrow cues. These cues also appeared in the placeholder boxes. Within a test block, the cue appeared in one of the placeholders while the other box remained empty. SOAs of 200 and 600 ms were used, and the participants performed 40 trials of each type.

Results

On average, the participants made errors on 3.2% of the catch trials. We first analyzed the RTs from the singly presented 50% valid gaze and arrow cues conditions with a 2 (Cue type: gaze, arrow) × 2 (Cue validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. See Table 6 for mean RTs. There were main effects for Cue validity, $F(1, 21) = 11.65$, $p < .01$, $\eta^2 = .36$, and SOA, $F(1, 21) = 80.00$, $p < .01$, $\eta^2 = .79$. Reaction times were faster for validly than for invalidly cued trials (330 vs. 337 ms), and for the trials at the 600-ms than 200-ms SOA (272 vs. 279 ms), demonstrating the traditional reflexive cueing effect for

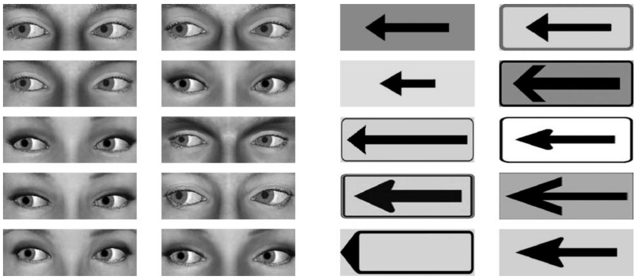

Figure 9. Gaze and arrow stimuli used in Experiment 6.

Table 6

Reaction Times by Stimulus Onset Asynchrony, Cue Type, and Cue Validity in the 50% Valid Single Cue Blocks in Experiment 6

	200 ms				600 ms			
	Gaze cue		Arrow cue		Gaze cue		Arrow cue	
Validity	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Valid	281	33	282	28	260	26	264	30
Invalid	288	32	295	29	267	28	264	34

both the gaze and arrow stimuli. Importantly, neither the main effect of Cue type nor the Cue type × Cue validity interaction reached significance.

Next, mean RTs (see Table 7) for the trials with cues and distractors were subjected to a 2 (Cue type: gaze, arrow) × 2 (Cue location: above, below) × 2 (Distractor validity: valid, invalid) × 2 (SOA: 200 ms, 600 ms) repeated measures ANOVA. See Figure 10 for a summary of the results. There were main effects for Distractor validity, $F(1, 21) = 22.86$, $p < .01$, $\eta^2 = .52$, and SOA, $F(1, 21) = 205.00$, $p < .01$, $\eta^2 = .91$. The interactions of Distractor validity × SOA, $F(1, 21) = 5.70$, $p = .03$, $\eta^2 = .21$, as well as Cue type × Distractor validity, $F(1, 21) = 21.92$, $p < .01$, $\eta^2 = .51$, also reached significance. Reaction times were faster for trials with valid than with invalid distractors (278 vs. 284 ms), and for trials with 600-ms than with 200-ms SOA (257 vs. 305 ms). The Distractor validity × SOA interaction resulted from the fact that the distractor effect was larger for trials with 200-ms than with 600-ms SOA (8 vs. 4 ms). The Cue type × Distractor validity interaction reflected the fact that the distractor effect was significantly larger for arrow than for gaze distractors (10 vs. 2 ms). And importantly, the distractor effect for arrows was significantly larger than zero, $t(21) = 5.46$, $p < .01$, whereas the distractor effect for gaze was not, $t = 1.60$, $p = .12$.

Discussion

The main findings of Experiment 6 can be summarized as follows. First, we verified that singly presented realistic gaze and arrow cues resulted in comparable, reflexive cueing effects. Second, when such cues were presented simultaneously, the nonpredictive distractors could interfere with attentional orienting by the attended, fully valid cues. However, against our predictions we observed distractor effects only for arrow, but not for gaze distractors. When compared to the gaze distractors, the arrow distractors resulted in an interference that was fivefold (10 vs. 2 ms) in magnitude. This is in strong contrast with the results of Experiment 5 where the visually similar gaze and arrow distractors resulted in no interference effect at all.

Table 7

Reaction Times by Stimulus Onset Asynchrony, Distractor Validity, Cue Type, and Cue Position in Experiment 6

	200 ms				600 ms			
	Valid distractor		Invalid distractor		Valid distractor		Invalid distractor	
Cue type	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Cue above								
Gaze	303	64	316	68	259	70	267	63
Arrow	295	46	300	46	249	42	248	36
Cue below								
Gaze	310	86	324	83	262	60	268	70
Arrow	299	48	300	50	251	41	253	41

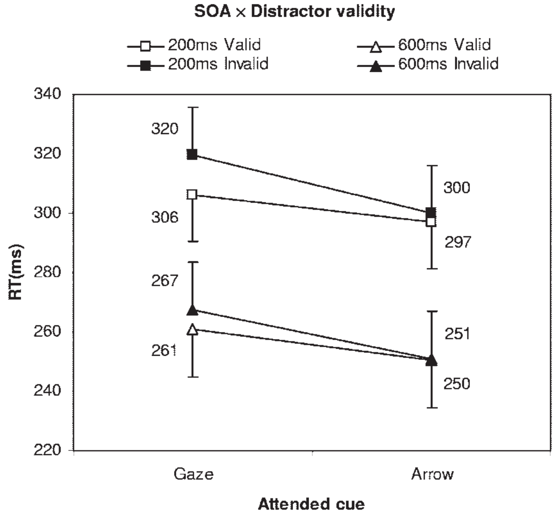

Figure 10. Mean reaction times (RT) and 95% contrast-wise confidence intervals as a function of stimulus onset asynchrony (SOA), distractor validity, and attended cue type in Experiment 6.

We found interesting that many of the participants spontaneously commented after the experiment that the arrow stimuli had been more conspicuous and visually variable than the gaze stimuli. This prompted us to perform further analyses regarding the visual characteristics of the arrow and gaze cues. These analyses revealed that when compared to gaze cues, the arrow cues had significantly larger contrast density as indexed by root mean square contrast, $F(1, 19) = 42.00$, $p < .01$, $\eta^2 = .70$, and more leftwards-skewed luminosity distribution $F(1, 19) = 16.32$, $p < .01$, $\eta^2 = .48$. Further, visual similarity statistic based on pixel-wise correlations was higher for the eye ($r = .60$) than for the arrow ($r = .46$) stimuli, $t = 2.20$, $p = .05$. Although we tried to match the visual features of the realistic gaze and arrow cues as closely as possible, we argue that it would be very difficult to create sets of realistic gaze and arrow stimuli that would have had equal contrast density and luminosity distribution, because the typical traffic signs are usually painted only with two or three colors. Low-level visual factors such as edge density (Mannan, Ruddock, & Wooding, 1996) and high local contrast (Krieger, Rentschler, Hauske, Schill, & Zetzsche, 2000) are known to attract eye fixations, that is, attention. When the cue and distractor are presented simultaneously, they compete for attentional resources and access to the visual system. Accordingly, it is understandable that as the arrow stimuli seemed to be visually more salient as indexed by contrast density, they were thus processed more efficiently when presented as distractors.

However, it is important to note that this is not a confounding stimulus factor. Instead, it is an inherent feature of the faces and arrows we encounter in everyday life. This experiment thus shows that even though gaze cues could sometimes trigger more reflexive shifts of attention that arrows, this phenomenon is contingent on the physical saliency of the cues: if arrow cues are more salient than eyes, they can override the orienting by gaze. In general sense, these findings complement those from Experiments 1–4 showing that the systems governing attentional control settings can be "leaky" under certain conditions. When the cues are fully valid and the distractors are visually matched with the cues (Experiment 5), the cognitive system can easily suppress the processing of the distractors. However, when the cues are spatially nonpredictive (Experiments 1–4) or when the distractors are visually salient (Experiment 6), the distractor processing cannot be suppressed or inhibited.

General Discussion

Studies on reflexivity of attentional orienting by social (eye gaze) and symbolic (arrows) cues have provided evidence that perception of both averted gaze (Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen, 1999) and pointing arrows (Hommel et al., 2001; Ristic et al., 2002; Tipples, 2002) results in reflexive shifts of attention. It is currently debated whether there is a difference in the degree of reflexivity of attention orienting triggered by gaze and arrow cues, and what is the cognitive (Friesen et al., 2004; Langdon & Smith, 2005) and neural (Hietanen et al., 2006; Kingstone, Tipper, Ristic, & Ngan, 2004) basis of the possible difference. In the present six experiments, we investigated how the cognitive system processes simultaneously perceived and competing, social and symbolic cues. This was accomplished by asking participants to localize or detect laterally presented targets preceded by combined gaze and arrow cues that could, independently of each other, be either valid or invalid with respect to the target location. Participants were instructed to focus their attention to one of these (a cue) and ignore the other (a distractor). When both the cues and distractors were visually matched and nonpredictive (50% valid), the data showed clear additive cueing effects for the cues and distractors, irrespectively of which cue (gaze/arrow) was to be attended (Experiments 1–4). Instead, when the cue was fully predictive (100%), no distractor effects were observed (Experiment 5). However, when fully predictive photorealistic eye and traffic sign (arrow) cues were employed, the arrows but not eyes resulted in considerable distractor effects (Experiment 6). In what follows we will discuss the implications the results have with regards to (a) the integration of simultaneously perceived directional cues, and (b) reflexivity of gaze- and arrow-triggered orienting of attention.

Integration of Simultaneously Perceived Directional Cues

The first novel result of the current series of experiments was that deliberately unattended, centrally and peripherally presented directional cues influenced orienting of attention. The data from Experiments 1–4 showed symmetric and additive cueing effects for the cues and distractors. First, both the gaze and arrow stimuli (i.e., both the cues and distractors) exerted an equally comparable influence on RTs. Second, there were no reliable differences between the effects of the attended cues and the distractors. Pooled across the experiments, the average "cueing effects" ($\mathrm{RT}_{\mathrm{invalid}}$ – $\mathrm{RT}_{\mathrm{valid}}$) resulting from the cues and the distractors were strikingly similar; 9 ms for the cues and 8 ms for the distractors. Across the Experiments 1–4, the fastest RTs were observed when both the cue and the distractor were valid (308 ms) and the slowest when they both were invalid (325 ms). When the cue and distractor were in conflict with each other, the RTs fell in between the valid-valid and invalid-invalid conditions (317 ms). Thus, the more congruent the directional meaning of the cues was, the stronger cueing effect was observed for orienting attention towards the cued location.

However, such symmetric integration occurred only when both the cues and distractors were nonpredictive as was the case in Experiments 1–4. When the distractor validity was kept at 50% but the cue validity was increased to 100%, the distractor effects disappeared completely. Hence, it can be questioned whether the distractors in Experiments 1–4 were truly unattended. Although it is known that the color detection load task employed in the current study facilitates the processing of the cues and leads to stronger cueing effects (Gibson & Bryant, 2005), it was clearly not sufficient to prevent the processing of the distractors. It is important to note that in Experiments 1–4, the tasks did not include any kind of top-down control of attention *orienting*. It was emphasized to the participants that both the cues and distractors were nonpredictive. Thus, in these experiments the attention orienting mechanisms triggered by gaze and arrow cues were "free" to work without any top-down control and, therefore, symmetric interference effects by gaze and arrow cues were observed. Only when we included a top-down attentional control for attentional orienting by making the attended cues 100% valid (Experiment 5), the effects of distractors disappeared completely. And it is important that even under such conditions there were no differences in the attentional effects of gaze and arrow distractors. Finally, when more realistic (and at the same time, visually more distinctive) gaze and arrow stimuli were employed (Experiment 6), we observed that 50% valid arrow but not gaze distractors influenced orienting by fully valid cues.

As the current experiments showed that (a) directional information of simultaneously presented directional cues is integrated for attentional orienting, and (b) the integration process is sensitive to top-down influences, it is interesting to contemplate the present experiments and their results against the saliency mapping models (see Itti & Koch, 2001 for a recent review). These models assume that orienting of attention is driven by the relative saliency (e.g., visual or attentional conspicuity) of the target location. Saliency of a location occupied by an object can arise from top-down and bottom-up influences, and in the case of the present experiments, the presentation of a directional cue is assumed to increase the saliency of the *cued* location. Separate saliency maps are computed for the different dimensions of an object (such as color, intensity, and orientation) or location that can bring about salience, and these maps are integrated into a master saliency map. Similarly, the output of the top-down and bottom-up attention mechanisms are integrated at the master saliency map (Treue, 2003). The constantly updated saliency map functions in a "winner takes it all" manner. This means that the most salient location of the map is always attended to.

In the seminal study on interactions of the reflexive and voluntary attention orienting systems, Müller and Rabbitt (1989) observed that the two attention systems interact with each other. In a combined peripheral—central cueing paradigm, the strongest cueing effects were observed when both cues pointed towards the target, although the reflexive system predominated orienting over the voluntary system. This was explained by the fact that the voluntary and reflexive systems share a common limited-capacity attention pool (i.e., the master saliency map), but the reflexive system proceeds automatically given its trigger stimulus, thus leaving little or no attentional resources left for the voluntary system. In the case of the present Experiments 1–4, despite of the attentional control manipulation, both the gaze and arrow cues contributed independently but equally to the master saliency map. Accordingly, two valid cues resulted in shortest and two invalid cues resulted in longest RTs (due to one unambiguously salient location, either valid or invalid, in the map), whereas the one valid and one invalid—condition (two moderately salient locations) fell in between these conditions. However, such an account must assume that the systems orienting attention by eye gaze and arrows do not operate in a totally deterministic manner—otherwise bidirectional interference would not have been possible (see e.g., Berger, Henik, & Rafal, 2005; Müller & Humphreys, 1991). This is evident when one considers the results of Experiment 5 with 100% valid cues: when sufficient top-down control was exerted over the attentional systems, distractor processing was completely suppressed. In other words, participants could modify the saliency weights of the locations cued by the attended cues and the distractors.

Taken together, the results from Experiments 1–5 suggest that the attentional systems process conflicting directional information in a flexible manner. When no reliable information about the target location is available, all potentially relevant directional information is automatically integrated to determine where attention should be allocated. This constitutes the attentional systems' "best guess" of the most salient location in the field of vision. Only when the target location is known with a high likelihood, the distracting directional information will be suppressed as it serves no obvious adaptive function. However, the visual conspicuity of the distractors can cause the distractors to be processed, and to leak through this voluntary control. Experiment 6 demonstrated that even when the cues are 100% valid and highly relevant to the primary task, visual conspicuity of the distractor can cause the information conveyed by the distractor to interfere with orienting triggered by the attended cue.

Do Gaze and Arrow Cues Trigger Reflexive Shifts of Attention?

A traditional and a relatively conservative criterion for an automatic process is that attending to or away from a stimulus does not, respectively, facilitate or inhibit its processing (Kahneman & Treisman, 1984). Processing of the 50% valid gaze and arrow cues and distractors seemed to fulfill this criterion. Attending to either of the cue types (gaze or arrow) did not facilitate its processing or inhibit the processing of the distractor. In other words, the attentional effects of an attended gaze cue (i.e., attend gaze, ignore arrows) were highly similar to those of an unattended gaze distractor (i.e., attend arrows, ignore gaze), and respectively for the arrows. However, when the cue validity was increased to 100%, the distractor effects disappeared completely, suggesting that attending to/away from a gaze or arrow cue actually influenced its processing. Hence, our data question the view that processing of the directional meaning conveyed by the gaze (Langton, 2000; Langton & Bruce, 2000; Zorzi et al., 2003; Ricciardelli et al., 2005) and arrow (Ricciardelli et al., 2005) cues is strictly automatic in nature.

Whether gaze and arrow cues are considered to trigger automatic or reflexive shifts of attention is, of course, contingent on how automaticity is defined (see Moors & De Houwer, 2006). In addition to assessment of the aforementioned criteria for automaticity, an alternative way would involve studying whether the gaze- and arrow-cued attentional orienting are contingent on neurophysiologically separable, dorsal/voluntary vs. ventral/reflexive attention orienting mechanisms. Regarding the latter approach, our data do not provide a definite answer. Even if gaze- and arrow-cued attention would rely on different attentional networks, the workings of these two systems could produce similar reaction times for gaze- and arrow-cued targets, just as we observed in the current study. However, neurophysiological evidence from functional magnetic resonance imaging (Hietanen et al., 2006) and electrophysiological (Hietanen et al., 2008) studies suggests that gaze- and arrow-cued orienting of attention *is* mediated by different attentional networks. Specifically, it has been shown that cueing with arrows engages the dorsal (or voluntary) attention orienting system more than cueing with gaze. However, up to date the studies have provided limited evidence for the position that the gaze cues would recruit the reflexive or ventral attention orienting system (Friesen & Kingstone, 2003; Hietanen et al., 2006; Hietanen et al., 2008; Kingstone et al., 2004) that is typically engaged by the peripheral onsets (Corbetta & Shulman, 2002).

Our data show that both arrow- and gaze-cued attentional orienting can sustain considerable amount of top-down influences or suppression (c.f. Experiments 1–4), but sufficiently engaging primary task (Experiment 5) will completely short-circuit the processing of task-irrelevant gaze and arrow signals. Although this finding suggests some degree of automaticity in both gaze- and arrow-cued orienting, it also provides us with an important distinction between gaze- and arrow-cued attentional shifts, and those triggered by peripheral onsets and governed by the ventral (reflexive) attentional systems. Although top-down control can modulate the workings of the ventral attentional system (Folk et al., 1992), one of the distinguishing features of this system is that it can override the voluntary attention orienting mechanism. In the Müller and Rabbitt (1989) study that compared the effects of simultaneous peripheral onset distractors and 100% valid arrow cues, the peripheral abrupt onsets always influenced attention orienting triggered by the arrows, whereas the arrow cues could only modulate the likelihood of attention orienting. The current data thus support the argument that neither gaze nor arrow cued shifts of attention are "reflexive" in the sense than those triggered by peripheral onset cues (c.f. Friesen & Kingstone, 2003), i.e., they are not likely to be mediated by the ventral (reflexive) attentional network.

Is There a Reflexivity Advantage for Gaze Over Arrows?

Reflexive attentional shifts have been reported to result from both gaze and arrow or other types of symbolic cues (see Introduction), but studies comparing the effects of these two cue types (Friesen et al., 2004; Hietanen et al., 2006; Langdon & Smith, 2005; Quadflieg, Mason, & Macrae, 2004) with different paradigms have provided mixed evidence for the potential RT differences for gaze-cued vs. arrow-cued attentional shifts. One of these studies (Quadflieg et al., 2004) found no differences between cueing effects for gaze and arrows, but reported overall faster RTs for gaze than arrow trials. Another study (Hietanen et al., 2006) reported larger cueing effects for gaze than for arrows but faster overall RTs for arrow than gaze trials. The two other studies found that gaze and arrow cues result in different patterns of RTs: Langdon and Smith (2005) found that gaze cues trigger facilitatory and inhibitory cueing effects, whereas arrow cues triggered facilitatory, inhibition-less priming effects. Friesen et al (2004) showed that gaze cueing is more resistant to top-down influences than arrow cueing.

A major difference between the current study and those reviewed above is that we presented the gaze and arrow cues at the same time; thus, the present results provide a more direct comparison of the attentional effects of gaze and arrow cues. The data from such a design support the view that attentional effects of gaze and arrow cues are highly similar. In six experiments, orienting by gaze and arrow cues showed a similar degree of automaticity across experimental manipulation of stimulus arrangement (Experiments 1–3), response mapping (Experiment 4), and cue validity (Experiment 5). If there was any reflexivity advantage, that was observed for realistic arrows over realistic gaze cues (Experiment 6), and it is likely that this was due to the higher visual saliency of the present arrow than gaze cues. Thus, the physical conspicuity of the directional information can influence whether gaze (or arrow) cues trigger "more reflexive" attentional shifts (see Tipples, 2002 for similar conclusions). For schematic faces and arrow symbols, the gaze cues may sometimes produce superior attentional effects (Friesen et al., 2004; Langdon & Smith, 2005), but when we consider gaze and arrow stimuli as they appear in our everyday life, the situation may be the other way around as well.

Interestingly, it has been shown that arrow cues may also interfere with "mind reading" from eye gaze in children. In the face reading task developed by Baron-Cohen and colleagues (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995) the participants are presented with an array of sweets with a face ('Charlie') that looks at one of the sweets. Participants are asked to judge which sweet Charlie wants. Already 4-year-old children can infer that Charlie wants the sweet bar he is looking at. Pellicano and Rhodes (2003) studied 3- to 4-year-old children using the face reading task with the modification that in addition to the face, they also presented an arrow that pointed to a sweet that the face was *not* looking at. They found that children actually preferred the arrow over the gaze direction as an indicator of the Charlie's intentions and desires. The data thus suggest that even young children have learned to attach not only attentional but also intentional meanings to arrows, and that such overlearned symbols may—at least on some occasions—have the potency to override the mentalistic significance of eye gaze direction.

We conclude that the directional meaning of simultaneously presented eyes and arrows can be encoded automatically. The cues increase the visual saliency of the cued location, but top-down control can modify how the directional information is weighted, that is, how much the cue contributes to the master saliency map or shared, limited-capacity attention pool. When the attentional systems are not fed with strong top-down control information, the attended and unattended cues are integrated symmetrically. Under strong top-down control, processing of both the gaze and arrow distractors can be fully suppressed, and attention is oriented according to the task-relevant cue. When the gaze and arrow distractors are visually comparable, they are equally easy (or difficult) to suppress, but the visual conspicuity of the distractor can enhance the processing of the distractor. All in all, the data support the view that gaze and arrow cues result in equally reflexive shifts of visual attention.

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