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Testing the effects of gaze distractors with invariant spatial direction on attention cueing

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Abstract

In four experiments, we tested the boundary conditions of gaze cueing with reference to the resistance to suppression criterion of automaticity. Participants were asked to respond to peripheral targets preceded by a central gaze stimulus. In one condition, gaze direction was random and uninformative with respect to target location (intermixed condition), as in the typical paradigm. In another condition, gaze direction was uninformative and, crucially, it was also kept constant throughout the sequence of trials (blocked condition). In so doing, we aimed at maximally reducing the informative value of the gaze stimulus since gaze would not only be task-irrelevant, but it would also provide no sudden and unpredictable information. Across the four experiments, the results showed a strong gaze-cueing effect. More specifically, a comparable gaze cueing emerged in the blocked condition and in the intermixed condition. These findings are consistent with the idea that gaze cueing is resistant to suppression and are discussed in relation to current views of the automaticity of gaze cueing.

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Introduction

Gaze cueing refers to the observation that manual response times (RTs) to peripheral targets are higher when they are preceded by uninformative central gaze stimuli looking at opposite locations (spatially incongruent trials) as compared to gaze stimuli looking towards the target location (spatially congruent trials). Since the first empirical reports (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; see McKay et al., 2021, for a review), research has attempted to understand the extent to which such a phenomenon can be considered automatic. The main purpose of the present study is to further explore this issue and test some boundary conditions of gaze cueing. Importantly, automaticity cannot be defined in an all-or-none fashion, but it is indeed a multifaceted construct and has been addressed following different avenues (e.g., Bargh, 1994; Jonides, 1981). These have mainly focused on capacity, awareness, and expectancies/resistance to suppression. Critically, research findings reported by studies aimed at testing these criteria do not always provide internally consistent outcomes.

The idea underlying the capacity criterion is that automatic processes should be relatively insensitive to the availability of cognitive resources. In the context of spatial cueing of attention, this issue has been almost invariably investigated in dual-task paradigms (e.g., Jonides, 1981). The first attempt to examine the effect of processing load on gaze cueing was conducted by asking participants to perform a gaze-cueing paradigm in a single or a dual-task condition (Law et al., 2010). In the dual-task condition, working memory was taxed with either a verbal or a spatial concurrent task. A reliable gaze-cueing effect of similar magnitude was observed irrespective of whether the gaze-cueing paradigm was performed in the single- or the dual-task condition, providing tentative evidence for automaticity. Subsequent studies using more demanding concurrent tasks, however, have shown that gaze cueing can be significantly affected under high load (Bobak & Langton, 2015; see also Pecchinenda & Petrucci, 2016).

Automaticity has also been addressed by examining whether the putatively automatic phenomenon can be observed independently of whether the triggering stimulus (i.e., the spatial cue

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in spatial cueing paradigms) is consciously perceived or not. Sato et al. (2007) have provided initial evidence that gaze-cueing effects can be observed in tasks requiring manual responses even when participants are unlikely to be consciously aware of the gaze stimulus (but see Al-Janabi & Finkbeiner, 2012, 2014). However, in a recent registered report, Dalmaso et al. (2023) have shown that masked gaze stimuli do not interfere with spatial orienting using an oculomotor task. Taken together, the results summarised above provide a seemingly scattered picture with respect to the automaticity of gaze cueing when the role of cognitive resources and awareness is considered.

More consistent evidence stems from a different issue related to automaticity, which is particularly relevant for the present study, namely the role of expectancies. In this regard, the criteria for automaticity have been declined according to different versions ranging from softer to more rigid constraints. A soft version is that attention shifts elicited by gaze stimuli can be defined as automatic if they occur even when they are not useful for performing the task. This version of the criterion is easily met by gaze cueing in that there is abundant evidence showing that, with two possible target locations, gaze cueing emerges even when participants are explicitly informed that gaze direction correctly points to the location of the upcoming target only on half of the trials and there is therefore no correlation between gaze direction and target location (e.g., Friesen & Kingstone, 1998; Hietanen & Yrttimaa, 2005).

Further evidence consistent with automaticity comes from studies with four possible target locations, in which gaze direction was congruent with the target location in only 25% of the total trials (e.g., Cole et al., 2015; Langton & Bruce, 1999). In these studies, robust gaze-cueing effects emerged, suggesting that gaze biased spatial attention even when paying attention to gaze was known to be not only task-irrelevant but also potentially disruptive for the task at hand (i.e., being predictive in only 25% of total trials). Other studies assessing the impact of expectancies have introduced a manipulation in which participants are informed that gaze stimuli are counter-predictive with respect to target location (e.g., a gaze averted to the left informs participants that the target is more likely to

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appear on the right; Driver et al., 1999; Friesen et al., 2004; Tipples, 2008). These studies showed that, at least at short Stimulus Onset Asynchronies (SOAs), participants cannot help but shifting their attention towards the location indicated by the gaze, even if they are fully aware that the gazed-at location is the least likely location for the target to appear. However, a side effect characterising this manipulation is that gaze direction is made task-relevant (i.e., the participant is somehow urged to process eye gaze in order to make predictions about the most likely target location), and therefore participants have no motivation to suppress the information provided by gaze.

In subsequent works, the criterion has been focused more directly with the view that shifts of attention are genuinely automatic when they occur under conditions in which participants are fully aware that gaze processing is detrimental for the task at hand. In such situations, the occurrence of attention shifts would be "resistant to suppression" (Jonides, 1981). Galfano et al. (2012) tested the boundary conditions of gaze cueing by devising an experimental setting in which participants were informed with 100% certainty about the location of the upcoming target by means of a word which preceded the averted gaze stimulus on a trial-by-trial basis. The results showed a robust gaze-cueing effect. Interestingly, such a phenomenon emerged even when participants knew that target location remained constant throughout a block of trials, and regardless of SOA. These findings were interpreted as strong evidence for resistance to suppression. More recently, experimental paradigms employing saccadic responses have been proposed and they showed conceptually consistent findings (Dalmaso et al., 2020a) using the oculomotor interference paradigm proposed by Ricciardelli et al. (2002; also see Kuhn & Benson, 2007).

The aim of the present work is to test an even more extreme condition for the emergence of gaze cueing and to provide further evidence to qualify the automaticity of this phenomenon in relation to the resistance to suppression criterion. The studies reviewed so far were mostly based on experimental paradigms that share one common feature, namely the task-irrelevant nature of the gaze stimulus (e.g., Friesen & Kingstone, 1998; Galfano et al., 2012; Hietanen & Yrttimaa, 2005). Indeed,

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gaze direction in those studies was always uninformative in relation to the task at hand. However, in each single trial, gaze conveys some kind of novel information in that it randomly shifts either leftwards or rightwards throughout the series of trials. In other words, participants are presented with an unpredictable spatial vector that they would have to ignore because of its non-diagnostic value in relation to the location of the target, but gaze, in itself, abruptly provides additional (unpredictable) spatial information. Efficient cognitive mechanisms should nonetheless balance between the capacity to shield against the interference of task-irrelevant information and the processing of novel stimuli that appear in the environment. This implies that the overall potential informativeness and meaning of a novel information can only be assessed if the stimulus is somehow processed. A further step towards the analysis of the extreme boundaries of the automaticity of gaze cueing would thus be to maximally reduce the informativeness of the gaze stimulus in the experimental context.

One way to drain the gaze stimulus of any informative value would be to keep its direction constant throughout the sequence of trials. In so doing, gaze would not only be task-irrelevant, but it would not provide any novel and unpredictable information. Two hypotheses can be put forward. On the one hand, participants may rapidly learn that the gaze stimulus merely represents an invariable event conveying invariant and task-irrelevant information so that, in turn, they may start to efficiently disregard it. Hence, it might be expected that gaze cueing would be significantly reduced as compared to a condition in which gaze direction varies unpredictably from trial to trial. On the other hand, if gaze is indeed a potent superstimulus, one might predict that it continues to affect participants' attention orienting even after repeated presentation of faces with the gaze always averted in the same direction. In this latter scenario, the magnitude of gaze cueing should not differ as a function of whether gaze stimuli are displayed with an invariant spatial direction or not.

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Experiment 1: Real face stimuli

Participants completed a gaze-cueing task in which, in two blocks of trials, the central face could unpredictably gaze either leftwards or rightwards with the same probability (i.e., the intermixed condition), while in the remaining two blocks of trials (i.e., the blocked condition), the central face gazed always in the same direction (i.e., leftwards/rightwards in a blockwise fashion). In so doing, we explored whether the gaze-cueing effect, which was expected to be robust and reliable in the intermixed condition, was attenuated in the blocked condition. Real faces were used to convey eye gaze stimuli.

Method

Participants

We followed the guidelines proposed by Brysbaert and Stevens (2018) for linear mixed-effect models (see the results section) to determine the minimum number of participants needed to be tested. According to these guidelines, 1600 observations (at least) per experimental cell should be recorded. On the basis of our experimental design, we established that the minimum number of participants was equal to fifty. All participants completed the task on a voluntary basis (no incentives were offered) and were recruited within the student population of the University of Padova. After one week during which no new data were recorded, and once checked that the minimum number of participants was reached, we closed data collection. Our final sample was composed of 80 individuals (*Mean age* = 22 years, *SD* = 3.14, 35 males). Informed consent was obtained before the experiment. The study was approved by the Ethics Committee for Psychological Research of the University of Padova, and was conducted in accordance with the Declaration of Helsinki.

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Apparatus, stimuli, and procedure

PsychoPy (Peirce et al., 2019) was used to develop the experiment, which was then delivered online using the Pavlovia platform (Bridges et al., 2020). The experiment could be completed only by using a standard computer. Four faces (width: 500 px; height: 500 px) depicting two males and two females were extracted from the MR2 database (Strohminger et al., 2016). For each face there was one version with direct gaze, and two other versions, created with photo editing software, with gaze averted leftwards and rightwards (e.g., Dalmaso et al., 2021). Examples of trials are reported in Figure 1. All stimuli were presented on a white background. At the beginning of each trial, a black fixation cross (Arial font, 0.1 normalised units) appeared at the centre of the screen for 500 ms, and it was followed by a central face with direct gaze for 900 ms. Then, the same face appeared with the gaze deviated either leftwards or rightwards. After a variable time duration (SOA) of either 200 ms or 700 ms, a black target line segment (width: 40 px; height: 12 px) appeared either leftwards or rightwards (±0.8 normalised units) with respect to the centre of the screen until a manual response was detected (timeout: 2000 ms). The vertical position of the target matched that of the eye-gaze stimulus. The target line segment could be oriented either vertically or horizontally, and the participants were required to discriminate, as fast and accurately as possible, its orientation by pressing one of two possible keys (i.e., F or K, counterbalanced across participants). They were also told to ignore the face and its gaze direction, since it was not reliably associated with the spatial location of the upcoming target, and to look at the centre of the screen for the whole duration of the trial. Both missed and wrong responses were signalled with a visual feedback (i.e., the black words 'TOO SLOW' or 'NO', respectively; Arial font, 0.1 normalised units) appearing centrally for 500 ms. There were four distinct blocks. In two consecutive blocks, the direction of the gaze (left or right) was random (i.e., the 'intermixed' condition). In another block, all faces looked leftwards, whereas, in the remaining block, all faces looked rightwards (i.e., the 'blocked' condition). The relative order of the two conditions and the one of the (invariant) direction of gaze in the blocked condition were

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counterbalanced across participants. All the other experimental conditions resulting from the manipulation of SOA and spatial congruency were presented in random order. An initial practice session (12 trials) was followed by the four experimental blocks (64 trials each; i.e., 256 experimental trials in total). The practice block changed depending on which specific experimental condition was presented first. After each block, a short break was allowed.

[Figure 1 about here]

Results

Trials with a missing response were rare (.19% of the trials) and they were not further analysed. Trials with a wrong response (4.45% of the trials) were discarded and analysed separately. Trials with a correct response and RTs smaller than 150 ms or greater than 1500 ms were considered outliers (see, e.g., Dalmaso et al., 2021) and discarded from the analyses (.29% of trials). All analyses were performed with R software (R Core Team, 2022). We considered as experimental factors congruency (2: congruent vs. incongruent), SOA (2: 200 vs. 700 ms) and condition (2: intermixed vs. blocked)[1].

The analyses of RTs of correct trials were performed by using a linear mixed effects model. The minimum number of observations per experimental cell was 2413, which guaranteed sufficient power. Based on the results of a likelihood ratio test, we focused on the model which included congruency, SOA, and condition, and their interactions, as fixed effects. The random effects were the intercepts for participants and face stimulus. We calculated effect sizes with a standard procedure to obtain a direct comparison with previous works investigating gaze cueing of attention. The main effect of congruency was significant, $F(1, 19380) = 39.238$, $p < .001$, $\eta^2_p = .349$, due to smaller RTs

[1] A preliminary analysis in which block order was also included as a factor did not reveal any significant interaction involving block order and spatial congruency (all *ps* > .366). Hence, block order was no longer considered in the analyses.

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on congruent trials (*M* = 576 ms, *SE* = 8.68) than on incongruent trials (*M* = 588 ms, *SE* = 8.68), as well as the main effect of SOA, $F(1, 19380) = 428.343$, $p < .001$, $\eta^2_p = .765$, due to smaller RTs at the longer SOA (*M* = 563 ms, *SE* = 8.68) than at the shorter SOA (*M* = 602 ms, *SE* = 8.68), and the main effect of condition, $F(1, 19381) = 19.681$, $p < .001$, $\eta^2_p = .046$, due to smaller RTs in the blocked condition (*M* = 578 ms, *SE* = 8.68) than in the intermixed condition (*M* = 587 ms, *SE* = 8.68). No other significant results emerged (*p*s > .232; see also Table 1).

Despite the low percentage of wrong responses, these were analysed with a mixed-effect logit model to exclude the presence of speed-accuracy trade-offs. The model included congruency, SOA, and condition, and their interactions, as fixed effects. The random effects were the intercepts for participants and face stimulus. The main effect of SOA was non-significant (*p* = .073), as well as all the other results (*p*s > .296).

[Table 1 about here]

Discussion

Gaze-cueing effects of similar magnitude emerged irrespective of condition. Hence, eye gaze can be thought as a stimulus conveying spatial information that is resistant to suppression despite being both task-irrelevant and, in the blocked condition, totally uninformative due to its invariant direction.

One may argue that the observation of a gaze-cueing effect in the blocked condition might reflect the adoption of a specific strategy rather than an automatic effect. Indeed, irrespective of whether gaze direction remained constant throughout a block or not, because target location was randomised, participants knew that gaze direction signalled the correct target location in half of the trials. In other words, the cost-benefit ratio for either attending or disregarding/suppressing the spatial

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information provided by gaze was the same. The lack of a clear unbalance in this ratio may thus have resulted in no strong motivation to suppress/disregard eye-gaze information also in the blocked condition. In the next experiment, we aimed to rule out this alternative account. Hence, we slightly modified the task by introducing an additional source of information with the goal of maximising the benefits of suppressing/ignoring the spatial information provided by the gaze stimulus. To this purpose, before the appearance of the gaze stimulus, a direction word (i.e., "left" or "right") appeared at the centre of screen indicating the exact location of the upcoming target with 100% certainty (also see Galfano et al., 2012). In so doing, attention could have been allocated towards the target location in advance, thus further weakening the relevance of the spatial information conveyed by the gaze stimulus.

Experiment 2: Real face stimuli and direction words

Method

Participants

Given that the experimental design was identical to Experiment 1, we decided to test an identical number of participants. Hence, a new sample composed of 80 individuals (*Mean age* = 24 years, *SD* = 2.9, 40 males) was recruited by using Prolific (compensation was £ 2,80). Only individuals living in Italy, whose mother language was Italian and with an age between 18 and 30 years, were allowed to take part, in order to obtain a comparable sample with the previous experiment. Informed consent was obtained before the experiment. The study was approved by the Ethics Committee for Psychological Research of the University of Padova, and was conducted in accordance with the Declaration of Helsinki.

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Apparatus, stimuli, and procedure

Everything was identical to Experiment 1, with the only exception that a direction word (i.e., "LEFT" or "RIGHT"; in Italian: "SINISTRA" or "DESTRA"; Arial font, 0.07 normalised units) was presented for 1000 ms at the centre of the screen before the appearance of the face (see Figure 1). Participants were explicitly instructed that the direction word was 100% predictive about the spatial location of the upcoming peripheral target whereas gaze direction was spatially uncorrelated with target location.

Results

Data were analysed as in Experiment 1, given that the experimental factors were the same[2]. Trials with a missing response were rare (.30% of the trials) and they were not further analysed. Trials in which participants provided a wrong response (6.18% of the trials) were discarded and analysed separately. Trials with a correct response and RTs smaller than 150 ms or greater than 1500 ms were considered outliers and discarded from the analyses (.42% of trials).

The minimum number of observations per experimental cell was 2348, which guaranteed sufficient power. The model included congruency, SOA, and condition, and their interactions, as fixed effects. The random effects were the intercepts for participants and face stimulus, and the by-participant random slope for the effect of condition. The main effect of congruency was significant, $F(1, 18902.6) = 49.324$, $p < .001$, $\eta^2_p = .324$, due to smaller RTs on congruent trials (M = 565 ms, SE = 10.7) than on incongruent trials (M = 580 ms, SE = 10.7), as well as the main effect of SOA, $F(1, 18900.9) = 500.544$, $p < .001$, $\eta^2_p = .755$, due to smaller RTs at the longer SOA (M = 549 ms, SE = 10.7) than at the shorter SOA (M = 596 ms, SE = 10.7), and the main effect of condition, $F(1, 77.9)$

[2] A preliminary analysis in which block order was also included as a factor did not reveal any significant interaction involving block order and spatial congruency (all *ps* > .252). For this reason, block order was no longer considered in the analyses.

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= 4.333, p = .041, η^2_p= .055, due to smaller RTs in the blocked condition (M = 566 ms, SE = 10.6) than in the intermixed condition (M = 579 ms, SE = 10.7). No other significant results emerged (ps > .176; see also Table 1).

As in Experiment 1, despite the low percentage of wrong responses, these were analysed with a mixed-effect logit model to exclude the presence of speed-accuracy trade-offs. The model included congruency, SOA, and condition, and their interactions, as fixed effects. The random effects were the intercepts for participants and face stimulus. The main effect of SOA was significant (p = .003), indicating less errors at the longer SOA. The congruency × SOA interaction was non-significant (p = .080), as well as all the other results (ps > .318).

Discussion

The results of this experiment are in line with the pattern emerged in Experiment 1, as also in this case the gaze-cueing effect was comparable in magnitude regardless of whether gaze direction randomly varied, or it remained invariant throughout the block. The occurrence of gaze cueing in a situation in which suppressing the spatial information provided by gaze would result in a clear benefit for the participants is consistent with previous data and shows that gaze cueing is resistant to suppression (Dalmaso et al., 2020a; Galfano et al., 2012). The fact that gaze cueing resisted also in a condition in which suppression should be facilitated, namely when gaze direction remained invariant in the same block of trials, lends even stronger support to the view that gaze cueing meets a highly rigid version of the resistance to suppression criterion.

In the next experiment, we aimed to provide a further stringent test by introducing a series of relevant changes with the goal of creating a highly conservative setting. To this purpose, we adopted the same experimental logic of Experiment 1, while using schematic faces rather than real faces. This choice was based on the reasoning that an impoverished and less ecological stimulus might be easier

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to be disregarded/suppressed, thus resulting in an increase of the probability to observe a dissociation between the blocked and the intermixed conditions. In the same vein, whereas in the blocked condition of the previous studies gaze direction was invariant but the identity of the presented faces was not, here we decided to use only one face stimulus. In order to maximise the similarity among the experimental trials in the blocked condition, a single SOA was used (i.e., 200 ms). In addition, the task required to identify target letters rather than to discriminate the spatial orientation of a target line. In so doing, the new task did not require processing of the spatial features of the target. This, in turn, would control for the possibility that gaze cueing in Experiments 1 and 2 occurred because participants were required to perform a discrimination of spatial features, thus making space a salient dimension in the experimental setting (e.g., Folk et al., 1992). Moreover, we removed the central gaze frame before the averted gaze frame, in order to get rid of the apparent movement effect generated by the sequence of successive frames, which is known to inflate the gaze-cueing effect (see McKay et al., 2021). This, in turn, might have played a significant role in the magnitude of the gaze-cueing effect observed in the previous experiments. Finally, even if it has been proved that online experiments can provide solid and trustable data and comparable to laboratory-based studies (e.g., Bridges et al., 2020), we deemed it important to replicate the observed pattern in a laboratory setting.

Experiment 3: Schematic face stimuli

Method

Participants

The minimum number of participants required for the experimental design of this third experiment was twenty-two (see Brysbaert & Stevens, 2018). Our final sample was composed of 30 individuals (*Mean age* = 20 years, *SD* = 1.37, 7 males), recruited within the student population of the

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University of Padova (no incentives were offered). Written informed consent was obtained before the experiment. The study was approved by the Ethics Committee for Psychological Research of the University of Padova, and was conducted in accordance with the Declaration of Helsinki.

Apparatus, stimuli, and procedure

Data were collected in a laboratory setting through a PC running E-Prime. Stimuli appeared on a monitor (1920 × 1080 px, 60 Hz) located 57 cm from the participant. Manual responses were collected with a standard keyboard. Screen background was set to grey (R = 128, G = 128, B = 128), given that the face stimulus was coloured in white (all materials can be found at the link provided in the Data Availability Statement).

The task was similar to the previous two experiments. A trial started with a central fixation cross (side: 1°) for 900 ms, followed by a central schematic face (side: 6°), without irises, which remained visible for 900 ms (see Figure 1). Then, the same face appeared with the irises oriented either leftwards or rightwards for 200 ms. Finally, a target letter (either L or T; Arial font, side: .8°) appeared either 14° leftwards of rightwards from fixation with the same probability. A trial ended after a manual response was detected or 3000 ms elapsed, whichever came first. In case of both missed responses and errors, visual central feedback (i.e., the black word 'TOO SLOW' or 'NO', respectively) appeared for 500 ms. There was an initial practice block (10 trials), followed by the four experimental blocks (288 experimental trials in total).

Results

Data were analysed as in Experiments 1 and 2, given that the experimental factors were the same with the only exception that the factor SOA here was not included[3]. Trials with a missing

[3] A preliminary analysis in which block order was also included as a factor did not reveal any significant interaction involving block order and spatial congruency (all *ps* > .483). For this reason, block order was no longer considered in the analyses.

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response were rare (.012% of the trials) and they were not further analysed. Trials in which participants provided a wrong response (4.34% of the trials) were discarded and analysed separately. Trials with a correct response and RTs smaller than 150 ms or greater than 1500 ms were considered outliers and discarded from the analyses (.41% of trials).

The minimum number of observations per experimental cell was 2053, which guaranteed sufficient power. The model included congruency and condition, and their interaction, as fixed effects. The random effects were the intercepts for participants, and the by-participant random slope for the effect of condition. The main effect of congruency was significant, $F(1, 8167.5) = 5.671$, $p = .017$, $\eta^2_p = .203$, due to smaller RTs on congruent trials ($M = 600$ ms, $SE = 14.4$) than on incongruent trials ($M = 607$ ms, $SE = 14.4$). No other significant results emerged (ps > .193; see also Table 2).

[Table 2 about here]

As in Experiments 1 and 2, despite the low percentage of wrong responses, these were analysed with a mixed-effect logit model to exclude the presence of speed-accuracy trade-offs. The model included congruency and condition, and their interaction, as fixed effects. The random effects were the intercepts for participants, and the by-participant random slope for the effect of condition. However, no significant results emerged (ps > .469).

Discussion

The results indicated that the gaze-cueing effect was comparable in magnitude regardless of whether gaze cues with different directions were presented in an intermixed or in a blocked fashion. This suggests that participants found it very hard to disregard/suppress spatial signals indicated by

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others through their eyes even when the gaze stimulus consistently pointed towards an invariant spatial location. This effect is consistent with the results emerged in the previous experiments employing real faces and provides support for the robustness of the pattern by making alternative accounts unlikely. In the next experiment, the procedure was identical to Experiment 3 with the addition of a direction word manipulation that, similarly to Experiment 2, provided the information about the exact location of the target in advance.

Experiment 4: Schematic face stimuli and direction words

Participants

Given that the experimental design was identical to Experiment 3, we decided to test an identical number of participants. Hence, a new sample composed of 30 individuals (*Mean age* = 24 years, *SD* = 2.34, 14 males) was recruited by using Prolific (compensation was £ 4,50). Only individuals living in Italy, whose mother language was Italian and with an age between 18 and 30 years, were allowed to take part, in order to obtain a comparable sample with respect to the previous experiments. Informed consent was obtained before the experiment. The study was approved by the Ethics Committee for Psychological Research of the University of Padova, and was conducted in accordance with the Declaration of Helsinki.

Apparatus, stimuli, and procedure

The study design was identical to Experiment 3, with the only exception that a direction word (i.e., “LEFT” or “RIGHT”; in Italian: “SINISTRA” or “DESTRA”; Arial font, 0.07 normalised units) was presented for 1000 ms at the centre of the screen before the appearance of the face. As in Experiment 2, participants were explicitly instructed that the direction word was 100% predictive

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about the spatial location of the upcoming peripheral target whereas gaze direction was spatially uncorrelated with target location. The experiment was programmed in PsychoPy and delivered online with Pavlovia (see Experiments 1 and 2).

Results

Data were analysed as in Experiments 3[4]. Trials with a missing response were rare (.21% of the trials) and they were not further analysed. Trials in which participants provided a wrong response (5.97% of the trials) were discarded and analysed separately. Trials with a correct response and RTs smaller than 150 ms or greater than 1500 ms were considered outliers and discarded from the analyses (1.86% of trials).

The minimum number of observations per experimental cell was 1969, which guaranteed sufficient power. The model included congruency and condition, and their interaction, as fixed effects. The random effects were the intercepts for participants, and the by-participant random slope for the effect of condition. The main effect of congruency was significant, $F(1, 7884.4) = 7.131$, $p = .008$, $\eta^2_p = .315$, due to smaller RTs on congruent trials ($M = 625$ ms, $SE = 26.2$) than on incongruent trials ($M = 635$ ms, $SE = 26.2$). No other significant results emerged (ps > .358; see also Table 2). As in Experiment 3, despite the low percentage of wrong responses, these were analysed with a mixed-effect logit model to exclude the presence of speed-accuracy trade-offs. The model included congruency and condition, and their interaction, as fixed effects. The random effects were the intercepts for participants, and the by-participant random slope for the effect of condition. No significant results emerged (ps > .635).

[4] A preliminary analysis in which block order was also included as a factor did not reveal any significant interaction involving block order and spatial congruency (all ps > .762). For this reason, block order was no longer considered in the analyses.

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Discussion

The results of Experiment 4 confirmed, again, that the gaze-cueing effect was not modulated by the way gaze cues with different directions were presented (i.e., intermixed vs. blocked fashion). In addition, they also confirmed that, as in Experiment 2, the direction word had no impact on the ability to suppress the spatial information conveyed by gaze stimuli (see also Dalmaso et al., 2020a; Galfano et al., 2012).

General Discussion

The goal of the present study was to test whether, with respect to manipulations employed in previous studies (e.g., Friesen & Kingstone, 1998; Friesen et al., 2004; Galfano et al., 2012), gaze cueing satisfies a further stringent criterion for resistance to suppression. To this purpose, in Experiment 1, we had participants taking part in two variants (intermixed vs. blocked) of the gaze-cueing paradigm with uninformative gaze stimuli. In the intermixed condition, the direction of the averted gaze varied unpredictably from trial to trial, as in the standard paradigm (e.g., Driver et al., 1999; Friesen & Kingstone, 1998). By contrast, in the blocked condition, the direction of the averted gaze was invariant throughout the series of trials. We reasoned that in the standard, intermixed, condition, gaze represents a stimulus with an unpredictable spatial vector that participants should disregard because of its non-diagnostic value in relation to the location of the target. However, it should also be noted that, in such a context, gaze may still be relevant because in each trial it provides abrupt and unpredictable spatial information. This may thus, by itself, prompt the more careful processing of the gaze stimulus, irrespective of whether participants are informed that gaze does not convey any useful information for the task at hand. Accordingly, gaze-cueing effects in the standard paradigm may be, at least partially, sustained by the continuous variability in the direction of gaze. Conversely, in the blocked condition, the novelty of the unpredictable gaze direction is completely abolished, and this may thus represent a more stringent condition to test one relevant aspect of

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resistance to suppression. If gaze cueing is observed also in this condition, then claims about automaticity as inferred by resistance to suppression would bear on more solid grounds, in that participants should be greatly facilitated in ignoring the gaze stimulus. The present data clearly showed that gaze-cueing effects of comparable magnitude were present in the intermixed and in the blocked conditions.

Experiments 2, 3, and 4 had the goal of replicating the basic finding emerged in Experiment 1 using experimental manipulations that provided even more stringent tests of resistance to suppression and controlled for alternative accounts. More specifically, in Experiment 2, before the onset of the gaze distractor, we provided participants with a direction word (i.e., “left” or “right”) that always informed them about the exact location of the upcoming target. This was done to further decrease the salience of the spatial information conveyed by the gaze distractor (also see Dalmaso et al., 2020a; Galfano et al., 2012). In so doing, we aimed to rule out the possibility that the persistent gaze-cueing effect emerged in the blocked condition of Experiment 1 might result from the adoption of a specific strategy implemented because target location was unknown in advance. The observed results are important for at least two reasons. On the one hand, the occurrence of a significant gaze-cueing effect in the intermixed condition lends support to the idea that this phenomenon takes place even when participants can rely on an independent 100% predictive direction cue, consistent with previous studies (Galfano et al., 2012; see also Dalmaso et al., 2020a). On the other hand, the lack of dissociation between the blocked and the intermixed conditions is in line with the results emerged in Experiment 1 and confirms that the gaze-cueing effect meets the resistance to suppression criterion as operationalised in the present experiments. In Experiment 3, we replicated the basic paradigm used in Experiment 1 with crucial modifications aimed at creating a more conservative experimental setting for testing our hypotheses. In particular, we aimed to rule out the possibility that a significant gaze cueing was observed in the blocked condition of previous experiments due to the contribution of different procedural factors. First, we removed the direct-gaze frame, in order to abolish any

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impression of apparent movement and hence set up an experimental context in which a weaker gaze-cueing effect could be generated (Xu et al., 2018). Second, we presented identical trials throughout the blocked condition by including only one SOA and employing a single face stimulus, in order to minimise the variability within the block. Third, the face stimulus was schematic, based on the rationale that an impoverished and less ecological stimulus could eventually be more easily disregarded. Finally, in Experiment 4, we used the same manipulation adopted in Experiment 2 with the same design and methods used in Experiment 3. In particular, a direction word indicating with 100% certainty the location of the upcoming target was also presented at the beginning of each trial (as in Experiment 2). The presence, in both Experiments 3 and 4, of a significant gaze-cueing effect of similar magnitude in both the intermixed and the blocked condition, consistent with the previous experiments, helps to consider alternative accounts unlikely and corroborates the idea that this phenomenon fulfils the resistance to suppression criterion for automaticity.

The observation that, in the current studies, gaze cueing was always present and impervious to the employed manipulations, irrespective of whether a real or schematic face was used, is consistent with the *eyeTUNE* framework (Dalmaso et al., 2020b). This framework postulates that gaze cueing may represent the default behavioural response in the absence of further information about the identity or group membership of the face conveying eye gaze. In this regard, it is now well established that several social features can indeed affect gaze cueing (e.g., Carraro et al., 2017; Dalmaso et al., 2012; Hungr & Hunt, 2012; Liuzza et al., 2013; Slessor et al., 2010; Zhang et al., 2021; see Dalmaso et al., 2020b for a review) and that such modulations are further contingent upon contextual settings (Zhang et al., 2023). Hence, the theoretical proposal is that gaze cueing can be framed as a conditionally-automatic phenomenon, namely that it is sensitive to moderating processes. In future studies, it will be important to test whether the resistance to suppression criterion, as tested in the present study, is met specifically by eye-gaze stimuli, because of their biological and social relevance, or can be observed even for non-social stimuli which are capable to elicit robust attentional shifts,

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such as arrows (e.g., Dalmaso et al., 2020a; Galfano et al., 2012; Tipples, 2008). According to a recent meta-analysis (Chacón-Candia et al., 2022), eye-gaze and arrow stimuli generate equivalent attentional effects. Therefore, one possibility is that resistance to suppression, as operationalised in the current study, may extend even to arrows.

As discussed in the introduction section, the concept of automaticity is multifaceted in that it can be assessed according to different criteria and, for each criterion, different approaches can be pursued for testing automaticity. We here specifically focused on resistance to suppression. So far, this criterion has been almost exclusively addressed by manipulating expectancies concerning the predictive value of the gaze stimulus (e.g., Driver et al., 1999; Friesen et al., 2004; Tipples, 2008). Such approach, however, has the unavoidable side effect of making eye gaze salient, which in turn may, by itself, paradoxically set the status of eye gaze to "task relevant" and hence hamper any interpretation of gaze cueing as reflecting strong automatic processing. Whereas these studies implicitly encouraged participants to process eye gaze, other research explicitly required participants to provide responses as a function of eye gaze direction, leading to mixed evidence (e.g., Besner et al., 2021; Cañadas & Lupiáñez, 2012; Marotta et al., 2018). Here, we used a different avenue to test resistance to suppression, based on the manipulation of the directional (in)variability of the gaze stimulus. The results seem to support a strong version of the resistance to suppression criterion. Taken together, the different studies in the literature provide a rather complex picture and suggest caution as concerns drawing general conclusions about automaticity as an all-or-none feature. In these regards, we consider it might be more fruitful to focus on the various conditions that – both in isolation and in interaction with each other – may eventually disrupt gaze-cueing effects. The clear message from the present studies is that the variable vs. invariable nature of gaze direction is an irrelevant factor that does not affect our tendency to shift spatial attention according to the gaze of others.

Data Accessibility Statement

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The data and materials from the present experiment are publicly available at the Open Science Framework website: https://doi.org/10.17605/OSF.IO/G56A7

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Declaration of Conflicting Interests

The authors declare that there is no conflict of interest.

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Figure Captions

Figure 1. Examples of stimuli and trials used in the study. Panels A and B illustrate the intermixed and blocked conditions as implemented in Experiment 1. Panel A shows examples of the intermixed condition, in which real faces gazing either leftwards or rightwards were randomly presented in the two blocks of trials, whereas Panel B shows examples of the blocked condition, in which real faces gazing either leftwards or rightwards were presented in two distinct blocks of trials. Panel C shows an example of the trial structure used in Experiment 2, in which the fixation cross was followed by a direction word indicating the location of the upcoming target with 100% probability. Panel D shows an example of the trial structure used in Experiment 3, in which a schematic face was used. Stimuli are not drawn to scale. In Experiment 4, we combined the trial structure and stimuli used in Experiment 3 with the addition of direction words (as in Experiment 2).

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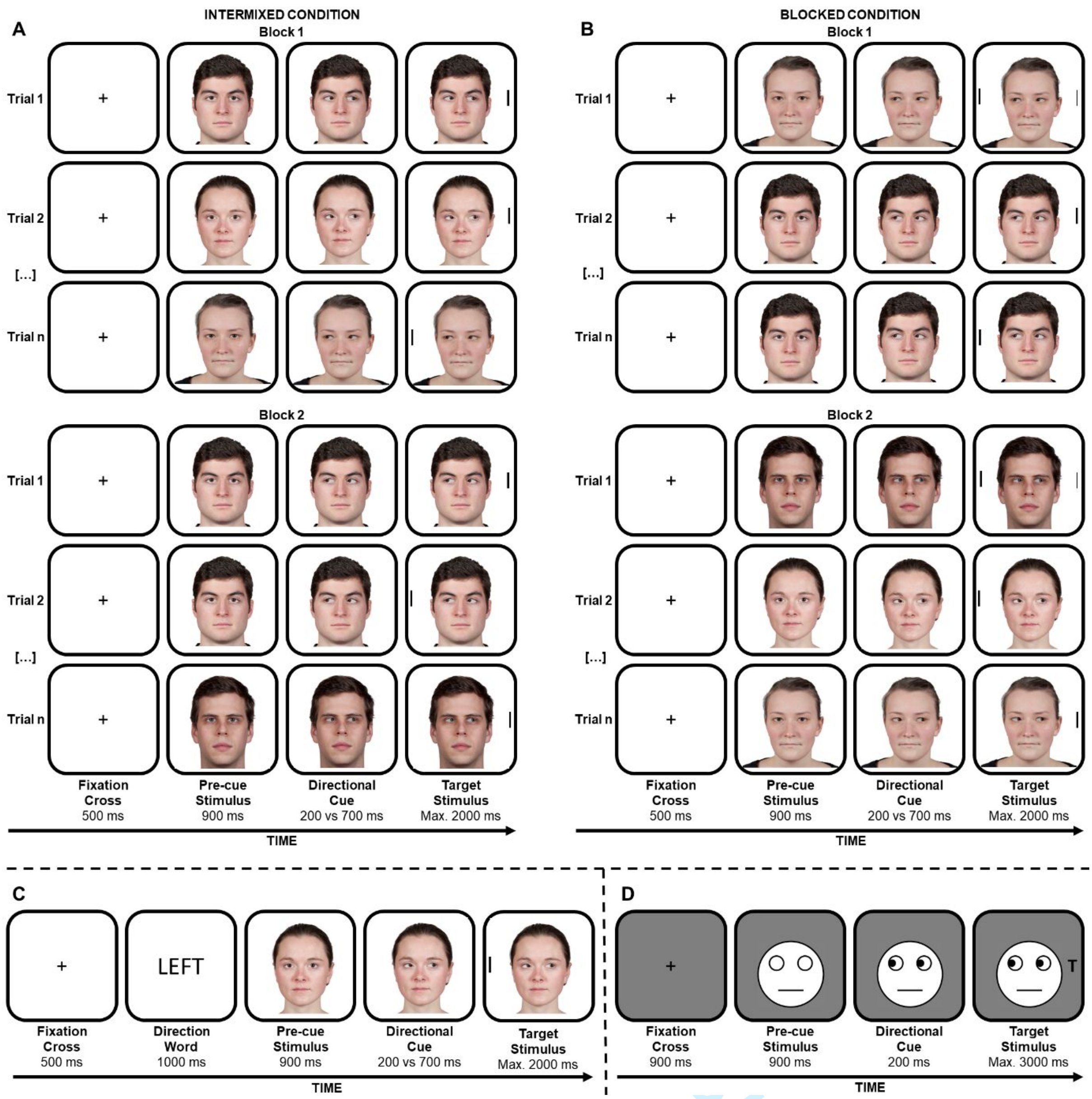

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	Intermixed condition				Blocked condition			
	200-ms SOA		700-ms SOA		200-ms SOA		700-ms SOA	
	Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Experiment 1								
RTs	598 (8.99)	613 (8.99)	561 (8.98)	574 (8.98)	592 (8.99)	604 (8.99)	554 (8.98)	562 (8.99)
Accuracy	96.2 (0.005)	96.6 (0.005)	97.1 (0.004)	97 (0.004)	96.8 (0.004)	96.2 (0.005)	97.5 (0.004)	96.8 (0.004)
Experiment 2								
RTs	595 (11.9)	609 (11.9)	546 (11.9)	565 (11.9)	583 (10.9)	595 (10.9)	538 (10.9)	549 (10.9)
Accuracy	93.7 (0.006)	94.4 (0.006)	95.9 (0.005)	95.6 (0.005)	94.4 (0.006)	94.4 (0.006)	96.1 (0.005)	94.8 (0.006)

Table 1. Mean RTs (in ms) and mean Accuracy (% correct) observed as a function of Condition, SOA, and Congruency in Experiments 1 and 2. Data in parentheses are SEM.

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	Intermixed condition		Blocked condition	
	Congruent	**Incongruent**	**Congruent**	**Incongruent**
Experiment 3				
RTs	605 (14.5)	612 (14.6)	595 (14.5)	602 (14.6)
Accuracy	96.3 (0.005)	96.2 (0.005)	96.7 (0.006)	96.5 (0.006)
Experiment 4				
RTs	629 (25.5)	641 (25.5)	621 (28.0)	628 (28.0)
Accuracy	95.6 (0.008)	95.7 (0.008)	95.6 (0.008)	95.9 (0.008)

Table 2. Mean RTs (in ms) and Accuracy (% correct) observed as a function of Condition and Congruency in Experiments 3 and 4. Data in parentheses are SEM.

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