The Quarterly Journal of Experimental Psychology

ISSN: 1747-0218 (Print) 1747-0226 (Online) Journal homepage: http://www.tandfonline.com/loi/pqje20

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To cite this article: Giovanni Galfano , Mario Dalmaso , Daniele Marzoli , Giulia Pavan , Carol Coricelli & Luigi Castelli (2012) Eye gaze cannot be ignored (but neither can arrows), The Quarterly Journal of Experimental Psychology, 65:10, 1895-1910, DOI: 10.1080/17470218.2012.663765

To link to this article: http://dx.doi.org/10.1080/17470218.2012.663765

Accepted author version posted online: 09 Feb 2012.
Published online: 18 Apr 2012.

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2012, 65 (10), 1895–1910

Psychology Press
Taylor & Francis Group

Eye gaze cannot be ignored (but neither can arrows)

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Recent studies have tried to shed light on the automaticity of attentional shifts triggered by gaze and arrows with mixed results. In the present research, we aimed at testing a strong definition of resistance to suppression for orienting of attention elicited by these two cues. In five experiments, participants were informed with 100% certainty about the future location of a target they had to react to by presentation of either a direction word at the beginning of each trial or instructions at the beginning of each block. Gaze and arrows were presented before the target as uninformative distractors irrelevant for the task. The results showed similar patterns for gaze and arrows—namely, an interference effect when the distractors were incongruent with the upcoming target location. This suggests that the orienting of attention mediated by gaze and arrows can be considered as strongly automatic.

Keywords: Attention; Automaticity; Gaze; Arrows; Spatial cueing.

Over recent decades, the study of visuospatial attention mechanisms has focused on the attempt to identify the stimuli that are potentially able to elicit reflexive attention shifts by means of the spatial-cueing paradigm (e.g., Posner & Cohen, 1984). In this paradigm, a peripheral target requiring some kind of response is preceded by a cue with a spatially congruent or incongruent spatial vector in order to test whether performance is enhanced when the target appears at a location in which attention has been oriented. Initially, it was thought that only peripheral abrupt onset cues were able to trigger reflexive attention shifts (Jonides, 1981). However, in recent years, evidence has been provided showing that arrows (i.e., a central cue) can trigger a shift of attention even when uninformative with respect to target location, thus suggesting that arrow-mediated orienting can be defined as automatic (Eimer, 1997; Ristic, Friesen, & Kingstone, 2002; Tipples, 2002). Moreover, it has been shown that participants also tend to shift attention following the direction signalled by the gaze of a face presented at fixation (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Frischen, Bayliss, & Tipper, 2007; Galfano et al., 2011; Hietanen, 1999; Langton & Bruce, 1999; S. P. Tipper, 2010), a phenomenon known as gaze-mediated orienting.

Although it is well established that both arrows and gaze can indeed elicit exogenous attention shifts, the extent to which attention orienting elicited by these stimuli is automatic is still debated. In this regard, Sato, Okada, and Toichi (2007)

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We would like to thank Steve Tipper and three anonymous reviewers for the many helpful suggestions on a previous version of the paper.

http://www.psypress.com/qjep
http://dx.doi.org/10.1080/17470218.2012.663765

have demonstrated that gaze-mediated orienting can occur without awareness of the cue stimulus. Automaticity is a multifaceted concept, and Jonides (1981) has proposed and made popular three criteria in the specific domain of attention shifting. One such criterion is related to insensitivity to capacity demands and states that orienting of attention can be defined as automatic if it is relatively unaffected by a concomitant task. In this regard, Law, Langton, and Logie (2011) have recently shown a significant gaze-mediated orienting effect independently of whether participants are asked to perform a concomitant secondary task.

A second important criterion is related to resistance to suppression and states that attention shifts can be defined as automatic if they occur even when they are not functional for performing the task. One way to address this criterion has been to make the central cue uninformative as regards to target location. There is consistent evidence showing that both gaze and arrows elicit reliable attention shifts even when the target is equally likely to appear at congruent or incongruent locations (e.g., Eimer, 1997; Friesen & Kingstone, 1998; Tipples, 2002).

A more stringent test of the resistance to suppression criterion is to make cues counterpredictive with respect to target location (Posner, Cohen, & Rafal, 1982). The logic underlying this manipulation was to motivate participants in shifting attention in the direction opposite to that signalled by the cue. Driver et al. (1999) showed that gaze-mediated orienting took place even when participants were informed that gaze correctly indicated the target location in only 20% of total trials. Moreover, Friesen, Ristic, and Kingstone (2004) presented participants with counterpredictive gaze and arrow cues so that the target appeared in the location opposite to the cued location in the majority of trials and only rarely (8%) in the cued location. Because counterpredictive gaze cues, but not counterpredictive arrow cues, were found to elicit attention shifts to the cued location, the authors concluded that gaze-mediated orienting can be considered as more strongly automatic than arrow-mediated orienting, as the latter was sensitive to the manipulation of expectancies. However, Tipples (2008) found that when participants were presented with counterpredictive gaze and arrows, a significant cueing effect was exhibited for both cue types, suggesting that, even though participants knew that the target was more likely to appear in the opposite direction to that signalled by the cue, they were unable to ignore the directional information provided by both cues. It is worth reiterating that by making the cue counterpredictive as to target location, the location in which the target is more likely to appear is the opposite to that indicated by the cue. This means that, with such manipulation, participants are somehow forced to process the directional information provided by the cue in order to extract information about the location of the upcoming target stimulus. Hence, any significant attention shifting in the cued location could result from a voluntary (not automatic) processing of the cue, necessary for establishing the most likely location for the target to appear (i.e., the cue becomes task relevant).

Other studies addressing resistance to suppression focused on paradigms investigating voluntary oculomotor responses (e.g., Hermens & Walker, 2010; Kuhn & Benson, 2007; Kuhn & Kingstone, 2009, Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). In these studies, gaze and arrows were task-irrelevant distractors because participants relied on a different cue to perform the task. For instance, Kuhn and Benson (2007) instructed participants to make a saccade in the direction signalled by an instruction: For half of the participants, a red fixation point indicated a saccade towards left and a green fixation point a saccade towards right, with the reverse association for the other half of the participants. In addition to the presentation of the coloured fixation point, either an arrow or a face with averted gaze was presented as a distractor given that the directional information conveyed by the cues had no relation to the instructed saccade. Results showed that participants were slower and made more directional errors in executing the saccade when the distractor was incongruent with the required saccade direction, irrespective of whether it was a gaze or an arrow. This pattern appears to be robust, and it has been confirmed by other studies using a similar paradigm (e.g., Hermens & Walker, 2010; Kuhn & Kingstone, 2009, but see Ricciardelli et al., 2002). These studies represent a significant advance in the assessment of the automaticity of gaze- and arrow-mediated orienting, in that participants had no need to process gaze and arrow cues because these stimuli did not convey any information about target location. However, participants in these studies had to associate a specific directional information to a colour cue and retrieve this information each time they saw the cue. Recent evidence suggests that arbitrary spatial associations between nonspatial cues and spatial vectors take time to develop and require robust training (Guzzon, Brignani, Miniussi, & Marzi, 2010, Experiment 3). In light of these arguments, one cannot rule out the possibility that the distracting effect exerted by both gaze and arrows resulted from using cues of different strength, with distractor stimuli signalling an explicit, unequivocal spatial vector overcoming task-relevant cues characterized by an arbitrary spatial meaning.

The aim of the present research was to address resistance to suppression of gaze- and arrow-mediated orienting, trying to shed light on the controversial results obtained so far. In the experiments presented in the next paragraphs, we relied on a modified version of the classic covert orienting paradigm. The key difference was that participants were informed with 100% probability where the target would have appeared on each trial by means of a direction word, and they had to press a key each time they detected the target. Thus, arrows and gaze were distractors presented before the target, not informative as to target location and totally irrelevant for the task. In this way, participants were encouraged to voluntary shift attention in advance to the location of the upcoming target, and the ability of gaze and arrow cues to elicit an involuntary attention shift and to interfere with voluntary orienting was tested. Unlike previous studies using counterpredictive cues, participants had no need to process gaze and arrow cues in that these stimuli did not convey any information about target location. In addition, unlike studies focusing on voluntary oculomotor responses, in the present research, the information about the location of the upcoming target stimulus was conveyed by means of a direction word, a self-evident cue that does not require an artificial mapping in order to be interpreted. Previous research demonstrated that direction words are very effective in pushing attention in the corresponding direction, even when not informative as to target location (Hommel, Pratt, Colzato, & Godijn, 2001). Thus, the choice of a cue (i.e., direction words) that has been shown to elicit robust attention shifts even when not informative about target location represents a much stronger test of the resistance to suppression criterion with respect to previous studies. This latter feature makes the present set of studies specifically suited to provide a more reliable and unambiguous test concerning the automaticity of gaze- and arrow-mediated orienting through the combined use of cues possessing a less unbalanced capability of pushing attention.

Experiments 1a and 2a addressed gaze-mediated orienting, whereas Experiments 1b and 2b addressed arrow-mediated orienting. In Experiments 1a and 1b, automaticity was tested using a trial-by-trial manipulation: On each trial, participants were presented with a direction word (i.e., "left" or "right") signalling with 100% probability the location of the upcoming target. After the direction word, a gaze (Experiment 1a) or an arrow (Experiment 1b) was presented at fixation as a distractor, since they were uninformative as to target location. In Experiments 2a and 2b, automaticity was assessed using a block-by-block manipulation: For the whole duration of a block, the target always appeared on the left or on the right, and participants were informed with 100% probability about the future location of the target before the beginning of each block. In this way, participants did not have to change attentional control settings depending on the word displayed on each trial, and the spatial location of the target stimulus was constant for a whole block of trials. Experiment 3 was conducted to rule out possible alternative explanations for the results of the previous studies by using a discrimination task rather than a simple detection task.

In all the experiments, eye position was monitored and recorded by means of eye-tracking equipment. At the beginning of the experiment, participants were asked to maintain fixation in the centre of the screen for the whole duration of a trial, trying not to make any eye movement. They were also informed that their eye movements were recorded and that the experimenter could see whether they were maintaining fixation or not. This was done in order to ensure that participants did not shift the eyes in advance towards the location in which the target was expected. Indeed, this behaviour would have probably resulted in a decreased probability of processing the distractor stimulus, because gaze and arrows would have not been foveated. Hence, if participants had shifted their eyes in the expected target location in advance, it would be no surprise to find no interference when the direction word and the distractor stimulus have incongruent spatial vectors. In sum, we recorded eye position in order to remove offline trials in which participants failed to maintain fixation within 2° of the fixation point in case the results did not show an interference effect (for a similar procedure, see Christ & Abrams, 2006).

As regards general predictions, three possible outcomes could have been expected. If both arrow and gaze distractors were able to trigger an automatic orienting of attention, then we should have observed slower response times (RTs) in detecting the target when the distractor was incongruent with target location. Indeed, this would have meant that participants were unable to ignore the direction cue that pushed the participants' attention in a genuinely automatic way, thus interfering with target detection. If only gaze was able to trigger an automatic shift of attention, then we should have expected an interference when participants were presented with the gaze distractor but not with the arrow distractor. Finally, if participants were able to suppress the spatial meaning of gaze and arrow cues, then no interference should have been predicted.

EXPERIMENT 1A

Method

Participants

Twenty-eight students (14 females) from the University of Padua participated in the experiment on a voluntary basis. Their mean age was 22.20 years. All participants had normal or corrected-to-normal vision.

Apparatus, stimuli, and procedure

Presentation of the stimuli and registration of responses were controlled with E-Prime 1.2 software. Stimuli were presented on a 17-inch computer monitor, with a resolution of 1,152 × 864 pixels. As anticipated earlier, testing was conducted on a Tobii T120 (Tobii Technology, Stockholm, Sweden), to monitor participants' eye movements for the whole duration of the experiment. Before the experiment started, a standard calibration procedure was conducted. Participants were instructed to fixate a central red dot on a grey background and to follow this dot as it moved around the screen in nine different positions. After successful calibration, the experimental trials began.

The screen background was set to black. Each trial began with a fixation cross of 0.82° in height and length, remaining in the centre of the screen for 1,000 ms (see Figure 1, Panel a). Two white-contoured boxes were placed on the right and on the left of the fixation point on the same horizontal meridian at a distance of 10.8° from the fixation point. Each box subtended a visual angle of 2.4° in height and width. The two boxes were visible throughout the trial. Then, the word "destra" (i.e., right in Italian) or "sinistra" (i.e., left in Italian) appeared in the centre of the screen. Words appeared in 24-point Arial bold font. After 1,000 ms, the word was replaced by a schematic face with gaze averted leftwards or rightwards with the same probability. The schematic face was the same as that used by Galfano, Rusconi, and Umiltà (2006, Experiment 3). The face subtended a visual angle of 3.7° in width and 3.2° in height. After either 100 ms or 1,200 ms, depending on the stimulus onset asynchrony (SOA), a target appeared in one of the two boxes. The target was a white dot subtending 1° of visual angle, appearing at a distance of 12° from the centre of the screen. These two different SOAs were used in order to investigate the time course of the interference effect, if any. Indeed, it might be that the shorter SOA did not allow participants to disengage

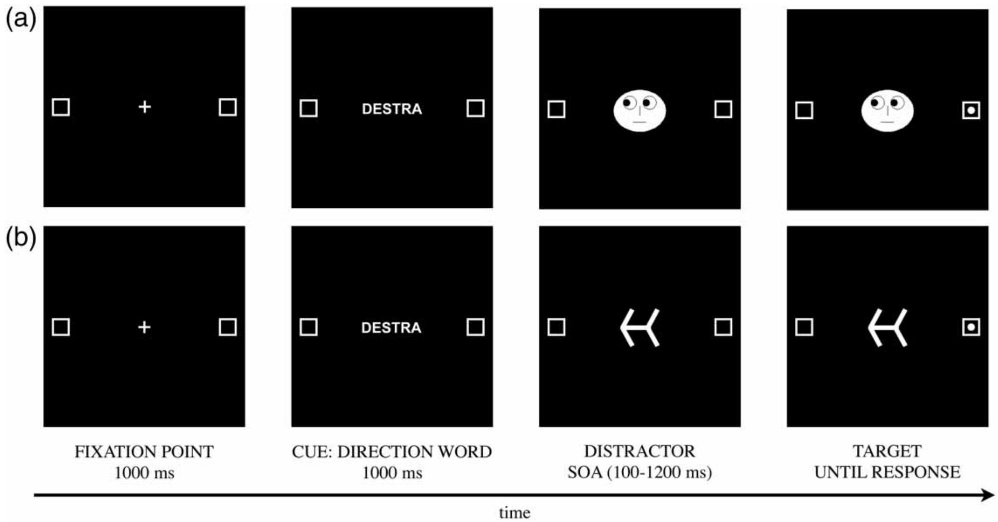

Figure 1. *Trial sequence for (a) Experiment 1a and (b) Experiment 1b. The word* "destra" *means right in Italian. A spatially incongruent trial is illustrated in both panels. Stimuli are not drawn to scale.*

attention from the location signalled by the distractor and reorient it to the location signalled by the word on spatially incongruent trials. In contrast, when participants had 1,200 ms between distractor onset and target onset, they could have enough time to reorient attention towards the location signalled by the word on spatially incongruent trials.

Participants went through 288 trials divided into four different blocks of 72 trials each. One third of all the trials (i.e., 96 trials, 24 for each block) were target-absent catch trials. There were potentially 48 data points for each relevant condition of the experimental design—namely, for each SOA (100 ms versus 1,200 ms) and congruency level (congruent versus incongruent). Gaze direction was randomized, and it pointed left or right with the same probability. The target had the same probability of appearing on the right or on the left throughout each block. Catch trials and experimental trials were randomly presented, but their proportion was constant in each block. Participants were explicitly told that the direction word was 100% predictive of target location. They were instructed to ignore gaze distractors and to press the spacebar using their dominant hand as fast as possible each time they saw the target on the screen. Finally, participants were required to refrain from responding and to wait for the next trial to begin when a catch trial was displayed. If the target was shown, and participants' response was not provided in 2,000 ms, the next trial began.

Results and discussion

In this and all the subsequent experiments, data were collapsed across gaze direction and target location, and a new variable called congruency was obtained. On congruent trials, targets appeared in locations that were congruent with gaze direction. On incongruent trials, targets appeared in the opposite location. Trials in which an error was committed were discarded from the analyses (0.2%). Both trials in which participants omitted to press the space bar in response to target appearance and responses on catch trials were considered as errors. Accuracy was not analysed given the low percentage of errors committed by participants. Participants failed to maintain fixation within 2° of the fixation point on 7% of the total trials.

A 2 (congruency: congruent trials versus incongruent trials) × 2 (SOA: 100 versus 1,200 ms) repeated measures analysis of variance (ANOVA) was performed on mean RTs. A main effect of congruency emerged, $F(1, 27) = 7.894$, *MSE* = 117.05, $p = .009$, showing that participants responded faster to congruent targets (M = 393 ms; $SE = 15$) than to incongruent targets (M = 398 ms; $SE = 15$; see Figure 2, Panel a). A main effect of SOA emerged, $F(1, 27) = 22.727$, $MSE = 1{,}470.13$, $p < .001$, probably reflecting the classic warning effect (e.g., Sanders, 1975). No interaction between congruency and SOA was found, $F(1, 27) = 0.523$, $MSE = 176.25$. Nonetheless, one-tailed t tests were performed to establish whether the interference effect was significant at each SOA. These revealed that interference was close to significance at the 100-ms SOA, $t(27) = 1.376$, $p = .09$, and statistically significant at the 1,200-ms SOA, $t(27) = 2.114$, $p = .02$.

This pattern suggests that gaze triggered an automatic attention shift in the signalled direction: Indeed, participants were faster in detecting the target on congruent trials than on incongruent trials, probably because attention was already engaged in the upcoming target location. Moreover, the nonsignificant interaction between congruency and SOA suggests that attention shifts triggered by gaze were early rising and long lasting.

In order to ascertain whether failures to maintain fixation showed a spatial bias congruent with gaze direction, a t test was performed on the number of eye movements with congruency (congruent trials versus incongruent trials) as factor. SOA was not included as factor in this analysis and in those of the subsequent experiments, as failures to maintain fixation at the 100-ms SOA were rare. The results showed no significant spatial bias, $t(27) = 0.235$.

EXPERIMENT 1B

Method

Participants

Thirty students (20 females) from the University of Padua participated in the experiment on a voluntary basis. Their mean age was 24.77 years. All participants had normal or corrected-to-normal vision. None of them had taken part in the previous experiment.

Apparatus, stimuli, and procedure

Everything was the same as that in Experiment 1a, except for the schematic face that was replaced by an arrow pointing to the left or to the right. The arrow was drawn so as to occupy the same area as the schematic face—namely, 3.7° in width and 3.2° in height, with a symmetric tale and head in order to be comparable to the two eyes conveying directional information (see Figure 1, Panel b).

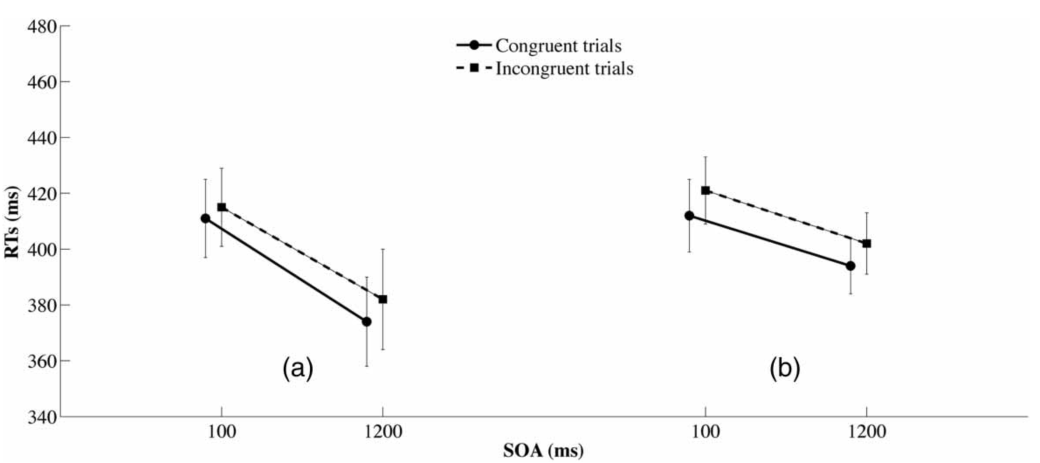

Figure 2. *Mean RTs (response times) for congruent and incongruent trials as a function of SOA (stimulus onset asynchrony) in (a) Experiment 1a and (b) Experiment 1b. Error bars indicate standard errors.*

Results and discussion

Participants committed no errors. Eye movement data from one participant were lost due to a hardware failure. Participants failed to maintain fixation on 20.2% of the total trials.

A 2 (congruency: congruent trials versus incongruent trials) × 2 (SOA: 100 ms versus 1,200 ms) repeated measures ANOVA was performed on mean RTs. A main effect of congruency emerged, $F(1, 29) = 27.555$, $MSE = 78.31$, $p < .001$, showing that participants were faster in detecting congruent targets ($M = 403$ ms; $SE = 10$) than incongruent targets ($M = 412$ ms; $SE = 10$; see Figure 2, Panel b). A main effect of SOA emerged, $F(1, 29) = 15.677$, $MSE = 666.15$, $p < .001$, probably reflecting the classic warning effect (e.g., Sanders, 1975). No interaction between congruency and SOA was found, $F(1, 29) = 0.239$, $MSE = 142.04$. The t tests confirmed that interference was significant at both the 100-ms SOA, $t(29) = 3.808$, $p < .001$, and the 1,200-ms SOA, $t(29) = 2.531$, $p = .008$. The results basically mirrored those obtained with a gaze distractor in Experiment 1a. Indeed, participants were faster detecting targets at congruent locations than at incongruent locations. This finding seems to indicate that participants shifted attention in the direction signalled by the arrow, and, for this reason, they were slower at detecting the target when it appeared in the opposite location to that signalled by the arrow. As for Experiment 1a, no interaction between SOA and congruency emerged, and, thus, participants were not able to suppress the attentional shift triggered by the arrow irrespective of whether the target appeared 100 or 1,200 ms after distractor onset.

In order to ascertain whether failures to keep fixation showed a spatial bias congruent with arrow direction, a t test was performed on the number of eye movements, with congruency as factor. Participants made more erroneous eye movements on spatially congruent ($M = 31.4$; $SE = 7.4$) than on incongruent trials ($M = 26.9$; $SE = 7.1$), $t(28) = 2.41$, $p < .05$. This pattern is in line with that reported by Kuhn and Kingstone (2009), showing that arrow distractors tend to activate automatic oculomotor responses.

In order to compare the RT effects obtained in Experiments 1a and 1b, a 2 (congruency: congruent trials versus incongruent trials) × 2 (SOA: 100 ms versus 1,200 ms) × 2 (experiment: 1a versus 1b) mixed-design ANOVA was conducted on mean RTs. Neither the main effect of experiment nor the interactions involving congruency were significant, $ps > .3$, demonstrating that the ability of gaze and arrow cues to elicit an automatic attentional shift was similar in the two experiments. Importantly, the absence of a main effect of experiment suggests that there was no significant difference in RTs between Experiments 1a and 1b. Therefore, even though participants committed no errors in Experiment 1b, their performance in terms of RTs was comparable to that in Experiment 1a, which seems to suggest that response strategies were similar in the two experiments.

In the next two experiments, one involving gaze and the other arrows, a different manipulation was used with respect to Experiments 1a and 1b. Indeed, the information about the future location of the target was provided using a block-by-block manipulation. The future location of the target was kept constant within each block (i.e., the same spatial set was used throughout a block of trials), and, thus, participants did not have to update the information about the location of the target on every trial as indicated by the direction word. This means that participants could shift attention in advance to a particular location without the need to wait for the direction word. Gaze distractors were used in Experiment 2a, whereas arrow distractors were used in Experiment 2b.

EXPERIMENT 2A

Method

Participants

Thirty-four students (18 females) from the University of Padua participated in the experiment on a voluntary basis. Their mean age was 22.18 years. All participants had normal or corrected-to-normal vision. None of them had taken part in the previous experiments.

Apparatus, stimuli, and procedure

Apparatus and stimuli were the same as those in Experiment 1a. Procedure was changed in that the indication about the future location of the target was given on a block-by-block basis. The experiment comprised 288 trials, divided into four blocks of 72 trials each. One third of all the trials (i.e., 96 trials, 24 for each block) were catch trials. Considering the whole experiment, there were potentially 48 data points for each critical condition—namely, for each SOA and congruency level. Before beginning the task, participants were informed about the future location of the target (i.e., left or right) for the next 72 trials. Half of the participants completed the blocks in this sequence: target on the right, target on the left, target on the right, and target on the left. The other half of participants completed the four blocks in the reverse order.

Results and discussion

Trials in which an error was committed were discarded from the analyses (0.2%). Accuracy was not analysed given the low percentage of errors committed by participants. Eye movement data from one participant were lost due to a hardware failure. Participants failed to maintain fixation on 5.9% of the total trials.

A 2 (congruency: congruent trials versus incongruent trials) × 2 (SOA: 100 ms versus 1,200 ms) repeated measures ANOVA was performed on mean RTs. A main effect of congruency emerged, $F(1, 33) = 7.760$, $MSE = 157.93$, $p = .009$, showing that participants responded faster to congruent targets ($M = 419$ ms; $SE = 11$) than to incongruent targets ($M = 425$ ms; $SE = 11$; see Figure 3, Panel a).

A main effect of SOA emerged, $F(1, 33) = 5.804$, $MSE = 1,020.32$, $p = .022$, probably reflecting a warning effect (e.g., Sanders, 1975). No interaction between congruency and SOA was found, $F(1, 33) = 0.933$, $MSE = 315.32$. The t tests showed that interference was significant only for the 1,200-ms SOA, $t(33) = 2.063$, $p = .02$, although means for congruent ($M = 427$ ms, $SE = 13$) and incongruent trials ($M = 430$ ms, $SE = 12$) at the 100-ms SOA were in the expected direction. Overall, similar to previous experiments, participants were faster in detecting congruent targets than incongruent targets. The results indicate that, even when participants were informed that the location of the upcoming target was constant for a whole block, a gaze distractor was able to trigger an automatic attentional shift towards the signalled location. Moreover, such a pattern was independent of SOA to a large extent.

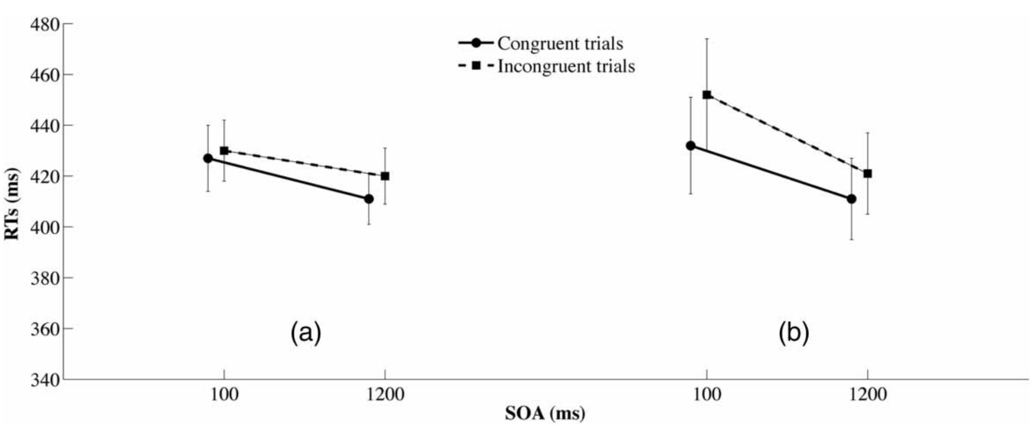

Figure 3. *Mean RTs (response times) for congruent and incongruent trials as a function of SOA (stimulus onset asynchrony) in (a) Experiment 2a and (b) Experiment 2b. Error bars indicate standard errors*

Participants were unable to ignore the information provided by the distractor when the target appeared 1,200 ms after distractor onset, when they were likely to have sufficient time to ignore the information conveyed by the distractor and shift attention towards the upcoming target location.

In order to ascertain whether failures to keep fixation showed a spatial bias congruent with gaze direction, a t test was performed on the number of eye movements with congruency as factor. No significant spatial bias was observed, $t(32) = 0.295$.

EXPERIMENT 2B

Method

Participants

Twenty-one students (11 females) from the University of Padua participated in the experiment on a voluntary basis. Their mean age was 22.29 years. All participants had normal or corrected-to-normal vision. None of them had taken part in the previous experiments.

Apparatus, stimuli, and procedure

Apparatus and stimuli were the same as those in Experiment 1b. Procedure was the same as that in Experiment 2a in that the information about the future position of the target was given to participants on a block-by-block basis.

Results and discussion

Trials in which an error was committed were discarded from analyses (0.2%). Accuracy was not analysed given the low percentage of errors committed by participants. Participants failed to maintain fixation on 4% of the total trials.

A 2 (congruency: congruent trials versus incongruent trials) × 2 (SOA: 100 ms versus 1,200 ms) repeated measures ANOVA was performed on mean RTs. A main effect of congruency emerged, $F(1, 20) = 13.280$, $MSE = 354.99$, $p = .002$, showing that participants were faster in detecting congruent targets ($M = 422$ ms; $SE = 17$) than incongruent targets ($M = 437$ ms; $SE = 18$; see Figure 3, Panel b).

A main effect of SOA emerged, $F(1, 20) = 6.322$, $MSE = 2{,}329.29$, $p = .021$, probably reflecting a warning effect (e.g., Sanders, 1975). No interaction between congruency and SOA was found, $F(1, 20) = 2.149$, $MSE = 272.28$. The t tests confirmed that interference was significant at both the 100-ms SOA, $t(20) = 2.98$, $p = .003$, and the 1,200-ms SOA, $t(20) = 2.64$, $p = .008$. Consistent with the results of the previous experiments, participants responded faster to congruent targets than to incongruent targets. This suggests that arrows triggered a shift of attention in the signalled direction even though they were totally task irrelevant, and, thus, on incongruent trials, participants were slower at detecting the target because attention was engaged to the opposite location. Importantly, this happened even though participants were informed about the location of the upcoming target at the beginning of each block. Furthermore, the shift of attention triggered by the distractor was early rising and long lasting, in that it was observable both with 100-ms and 1,200-ms SOAs.

In order to ascertain whether failures to keep fixation showed a spatial bias congruent with arrow direction, a t test was performed on the number of eye movements with congruency as factor. No significant spatial bias emerged, $t(20) = 0.066$.

In order to compare results obtained in Experiments 2a and 2b, a 2 (congruency: congruent trials versus incongruent trials) × 2 (SOA: 100 ms versus 1,200 ms) × 2 (experiment: 2a versus 2b) mixed-design ANOVA was conducted on mean RTs. The only significant effect involving experiment was the Experiment × Congruency interaction, $F(1, 53) = 4.506$, $MSE = 232.29$, $p = .038$, indicating that, even though the interference effect proved to be significant for both gaze and arrow distractors, it was larger for arrows (Experiment 2b) than for gaze (Experiment 2a). This finding is somewhat surprising in light of previous results showing that gaze-mediated orienting, a presumably innate phenomenon (e.g., Farroni, Massaccesi, Pividori, & Johnson, 2004), is more automatic than arrow-driven orienting, a learned phenomenon (e.g., Friesen et al., 2004), and it seems to undermine the view of eyes as a special stimulus (e.g., Friesen & Kingstone, 1998). However, this pattern is not entirely novel, in that it has already been reported in a sample of healthy participants used as a control group in a study aimed to address gaze- and arrow-mediated orienting in schizophrenic patients (Akiyama et al., 2008). Moreover, Kuhn et al. (2011) have recently investigated differences in oculomotor responses elicited by gaze and arrow distractors between children and adults and reported stronger interference for arrows than for gaze. This pattern seems to be consistent with the one that emerged in the analyses of failures to maintain fixations in the present experiments. Indeed, the only case in which a significant directional bias on involuntary saccades was observed is related to arrow distractors (Experiment 1b).[1] In sum, it seems that the stronger interference effect for arrows that emerged in the present research is not an isolated case. Future studies will need to address this issue in more detail to identify experimental conditions in which arrows may prove to be more powerful than gaze.

A possible criticism to the whole pattern emerging from the experiments reported so far is that because we used a simple detection task with a large number of catch trials (33% of total trials), participants may have decided to disregard the information conveyed by the direction word (or instruction cue), which was 100% predictive of target location only on 66% of the total trials (i.e., only on target-present trials). Had participants used this strategy, then the current pattern of robust gaze- and arrow-mediated orienting would not be particularly innovative with respect to previous existing evidence (e.g., Ristic et al., 2002; Tipples, 2002). In this regard, however, our participants were not informed about the exact frequency of catch trials, which makes it unlikely that they deliberately chose to ignore the direction word (or the provided instructions). Nevertheless, in order to definitely rule out this alternative interpretation of the data, we carried out an additional experiment combining the procedure used in Experiments 1a and 1b with a discrimination task in which no catch trials were present. This manipulation made the word cue genuinely predictive in all trials. In addition, both gaze and arrow distractors were used, allowing for a within-participants comparison.

EXPERIMENT 3

Method

Participants

Sixteen students (8 females) from the University of Padua participated in the experiment on a voluntary basis. Their mean age was 25 years. All participants had normal or corrected-to-normal vision. None of them had taken part in the previous experiments.

Apparatus, stimuli, and procedure

These were the same as those in Experiments 1a and 1b (i.e., adopting a trial-by-trial manipulation), with the following exceptions. The peripheral boxes were placed at a distance of 4° from the fixation point. Gaze and arrow distractors were tested in different blocks of trials. The target was a white letter (L or T), subtending 1.2° in height and 1° in length. The participants were asked to perform a letter discrimination task. They responded using their index fingers positioned on a standard keyboard. Response buttons were arranged orthogonally (i.e., up versus down) to the position of the target letters (i.e., left versus right) to minimize effects related to stimulus–response mapping (e.g., Galfano, Mazza, Tamè, Umiltà, & Turatto, 2008). Response button assignment was counterbalanced across participants. The intertrial interval was 1,000 ms. There were six blocks of 48 trials each. Three blocks contained gaze distractors, and three blocks contained arrow distractors. Participants always completed three blocks with the same distractor type before switching to the other distractor. The order of distractor types was counterbalanced across participants.

[1] One possibility to account for this spatial bias is that, following the premotor theory of attention (e.g., Rizzolatti, Riggio, Dascola, & Umiltà, 1987), while participants perceive the word cue and shift attention accordingly, saccadic eye movements to the attended location are inhibited. This inhibition of saccades towards the attended location may result in the oculomotor system being vulnerable to other cues (such as the arrow distractor) activating responses to the unattended location.

Results and discussion

Participants failed to maintain fixation on 31.5% of the total trials. In addition, data from one participant were also excluded from the analyses because of difficulties in complying with the instructions of maintaining fixation and responding as fast as possible (mean RTs were more than 2 standard deviations above the mean of the remaining sample).

A 2 (congruency: congruent trials versus incongruent trials) × 2 (SOA: 100 ms versus 1,200 ms) × 2 (distractor type: gaze versus arrow) repeated measures ANOVA was performed on mean RTs for correct responses. A main effect of congruency emerged, $F(1, 14) = 10.951$, $MSE = 716.63$, $p = .005$, due to an overall interference effect reflecting faster responses to congruent targets ($M = 608$ ms, $SE = 28$) than to incongruent targets ($M = 625$ ms, $SE = 30$). SOA also yielded a significant main effect, $F(1, 14) = 40.720$, $MSE = 1{,}673.01$, $p < .001$, probably reflecting a warning effect (Sanders, 1975). In line with previous experiments, no significant Congruency × SOA interaction was observed, $F(1, 14) = 1.335$, $MSE = 487.528$. Critically, neither the Distractor Type × Congruency interaction nor the triple interaction were statistically significant, $F(1, 14) = 0.003$, $MSE = 730.894$, and $F(1, 14) = 0.778$, $MSE = 793.794$, respectively. The t tests confirmed that interference was significant at both the 100-ms SOA, $t(14) = 2.937$, $p = .005$, and the 1,200-ms SOA, $t(14) = 2.639$, $p = .009$, for gaze (see Figure 4, Panel a). In the case of arrows, interference was significant only at the 1,200-ms SOA, $t(14) = 1.806$, $p = .04$, although means for congruent ($M = 653$ ms, $SE = 36$) and incongruent trials ($M = 660$ ms, $SE = 33$) at the 100-ms SOA were in the expected direction (see Figure 4, Panel b).

An ANOVA with the same factors as those above was conducted on the percentage of incorrect keypresses (5.06% of the total trials). No source of variance was statistically significant. Yet, participants tended to commit more errors on incongruent ($M = 5.52\%$, $SE = 1.11$) than on congruent trials ($M = 4.61\%$, $SE = 1.15$), although the main effect of congruency was not significant, $F(1, 14) = 2.005$, $MSE = 12.196$. Importantly, this pattern makes it unlikely that the present results can be accounted for by any speed–accuracy trade-off.

In order to ascertain whether failures to keep fixation showed a spatial bias congruent with distractor direction, separate t tests for each distractor type were performed on the number of eye movements with congruency as factor. No significant spatial bias emerged for either gaze, $t(14) = 0.956$, or arrows, $t(14) = 1.144$.

The RT pattern that emerged in the present experiment confirms and extends the results obtained in Experiments 1a and 1b, demonstrating that our participants were not able to prevent shifting attention following the spatial vector indicated by both gaze and arrows, even when they were fully aware that the best strategy would be to ignore these distracting cues. The present findings strongly support the view that the use of a high percentage of catch trials in the simple detection experiments is unlikely to have influenced participants' strategies while performing the task. Finally, these results are important in suggesting that gaze and arrows push attention in a strongly automatic manner, and to a comparable extent, in a within-participants experimental design.[2]

[2] Although not strictly relevant to our hypotheses, in order to further test possible differences between the effects exerted by gaze and arrow distractors, for all studies we performed additional analyses on RTs including the between-participants factor of gender (the number of female and male participants was roughly balanced in our experiments). Bayliss, di Pellegrino, and Tipper (2005) have provided evidence suggesting that, compared to female participants, males show a reduced cueing effect for both gaze and arrows. According to the authors, this pattern may reflect sex differences in responding to communicative signals. In brief, the only significant interaction involving gender as factor was observed in Experiment 1a: Gender × Congruency, $F(1, 26) = 5.957$, $p < .02$. The t tests indicated that female participants were faster in detecting congruent targets ($M = 420$ ms, $SE = 25$) than incongruent targets ($M = 431$ ms, $SE = 25$), $t(13) = 3.864$, $p = .002$. In contrast, RTs for congruent targets ($M = 364$ ms, $SE = 13$) and incongruent targets ($M = 366$ ms, $SE = 14$) were not statistically different for male participants, $t(13) = 0.438$. This pattern is partially consistent with that reported by Bayliss et al. (2005), because a difference in attention shifting between female and male participants was clearly visible at least for gaze distractors in Experiment 1a. However, it should be noted that the lack of other gender differences in the present experiments may simply reflect a lack of power, in that Bayliss et al. (2005) tested much larger samples.

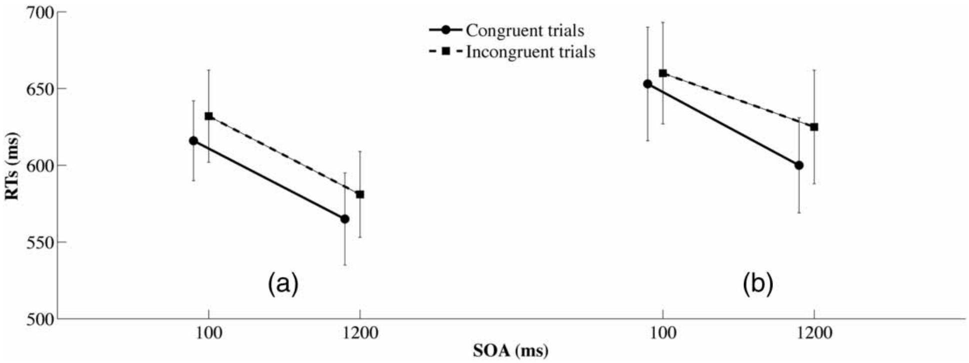

Figure 4. *Mean RTs (response times) for congruent and incongruent trials as a function of SOA (stimulus onset asynchrony) in Experiment 3 for (a) gaze distractors and (b) arrow distractors. Error bars indicate standard errors.*

GENERAL DISCUSSION

In recent years, a flourishing literature (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Tipples, 2002) has challenged the traditional view, according to which central cues elicit voluntary orienting whereas peripheral cues trigger automatic orienting of attention. On the one side, evidence has been reported showing that gaze triggers a reflexive shift of attention. On the other side, arrows have also been shown to elicit automatic shifts of attention (e.g., Tipples, 2002), even though some studies suggested that arrow-mediated orienting is less automatic than gaze-mediated orienting (e.g., Friesen et al., 2004).

The aim of the present experiments was to compare orienting of attention triggered by gaze and arrows in an attempt to test a strong version of the resistance to suppression criterion. In particular, in Experiments 1a and 1b, participants were informed with 100% certainty about the upcoming target location on a trial-by-trial basis by means of a direction word presented at the beginning of each trial. In Experiments 2a and 2b, the location of the target was constant for the whole duration of a block, and participants were informed about the target location at the beginning of each block. Gaze (Experiments 1a and 2a) and arrows (Experiments 1b and 2b) were distractors that were not informative as to target location and completely irrelevant for the task. The aim was to test whether the distractors were able to influence participants' allocation of attention under conditions in which participants were strongly motivated to ignore them. The results consistently showed that participants were faster in detecting the target when the location signalled by the distractor and the upcoming target location were congruent than when they were incongruent. This finding suggests that both gaze and arrow distractors triggered an automatic shift of attention in the cued location: When the target appeared in the location indicated by the distractor (i.e., congruent trials), participants were faster in detecting the target because their attention was already set in that location. When the target appeared in the opposite location with respect to the directional information provided by the distractor (i.e., incongruent trials), participants were slower in that they had to disengage attention from the incongruent location and reorient it to the target location. Thus, the distractors triggered a shift of attention, which probably interfered with efficient target detection. This effect was significant for both gaze and arrows, thus suggesting that neither cue can be ignored. In Experiment 3, we used a within-participants design and combined a trial-by-trial manipulation with a letter discrimination task. This was done in order to rule out an alternative account for the observed pattern that would ascribe the presence of significant interference effects to participants adopting the strategy to ignore the direction word (or instruction cues). According to this explanation, participants might have decided not to use the information about target location because of the relatively high number of catch trials. In other words, although both word and instruction cues were 100% predictive of target location, the presence of 33% of catch trials would have resulted in making them predictive of target location on 66% of total trials. Results from the control experiment, in which no catch trials were used, ruled out this alternative account and confirmed the presence of robust interference effects for both gaze and arrow distractors.

Interestingly, in all five experiments, the interference effect was not modulated by the SOA between distractor and target onset. Two different SOAs were used: a very brief SOA of 100 ms and a long SOA of 1,200 ms. The consistent lack of interaction between congruency and SOA probably reflects the fact that attention was automatically pushed to the location signalled by the distractor, and this effect was both early rising and long lasting. Indeed, when the SOA between distractor and target onset was 100 ms, participants probably did not have enough time to disengage attention from the location indicated by the distractors and reorient it to the location in which the target was expected to appear. Surprisingly, the interference effect was observable also when the SOA was 1,200 ms. The *t* tests seem to indicate that it was even stronger than at the 100-ms SOA. In this case, participants had sufficient time to reorient attention towards the location of the upcoming target. Yet, even after 1,200 ms from distractor onset, our results suggest that participants' attention was probably still engaged in the location signalled by the distractor. This latter pattern is not consistent with evidence reported by Frischen and Tipper (2004). In their study, they addressed inhibitory after-effects of gaze-mediated orienting. To this end, they used several types of task and observed that, unlike the present results, RTs for congruent and incongruent trials showed no significant differences with a 1,200-ms SOA. One possibility is that this discrepancy is due to the different experimental paradigm implemented in the current research. Future studies will address this issue more thoroughly.

The finding that the information conveyed by distractors interfered with the task indicates that orienting of attention mediated by both gaze and arrows resists suppression and can be defined as strongly automatic. Indeed, even though participants were informed with 100% certainty about the upcoming target location, and, thus, they were motivated to voluntarily attend to that location, results showed that they could not ignore the information conveyed by the distractors. However, it is important to point out that the similar behavioural effect obtained for gaze and arrows—namely, the elicitation of an automatic attention shift—does not necessarily imply that the underlying processes are the same for these two cue types. Indeed, arrows are able to elicit an automatic attention shift probably because they are a well-learned symbol, which conveys a strong spatial information that is reinforced every day, for instance by means of road signs. On the contrary, gaze is likely to trigger an automatic attention orienting because it may represent a special cue characterized by a strong biological significance given its relevance in everyday life (Ristic et al., 2002), and, for such reasons, humans would have developed a reflexive attention shift in response to the view of an averted gaze that would also be supported by a dedicated neural circuit (Hietanen, Nummenmaa, Nyman, Parkkola, & Hämäläinen, 2006; but see C. M. Tipper, Handy, Giesbrecht, & Kingstone, 2008). Moreover, the presence of gaze-mediated orienting of attention in both newborns as young as 2 days old (e.g., Farroni et al., 2004) and several species of nonhuman primates (e.g., Deaner & Platt, 2003; Tomasello, Call, & Hare, 1998) suggests that this phenomenon can be defined as innate, thus reinforcing the special nature of gaze as compared to other cue types.

Previous studies comparing orienting of attention elicited by gaze and arrows have led to mixed results. In the present experiments, a stronger test of the resistance to suppression criterion was operationalized as compared to previous studies using counterpredictive cues (e.g., Friesen et al., 2004;

Tipples, 2008). Indeed, unlike counterpredictive cues that have to be processed in order to infer the most likely target location, in our experiments neither gaze nor arrows were useful in order to infer the target location. Participants were informed with 100% certainty about the upcoming target location by means of a direction word (or instructions provided at the beginning of a block of trials) and, therefore, were strongly motivated to voluntarily attend to that location. Nonetheless, the results showed that the mere view of gaze and arrows triggered an attention shift in the corresponding direction.

The paradigm that we have adopted is more similar to experiments using voluntary oculomotor responses in which gaze and arrows are presented as distractors (e.g., Kuhn & Benson, 2007). However, in the present research, an important change has been made: Indeed, in previous studies, participants were typically instructed to perform a saccade in a specific direction, depending on the colour of a geometric shape (e.g., Kuhn & Benson, 2007; Ricciardelli et al., 2002). In order to perform this task, participants had to learn an arbitrary association between a specific colour and a specific spatial vector and retrieve it from memory each time they saw the colour cue. In the present research, we adopted a more self-evident cue—namely, a direction word that does not require any artificial mapping in order to be processed. Moreover, arbitrary associations between a symbol and spatial information take time to develop and to become effective (Guzzon et al., 2010), whereas direction words trigger attention shifts even when uninformative as to target location (Hommel et al., 2001). Thus, the fact that both gaze and arrows interfered with attentional deployment even under conditions that were likely to strongly encourage attending to a specific location suggests that orienting of attention elicited by these two signals can be defined as strongly automatic.

It is worth noting, however, that the experimental procedure that was adopted in the present research was much simpler than situations we face in everyday life. Indeed, participants faced an environment in which gaze and arrows were not embedded in a complex context. We cannot rule out the possibility that results would change by adopting more ecological paradigms in which gaze and arrows are surrounded by other meaningful stimuli. Indeed, the salience of these two cues and, consequently, their ability in pushing attention might be influenced by the context. For instance, it has recently been shown that when gaze and arrows are presented in the same visual scene, gaze seems to receive a stronger attentional priority than arrows (Birmingham, Bischof, & Kingstone, 2009). In addition, even with a simple environment such as that characterizing a spatial cueing paradigm, evidence has been provided suggesting that gaze-mediated orienting can be modulated by social factors related to the identity of the cueing face and the identity of the participants (e.g., Dalmaso, Pavan, Castelli, & Galfano, in press; Pavan, Dalmaso, Galfano, & Castelli, 2011; Shepherd, Deaner, & Platt, 2006), probably because social variables deeply shape human relations and the perception that we have of the individuals conveying the gaze cues.

In conclusion, the present set of experiments, in which a stronger definition of automaticity was operationalized as compared to previous studies, demonstrated that eye gaze is not unique in eliciting a strongly automatic orienting of attention and that arrows are also able to induce a very similar effect.

Original manuscript received 24 May 2011
Accepted revision received 30 January 2012
First published online 19 April 2012

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