Consciousness and Cognition 109 (2023) 103476

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Can masked gaze and arrow stimuli elicit overt orienting of attention? A registered report

Mario Dalmaso *, Luigi Castelli, Chiara Bernardini, Giovanni Galfano

Department of Developmental and Social Psychology, University of Padova, Italy

ARTICLE INFO

Keywords:
Gaze distractor
Arrow distractor
Masking
Eye movements
Saccades
Social cognition

ABSTRACT

Viewing an averted gaze can elicit saccades towards the corresponding location. Here, the automaticity of this gaze-following behaviour phenomenon was further tested by exploring whether such an effect can be detected in response to briefly-presented masked averted gazes. Participants completed an oculomotor interference task consisting of making leftward/rightward saccades according to a symbolic instruction cue. Crucially, either a task-irrelevant averted-gaze face or an arrow (i.e., a non-social control stimulus) was also presented in different blocks of trials. Faces and arrows were presented for either 1000 ms, or 8 ms and then backward-masked, to reduce the likelihood of conscious processing. Worse oculomotor performance emerged when the saccade direction did not match (vs match) that suggested by the task-irrelevant gaze/arrow stimuli in the unmasked condition. However, in the masked condition, no oculomotor interference occurred for any task-irrelevant stimulus. Results enrich knowledge about boundary conditions for gaze/arrow-driven orienting using ecological attention measures.

1. Introduction

Spatial signals provided by others play a primary role in orienting the visual attention of an observer (e.g., Capozzi & Ristic, 2018; Dalmaso et al., 2020b; Emery, 2000; Frischen et al., 2007; McKay et al., 2022). In particular, it is known that we tend to produce saccadic eye movements towards the same spatial location indicated by averted-gaze signals coming from an individual we are attending to (e.g., Kuhn & Benson, 2007; Ricciardelli et al., 2002). This form of gaze following behaviour permits people to establish episodes of shared attention towards the same object or spatial spot, thus facilitating the building of fluid and effective relationships with both others and the environment around us.

Gaze following capacities have been widely investigated through an oculomotor interference task employing eye-gaze stimuli acting as distractors, while participants perform instructed saccades towards peripheral locations (e.g., Ciardo et al., 2014; Dalmaso et al., 2015; Dalmaso et al., 2020a; Kuhn & Kingstone, 2009; Porciello et al., 2016; Ricciardelli et al., 2002; Zhang et al., 2021). More precisely, this task consists of asking participants to look at a fixation spot placed at the centre of the screen and flanked by two placeholders. Then, this spot typically changes in colour (i.e., the instruction cue), and participants are instructed to produce either a leftward or a rightward saccade towards one of the two placeholders, depending on the colour change (e.g., blue for a leftward saccade, green for a rightward saccade). At the same time, a central task-irrelevant face, looking either left or right, is also presented. Typically, smaller latencies emerge on trials in which the spatial vectors conveyed by the instruction cue and the eye-gaze signal are spatially

* Corresponding author.
E-mail address: mario.dalmaso@unipd.it (M. Dalmaso).

https://doi.org/10.1016/j.concog.2023.103476
Received 27 January 2022; Received in revised form 19 January 2023; Accepted 21 January 2023
Available online 10 February 2023

congruent (e.g., right-right; a congruent trial) rather than spatially incongruent (e.g., right-left; an incongruent trial). This oculomotor interference effect appears to be a robust and automatic phenomenon, as it can be detected even when participants are explicitly informed that eye-gaze direction is spatially unpredictive, namely when it matches the spatial direction of the requested saccades with only a 50 % probability (e.g., Kuhn & Benson, 2007; Ricciardelli et al., 2002). Furthermore, a recent study has also observed that the phenomenon cannot be suppressed even when participants are allowed to program the instructed saccadic eye movement well in advance with respect to the onset of the distracting eye-gaze stimulus (Dalmaso et al., 2020c). Comparable oculomotor responses to those observed for eye-gaze stimuli have been reported even when arrows are employed, thus suggesting that both social and non-social spatial stimuli are similarly treated by our attentional mechanisms (e.g., Dalmaso et al., 2020c; Hermens & Walker, 2010; Kuhn et al., 2010; Kuhn & Benson, 2007; Kuhn & Kingstone, 2009).

The present work aims to further test one aspect of the automaticity of gaze-driven oculomotor behaviour by taking a novel and yet unexplored perspective, consisting of presenting participants with masked averted-gaze stimuli that they are not aware of. In this regard, it is important to note that some hints that gaze-mediated orienting can emerge even when gaze stimuli are masked come from a set of works that focused on covert attention shifts (i.e., without eye movements). The first study on this topic (Sato et al., 2007) used a version of the so-called gaze-cueing task (e.g., Driver et al., 1999; Friesen & Kingstone, 1998). In Sato et al. (2007), participants were asked to keep the eyes at central fixation for the whole duration of the trial – namely, avoiding eye movements – and to provide a manual response to a peripheral target appearing either leftwards or rightwards with respect to the centre of the screen. Before target onset, a task-irrelevant non-predictive central face was presented, looking either leftwards or rightwards. Similar to the instructed saccade task described above, this gaze-cueing task was characterised by spatially congruent and incongruent trials occurring with the same frequency. Crucially, in one viewing condition (i.e., unmasked), the central face was clearly visible to participants while, in another viewing condition (i.e., masked), it was presented for less than 30 ms and then backward-masked. The unmasked and masked faces were presented in two separate blocks. In so doing, smaller reaction times (RTs) emerged on congruent trials than on incongruent trials and this was true for both the unmasked and the masked conditions, even if the magnitude of this effect was smaller in the masked condition. This gaze-cueing effect for both unmasked and masked stimuli has also been investigated in subsequent studies using a variety of stimuli and methods from the same research group (Sato et al., 2010, 2016,2017; Uono et al., 2018) and other laboratories (Al-Janabi & Finkbeiner, 2012, 2014; Bailey et al., 2014; Lu et al., 2012; Mitsuda & Masaki, 2018; Xu et al., 2011). Overall, the findings support the idea that covert gaze-mediated orienting survives even without conscious awareness of gaze cues. However, none of the aforementioned covert attention studies compared eye-gaze stimuli with arrows, thus missing a direct comparison with the non-social domain. Importantly, there is evidence that unpredictive central arrow cues (i.e., arrows indicating the upcoming target location with a 50 % frequency), presented for a brief time period (i.e., 17 ms) and then masked, can elicit reliable covert attention shifts in observers although these stimuli could not be consciously perceived (Cole & Kuhn, 2010). However, this finding is inconsistent with subsequent studies that used different methodologies (Gayet et al., 2014; Reuss et al., 2011). Hence, again, arrows appear as good conceptual candidates to draw comparisons between the attentional responses elicited by social and non-social stimuli, although previous evidence about arrow-mediated cueing with masked stimuli still appears to be far from being conclusive.

Taking inspiration from the gaze cueing literature with masked stimuli, in the present work we explored masked gaze- and arrow-mediated orienting by means of saccadic eye movements, which represent a more direct, informative, and ecological measure of attention allocation over space as compared to manual responses. Importantly, saccadic selection has proven to be a more sensitive measure than manual selection in different paradigms that address attention control and spatial orienting (Bompas et al., 2017; Malienko et al., 2018). Because, to the best of our knowledge, this is the first attempt to merge these two research streams (i.e., overt attention responses to masked gaze and arrow stimuli), our experiment was based on methodologies that have been widely used in both areas. In particular, we adopted a version of the instructed saccade task devised by Ricciardelli et al. (2002) in conjunction with the unmasked/masked manipulation used by Sato and colleagues in several works (e.g., Sato et al., 2007, 2016; Uono et al., 2018). In one condition, both unmasked and masked non-predictive averted-gaze stimuli were employed. In another condition, averted-gaze stimuli were replaced by both unmasked and masked non-predictive arrows. Based on previous literature addressing covert orienting of attention, the following results were expected: 1) an overall main effect of spatial congruency, due to smaller latencies on congruent trials than on incongruent trials (i.e., the standard oculomotor interference effect; e.g., Dalmaso et al., 2020c; Ricciardelli et al., 2002); 2) a two-way interaction between spatial congruency and viewing condition (i.e., unmasked vs masked), due to a smaller oculomotor interference effect for masked than unmasked stimuli (see also Sato et al., 2007, 2016); 3) a significant oculomotor interference effect for both unmasked and masked averted-gaze and arrow stimuli (e.g., Cole & Kuhn, 2010; Sato et al., 2007). If confirmed, this latter pattern of results would provide further evidence that both social and non-social stimuli are treated similarly, as indexed by the oculomotor responses.

2. Methods

2.1. Power analyses

The sample size necessary for testing the expected outcomes was estimated a priori, through dedicated simulations, using the R package Superpower (Lakens & Caldwell, 2021). All codes are available on the Open Science Framework repository associated with this work. As a first step, we aimed to address the minimum sample size to observe a reliable oculomotor interference effect for both gaze and arrow stimuli. To this purpose, we used the mean RTs and Standard Errors (converted to Standard Deviations) reported in the study by Dalmaso et al. (2020c, see Table 1, Experiment 1), which represents the most similar experimental setting with respect to that employed in the present study. A vector of correlation coefficients from Dalmaso et al.'s (2020c) data was used. In order to detect a significant main effect of Spatial congruency in a 2 (Spatial congruency: congruent vs incongruent) × 2 (Distractor type: gaze vs arrow) ANOVA, as well as a significant effect of Spatial congruency separately for gaze and arrow stimuli, a sample size of 15 would be required (power = 90 %, α = 0.05 two-tailed, 10,000 simulations). Next, we aimed to address the minimum sample size to observe a significant cueing effect for both unmasked and masked stimuli. In so doing, we relied on the mean RTs and Standard Errors (converted to Standard Deviations) derived from Sato et al. (2007, see Figure 4, Eye condition). These data were used for both the averted gaze and arrow stimuli because similar results were expected for both gaze and arrow signals. The correlation was set to 0.92, based on a recent *meta*-analysis (McKay et al., 2022). In order to detect a significant Spatial congruency × Condition interaction in the planned 2 (Spatial congruency: Congruent vs incongruent) × 2 (Condition: Unmasked vs masked) × 2 (Distractor type: Gaze vs arrow) ANOVA, as well as a significant effect of Spatial congruency separately for gaze and arrow stimuli in both unmasked and masked conditions (i.e., four planned comparisons), a sample size of 79 would be required (power = 90 %, α = 0.05 two-tailed, 10,000 simulations). Thus, data from 80 participants were collected.

2.2. Sample characteristics

Eighty participants (*Mean age* = 22.39 years, *SD* = 2.75, *age range* = 18–30 years, 21 males) were tested. They were students at the School of Psychology of the University of Padova. All participants were naïve with respect to the purpose of the study and had normal or corrected-to-normal vision. The experimental procedure was approved by the Ethics Committee for Psychological Research of the University of Padova (Protocol #4654) and the experiment was conducted in accordance with the Declaration of Helsinki. All participants provided written informed consent form before participating in the experimental session.

2.3. Participant exclusion criteria

We planned to exclude participants from the analyses if they did not complete the whole study due to difficulties tracking their eyes, such as in the case of individuals wearing some types of glasses or contact lenses, which can interfere with recording eye movements. Nevertheless, no participants were excluded.

2.4. Apparatus

Eye movements were recorded monocularly (i.e., the right eye) with an EyeLink 1000 Plus (SR Research ltd, Ottawa, Canada) at a frequency of 1000 Hz. Participants sat 70 cm away from a 24-inch monitor (1280 × 1024 pixels, 120 Hz) and a chinrest was used to prevent head movements. A display PC running Experiment Builder (https://www.sr-research.com) handled the timing and presentation of the stimuli. The experimenter used a host PC to monitor the progress of the whole experiment.

2.5. Stimuli and procedure

Similarly to previous studies (Al-Janabi & Finkbeiner, 2012; Sato et al., 2007; Uono et al., 2018), a single grayscale human face was used for gaze stimuli. This face was extracted from the MR2 Face Database (Strohminger et al., 2016), a high-resolution database of real faces of young adults (see Dalmaso et al., 2021). One male face was used, and there were four different versions: one with the face looking leftwards, one with the face looking rightwards, and two scrambled versions of the same stimuli that served as masks. The scrambled faces were generated using WebMorph (https://webmorph.org; DeBruine, 2017), a web-based software for visual stimuli processing. Two black arrows were used in the arrow condition. The area of the two arrows covered the same area occupied by the eyes of the face, to present participants with comparable spatial signals (see also Dalmaso et al., 2020c). The scrambled version of the arrow stimuli was generated using the same procedure employed for gaze stimuli. Averted-gaze faces and arrow stimuli were presented in separate experimental blocks whose order was counterbalanced across participants. Within each of these two blocks, unmasked and masked stimuli were presented in two distinct sub-blocks whose order was also counterbalanced across participants (see, e.g., Sato et al., 2007).

Two different parts made up the experimental session. The first part was the oculomotor interference task (example trials are illustrated in Fig. 1). Each experimental session was preceded by a 5-point calibration/validation procedure. Then, the experiment started. First, participants were asked to maintain fixation on a central black dot (diameter: 0.5°), and then the experimenter pressed a key on the host PC keyboard to continue the trial. This ensured that, at the beginning of the trial, the participant looked at the centre of the screen and allowed us to perform a drift-checking procedure. The central dot was then flanked for 500 ms by two squared placeholders (side: 0.9°), placed 9.7° leftwards and rightwards with respect to the centre of the screen. Then, a central stimulus (averted-gaze face or arrow) appeared for about 8 ms (i.e., one monitor refresh = 8.33 ms[1]). Subsequently, and depending on the block, the central stimulus (unmasked condition) or its scrambled version (masked condition) remained visible for an additional 992 ms. At the same time, the central dot changed shape (i.e., the instruction cue) becoming either a cross or the same cross rotated 45°. A change in shape – rather than in colour (see, e.g., Ricciardelli et al., 2002) – was used in order to avoid perceptual differences between the two

[1] The 8-ms duration was chosen based on previous studies on subliminal face processing (e.g., Kiss & Eimer, 2008; Mitsuda & Masaki, 2018; Smith, 2021). It was aimed to get a more conservative and stringent test of subliminal gaze processing with respect to previous works (e.g., Al-Janabi & Finkbeiner, 2012; Bailey et al., 2014; Sato et al., 2007) in which longer durations were adopted.

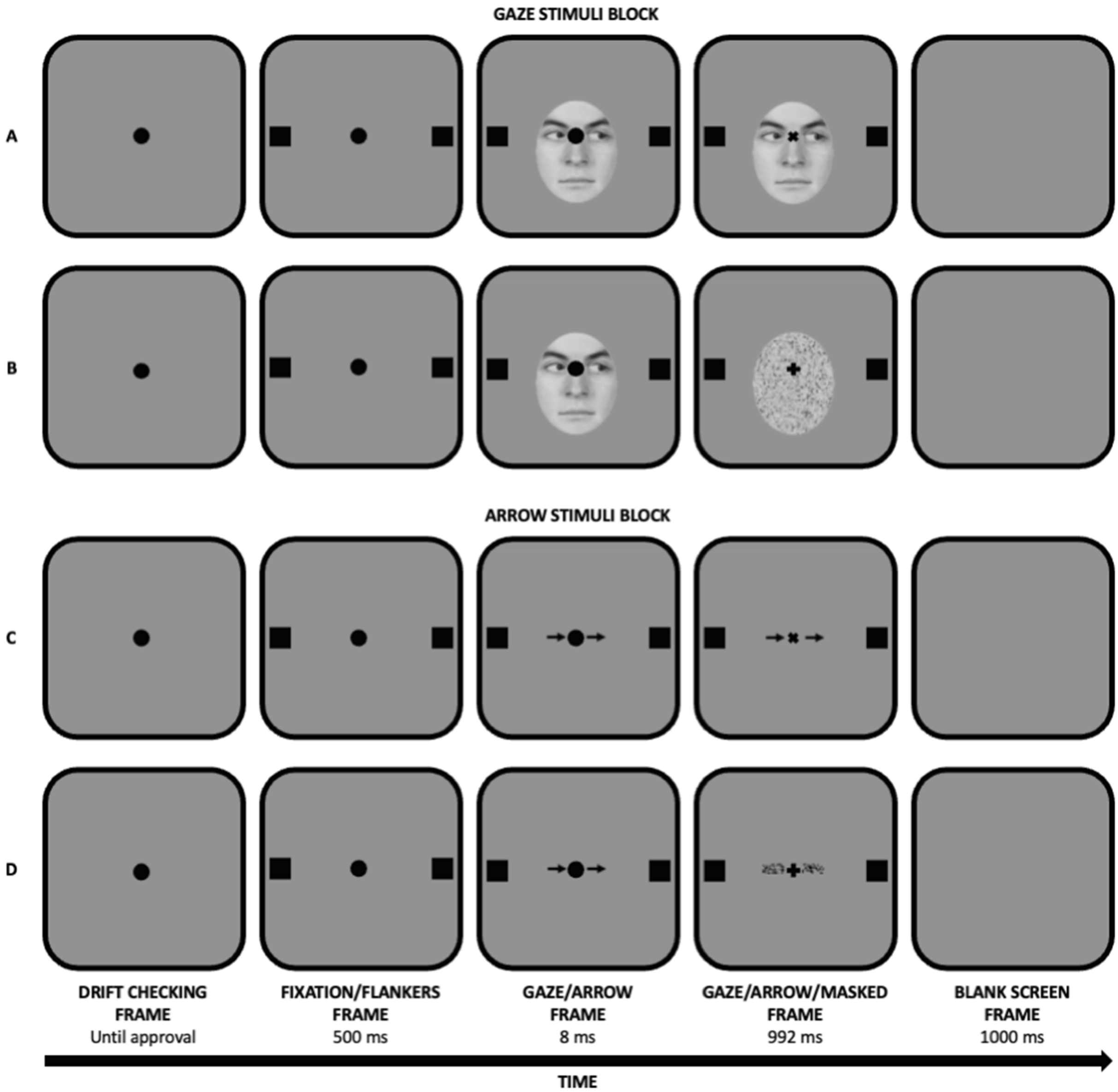

Fig. 1. Examples of trials and stimuli (not drawn to scale) that were used in Experiments 1 and 2. Panels A and C show an unmasked face looking rightwards and an unmasked arrow pointing rightwards, respectively. Panels B and D show a masked face looking rightwards and a masked arrow pointing rightwards, respectively. Please note that, depending on the instruction, participants were asked to perform a leftward or a rightward saccade according to the shape assumed by the central dot.

instruction cues. Finally, a blank screen appeared for 1000 ms. The fact that the instruction cue was provided after 8 ms was intended to present the central stimulus in the masked condition in isolation and without any other element that could interfere with its processing. Furthermore, previous studies employing this instructed-saccade task reported reliable gaze-following responses only when the instruction cue and the central stimulus were presented simultaneously or at least in close temporal proximity (see, e.g., Dalmaso et al., 2015, 2020a; Kuhn & Kingstone, 2009; Ricciardelli et al., 2002), thus further suggesting the need to employ only a brief temporal interval between these two crucial stimuli. Participants were instructed to always keep their eyes on the central dot and to perform – as fast and accurately as possible – a leftward or a rightward saccade when the central dot changed shape. They were also asked to ignore the central stimulus (and its direction) and the scrambled stimuli, since they were task-irrelevant. Half of the participants performed a left saccade in the presence of the 0° cross and a right saccade in the presence of the 45° cross. The other half responded by adopting the opposite mapping (that is, 45° leftward, 0° rightward). The four experimental blocks were each composed of 72 trials (i.e., 288 experimental trials in total) and preceded by a practice block of 10 trials. In so doing, 36 trials were collected for each cell of the experimental design. A short break was allowed after each block. All the experimental conditions were presented an equal number of times and were selected in random order.

It is worth nothing that, in previous studies, participants did not consciously report the direction of gaze of a face stimulus when presented for a time period smaller than 30 ms and then masked, a result assessed through either verbal reporting or a visual threshold task that was typically delivered at the end of the spatial cueing task (see Sato et al., 2007, 2010,2016,2017; Uono et al., 2018). A similar approach was also used here to ensure that, in the present context, the spatial features of the gaze and arrow stimuli appearing before the scrambled stimuli were presented without the participant's awareness. Participants completed 56 trials (2 blocks composed of 28 trials each, one block for each type of central stimulus), similar to those used in the masked condition of the oculomotor interference task (see Fig. 1, panels B and D), with the only exception that, after the blank screen, participants were asked to report the direction of the central stimulus. Block order mirrored that of the oculomotor interference task. Manual responses were recorded through two horizontally aligned keys (i.e., D and K keys) on a standard keyboard placed in front of the display PC monitor. The central stimulus pointing either leftwards or rightwards appeared for 8.33 ms (i.e., 1 monitor refresh). Please note that participants' ability to explicitly report the direction of the stimulus was assessed at the end of the main task to prevent the adoption of any attentional control settings that prioritize the processing of eye gaze and arrow stimuli (see also Al-Janabi & Finkbeiner, 2012).

2.6. Data handling of the oculomotor interference task

Data handling was conducted following the registered procedures. Data were collected between June 23rd and November 25th, 2022. Saccades were identified through the standard algorithm of DataViewer software (SR Research ltd, Ottawa, Canada) that classifies an eye movement as a saccade if its velocity and acceleration exceed $30^{\circ}/s$ and $8000^{\circ}/s^2$, respectively. Moreover, only saccades with a minimum amplitude of 2° were considered, in order to exclude particularly small saccades (e.g., Kuhn & Benson, 2007; Kuhn & Kingstone, 2009). On each trial, we extracted the first blink-free saccade performed after the onset of the imperative signal (i.e., the instruction cue). Saccades with blinks were rare (1.12 % of trials). Saccades directed towards the opposite location as that conveyed by the imperative signal were considered as saccadic directional errors and analysed separately (7.78 % of trials). Correct saccades with a latency smaller than 80 ms or greater than 800 ms were considered outliers and discarded from the analyses, a procedure that typically removes about 1 % of trials with this type of paradigm (e.g., Dalmaso et al., 2020a). Here, the identified outliers counted for 0.69 % of trials. Analyses were conducted using Data Viewer (https://www.sr-research.com), R (https://cran.r-project.org) and JAMOVI (https://www.jamovi.org) software.

2.7. Planned analyses and expected results of the oculomotor interference task

All analyses were conducted following the registered procedures. Saccadic latencies were our main dependent measure to unveil the predicted oculomotor behaviour. More precisely, the mean latencies of correct saccades were analysed through a repeated-measures ANOVA, with Spatial congruency (2: congruent vs incongruent), Condition (2: unmasked vs masked) and Distractor type (2: gaze vs arrow) as within-participants factors. Planned paired t-tests were used to compare congruent vs incongruent trials within the two conditions.

As anticipated earlier, we predicted the main effect of Spatial congruency to be significant, with smaller latencies on congruent than on incongruent trials. This can be interpreted as evidence that the central distractor stimuli elicited an overall oculomotor interference effect. The main effect of mask condition was expected to be non-significant, in line with previous studies on covert orienting in response to masked stimuli. Importantly, the Spatial congruency × Condition interaction was expected to be significant. More specifically, we expected the difference between congruent and incongruent trials to be significant in both the unmasked and the masked conditions but, in keeping with findings from the covert orienting literature, the magnitude of this difference was expected to be smaller in the masked condition. Based on previous studies conducted on covert orienting (e.g., Cole & Kuhn, 2010), similar results were expected for both eye gaze and arrow distractors. This would provide further evidence that eye-gaze and arrow stimuli can lead to similar oculomotor behaviours (see also, e.g., Dalmaso et al., 2020c; Hermens & Walker, 2010; Kuhn et al., 2010; Kuhn & Kingstone, 2009).

3. Results

All main effects were significant. The main effect of Spatial congruency, $F(1, 79) = 49.495$, $p < .001$, $\eta_p^2 = .385$, was due to smaller latencies on congruent trials ($M = 394$ ms, $SE = 6.051$) than on incongruent trials ($M = 403$ ms, $SE = 5.981$), the main effect of Condition, $F(1, 79) = 9.457$, $p = .003$, $\eta_p^2 = .107$, was due to smaller latencies on masked trials ($M = 394$ ms, $SE = 5.837$) than on unmasked trials ($M = 402$ ms, $SE = 6.385$), while the main effect of Distractor type, $F(1, 79) = 12.739$, $p < .001$, $\eta_p^2 = .139$, was due to smaller latencies for arrows ($M = 392$ ms, $SE = 6.066$) than for gaze ($M = 404$ ms, $SE = 6.325$).

Interactions were all significant as well. The predicted Spatial congruency × Condition interaction, $F(1, 79) = 70.265$, $p < .001$, $\eta_p^2 = .471$, indicated that latencies were smaller on congruent than incongruent trials in the unmasked condition ($p < .001$), but not in the masked condition ($p = .866$). The Spatial congruency × Distractor type interaction, $F(1, 79) = 7.912$, $p = .006$, $\eta_p^2 = .091$, indicated that latencies were smaller on congruent than incongruent trials for both arrow and gaze stimuli ($ps < 0.001$), but the difference was greater in the former case (12 ms vs 6 ms). The Condition × Distractor type interaction, $F(1, 79) = 45.066$, $p < .001$, $\eta_p^2 = .363$, indicated that latencies were smaller in the masked than unmasked condition for arrows ($p < .001$), while the opposite pattern emerged for the gaze stimulus ($p = .011$). Finally, the three-way interaction, $F(1, 79) = 13.874$, $p < .001$, $\eta_p^2 = .149$, was further analysed with two ANOVAs conducted separately for the two conditions (see also Fig. 2). For the unmasked condition, the main effect of Congruency was significant, $F(1, 79) = 79.507$, $p < .001$, $\eta_p^2 = .502$, while the main effect of Distractor type was not significant, $F(1, 79) = 1.090$, $p = .300$,

η_p^2 =.014. The Congruency × Distractor type interaction was significant, $F(1, 79) = 18.120$, $p <.001$, η_p^2 =.187, indicating that latencies were smaller on congruent than on incongruent trials for both stimuli ($ps < 0.001$), but the difference was greater for arrow than for gaze stimuli (26 ms vs 11 ms). For the masked condition, the main effect of Distractor type was significant, $F(1, 79) = 55.542$, $p <.001$, η_p^2 =.413, due to smaller latencies for arrows than for gaze (380 ms vs 408 ms). The other results were non-significant ($ps >$. 377).

We expected effects to emerge from latency analyses, but the mean percentage of saccadic direction errors was planned to be analysed as well, by using the same approach employed for saccadic latencies. Accuracy analyses were therefore carried out for the sake of completeness to rule out the occurrence of potential speed-accuracy tradeoffs.

All main effects were significant. The main effect of Spatial congruency, $F(1, 79) = 33.484$, $p <.001$, η_p^2 =.298, was due to fewer errors on congruent trials ($M = 5.979$ %, $SE = 0.439$) than on incongruent trials ($M = 9.590$ %, $SE = 0.811$), the main effect of Condition, $F(1, 79) = 9.089$, p =.003, η_p^2 =.103, was due to fewer errors on masked trials ($M = 7.096$ % ms, $SE = 0.498$) than on unmasked trials ($M = 8.473$ %, $SE = 0.717$), while the main effect of Distractor type, $F(1, 79) = 6.277$, p =.014, η_p^2 =.074, was due to fewer errors for gaze ($M = 7.174$ %, $SE = 0.536$) than for arrows ($M = 8.394$ %, $SE = 0.699$).

The Condition × Distractor type interaction was not significant (p =.549), whereas all the other interactions were significant. The Spatial congruency × Condition interaction, $F(1, 79) = 51.045$, $p <.001$, η_p^2 =.393, indicated fewer errors on congruent than incongruent trials in the unmasked condition ($ps < 0.001$), but not in the masked condition (p =.509). The Spatial congruency × Distractor type interaction, $F(1, 79) = 8.990$, p =.004, η_p^2 =.102, indicated fewer errors on congruent than incongruent trials for both arrow and gaze stimuli ($ps < 0.001$), but the difference was greater in the former case (4.775 % vs 2.449 %). Finally, the three-way interaction, $F(1, 79) = 7.872$, p =.006, η_p^2 =.091, was further analysed with two ANOVAs conducted separately for the two conditions (see also Fig. 2). As for the unmasked condition, the main effect of Congruency was significant, $F(1, 79) = 51.740$, $p <.001$, η_p^2 =.396, while the main effect of Distractor type was not significant, $F(1, 79) = 2.192$, p =.143, η_p^2 =.027. The Congruency × Distractor type interaction was significant, $F(1, 79) = 13.157$, $p <.001$, η_p^2 =.143, indicating that errors were fewer on congruent than on incongruent trials for both stimuli ($ps < 0.001$), but the difference was greater for arrow than for gaze stimuli (9.86 % vs 5.296 %). As for the masked condition, the main effect of Distractor type was significant, $F(1, 79) = 7.252$, p =.009, η_p^2 =.084, due to fewer errors for gaze than for arrow stimuli (6.375 % vs 7.816 %). The other results were non-significant ($ps >$. 509).[2]

3.1. Manipulation check analyses: Assessing the ability to discriminate the direction of masked distractor stimuli

The percentage of correct responses in the final task addressing discrimination of the direction of distractor stimuli was analysed using a *t*-test. In line with previous studies, we expected to observe no significant differences between the correct and incorrect responses (i.e., a percentage of correct responses close to chance level; e.g., Sato et al., 2007; 2010).

The results confirmed our hypothesis. One sample *t*-test analyses showed no evidence that the percentage of correct responses was different from chance level (i.e., 50 %) for both gaze ($M = 50.67$ %, $SE = 0.84$; $t(79) = 0.797$, p =.428, $d = 0.089$) and arrow ($M = 50.36$ %, $SE = 0.88$; $t(79) = 0.406$, p =.686, $d = 0.045$) stimuli.

4. General discussion

In this registered report, we explored whether briefly-presented masked gaze stimuli can impact the programming of saccadic eye movements. Participants were instructed to perform a leftward or a rightward saccade according to a symbolic instruction cue presented in the centre of the screen. At the same time, in one block of trials, an averted-gaze face was presented for either a relatively long time (1000 ms), or for a short time (8 ms) and then backward-masked. In another block of trials, the face was replaced by arrow stimuli, acting as a non-social control condition. The participants, at the very end of the study, also completed a secondary additional task aimed at assessing whether, in the case of the 8-ms presentation, they were able to discriminate the spatial direction of the two kinds of stimuli.

Starting from this latter task, the data clearly showed that the overall performance was not statistically different from the chance level for both arrows and gaze. This indicates that our manipulation aimed at reducing the visibility of the two stimuli worked properly and aligns with both our predictions and the results of previous studies that adopted a similar procedure (see, e.g., Al-Janabi & Finkbeiner, 2012; Sato et al., 2007; Uono et al., 2018).

As for the oculomotor task, the present work was aimed at testing three main hypotheses. First, we predicted an overall main effect of spatial congruency, with smaller latencies on congruent trials than on incongruent trials. This hypothesis was confirmed, thus corroborating the notion that this task can induce strong and reliable oculomotor interference (see, e.g., Dalmaso et al., 2020c; Ricciardelli et al., 2002). Second, we predicted an interaction involving the Congruency and Condition (i.e., unmasked vs masked) factors, which was supposed to reflect a smaller, but significant, oculomotor interference for the masked stimuli than for the unmasked stimuli. The results we observed do not confirm this prediction. Indeed, the effect of oculomotor interference was significant in the unmasked condition alone, while the latencies for congruent and incongruent trials were not statistically different in the masked condition. The lack of any evidence for oculomotor interference in this latter condition deviates from what was reported in some previous studies in which even masked stimuli could elicit a relatively small yet significant spatial cueing effect in covert orienting of attention (see, e.g.,

[2] One reviewer suggested to explore the possible role of block order (i.e., gaze stimuli first vs arrow stimuli first) on the oculomotor interference effect. These exploratory, unplanned, analyses showed that block order did not play any role. Indeed, all the interactions involving Congruency and Block order were non-significant, both in latencies ($ps > 0.320$) and in error ($ps > 0.223$) analyses.

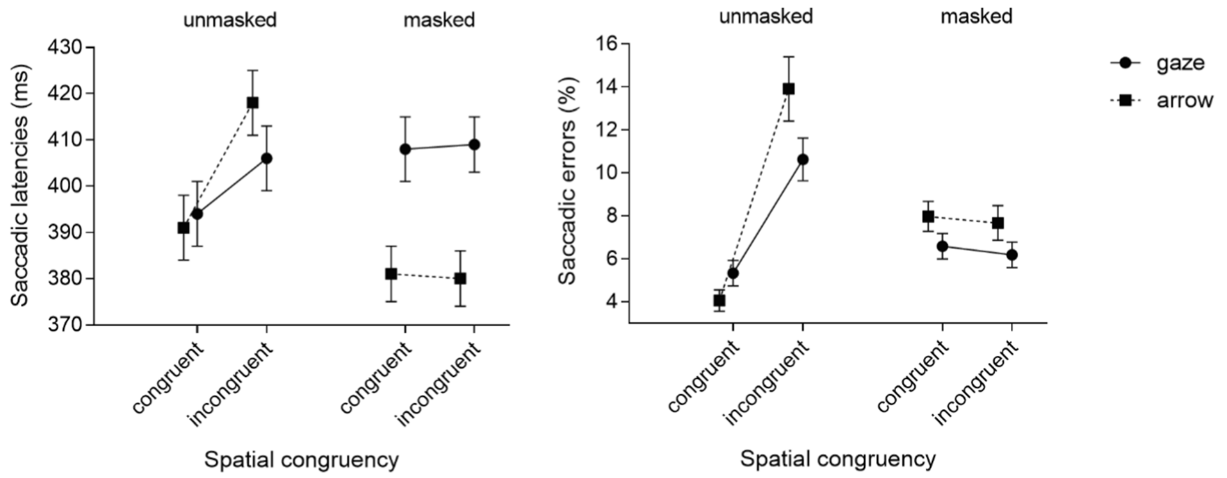

Fig. 2. Mean saccadic latencies (left panel) and errors (right panel) as a function of spatial congruency and condition for gaze and arrow distractors.

Sato et al., 2007, 2016). Third, we predicted the oculomotor interference effect to be significant for both the unmasked and the masked gaze and arrow stimuli (see, e.g., Cole & Kuhn, 2010; Sato et al., 2007), in line with the idea that both stimuli should lead to a similar pattern of results. Related to this point, we observed two unexpected results, namely a two-way interaction between Congruency and Distractor type, indicating that the oculomotor interference effect was reliable for both stimuli, but its magnitude was greater for arrow than for gaze stimuli. This pattern was further qualified by the three-way interaction involving all experimental factors. In sum, this latter interaction confirmed that, in the masked condition, no significant oculomotor effects emerged for both arrow and gaze stimuli whereas, in the unmasked condition, the oculomotor interference effect was significant for both stimuli, but it was also greater in magnitude in the case of arrows. It is important to note that even if it is true that we built our main hypotheses and the design of the task around the patterns expected for saccadic latencies, the same results were also reflected in saccadic accuracy. This can be interpreted as further proof of the robustness of the observed pattern of data and indicates that our task impacted saccadic programming and execution not only in the temporal domain but also at the spatial level.

Taken together, the results provided by this registered report could be summarised as follows: 1) the brief (i.e., 8 ms) presentation of averted gaze or arrow stimuli, which were then masked, was unable to elicit the oculomotor interference effect in the task employed here; 2) the absence of any perceptual awareness in the masked condition was also confirmed at the subjective level; 3) when the two stimuli were presented without any viewing restriction (i.e., unmasked), the oculomotor interference effect was significant for both arrow and eye-gaze stimuli, although it was stronger in the former case.

As for the first result, the fact that the brief and masked presentation of arrow and gaze stimuli could abolish the oculomotor interference effect contrasts with previous studies on covert attention showing that spatial cueing effects can emerge, in restricted viewing conditions, in response to both arrows (Cole & Kuhn, 2010) and gaze stimuli (e.g., Al-Janabi & Finkbeiner, 2012; Bailey et al., 2014; Lu et al., 2012; Mitsuda & Masaki, 2018; Sato et al., 2007; Xu et al., 2011). We suggest that one of the possible explanations for this discrepancy can be identified in the temporal parameters we used. Even if there is evidence showing that an 8-ms presentation of facial stimuli would be enough to observe modulations at different processing levels (see, e.g., Kiss & Eimer, 2008; Mitsuda & Masaki, 2018; Smith, 2012), most of the studies investigating gaze-cueing of attention for masked stimuli used longer temporal durations, even up to 30 ms (e.g., Al-Janabi & Finkbeiner, 2012). Future studies could employ a wider range of durations (e.g., 8 to 30 ms) to explore the impact of such a temporal parameter. That said, it is worth remarking that there is evidence showing that eye movements can be influenced by visual stimuli presented for extremely brief temporal durations (e.g., Spering & Carrasco, 2015), and this keeps true even when stimuli are presented at fixation (see, e.g., Hinze et al., 2021). Future research would benefit from comparing the performance emerging from tasks based on manual and oculomotor responses addressing covert and overt orienting, with the aim of revealing both the similarities and the differences across the two domains (see also, e.g., Bonmassar et al., 2019).

Importantly, our findings showed that, in the unmasked condition, the oculomotor interference effect was present for both eye-gaze and arrow stimuli. The fact that oculomotor interference was greater for arrows than for gaze stimuli contrasts with most studies on overt and covert visual orienting that reported similar outcomes for the two stimuli (at least in healthy adults; see, e.g., Dalmaso et al., 2020c; Hermens & Walker, 2010; Kuhn et al., 2010; Kuhn & Benson, 2007; Kuhn & Kingstone, 2009; for a recent *meta*-analysis, see also Chacón-Candia et al., 2022). Nevertheless, it should be noted that the literature also offers pieces of evidence showing a greater interference effect for gaze stimuli over arrows (Ricciardelli et al., 2002), but also the opposite scenario (Kuhn et al., 2011). We believe that these disparities are likely to reflect some differences at the perceptual level. As for the stimuli employed here, we opted to employ the face of a real individual to present participants with a social stimulus with good ecological validity, and the same reasoning also guided the choice for the arrow stimuli which were created to match, as closely as possible, standard arrows people experience in everyday life (e.g., digital interfaces, street signals, etc.). Although the arrows were also created to be the same size as the eye-gaze stimuli, with the aim of maintaining a relatively good level of comparability between the two stimuli, it is undeniable that when participants were presented with the face stimulus they were exposed to a much more complex and rich source of visual information than the two arrows. This greater complexity and richness could, in turn, have caused a reduction in the salience of the region (i.e., eye-gaze) providing the spatial information, which instead represented the only element constituting the arrow stimuli. The choice of the most suitable stimuli to study visual orienting in both social and symbolic domains often represents a problematic issue, given that any gain in experimental control obtained through the presentation of perceptually similar stimuli brings with it an inevitable reduction in the ecological value of research, and vice versa. In future works, it will be important to explore whether the differences between gaze and arrow stimuli that emerged here still occur even when stimuli are built up in a way that make them more similar at the perceptual level.

To conclude, the results provided by this registered report extend our knowledge concerning the mechanisms underlying attentional orienting elicited by gaze and arrow stimuli as revealed by eye movements, and provide new insights into the boundary conditions in which oculomotor interference can take place.

CRediT authorship contribution statement

Mario Dalmaso: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Luigi Castelli:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Chiara Bernardini:** Investigation, Writing – review & editing. **Giovanni Galfano:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Experiment code, stimuli, and data are made publicly available on the Open Science Framework repository (https://doi.org/10.17605/OSF.IO/3TFYP).

Acknowledgements

We thank Gregory Francis and three anonymous reviewers for their very helpful comments on earlier drafts of this paper.

References

Al-Janabi, S., & Finkbeiner, M. (2012). Effective processing of masked eye gaze requires volitional control. *Experimental Brain Research, 216*(3), 433–443. https://doi.org/10.1007/s00221-011-2944-0

Al-Janabi, S., & Finkbeiner, M. (2014). Responding to the direction of the eyes: In search of the masked gaze-cueing effect. *Attention, Perception & Psychophysics, 76*, 148–161. https://doi.org/10.3758/s13414-013-0570-6

Bailey, P. E., Slessor, G., Rendell, P. G., Bennetts, R. J., Campbell, A., & Ruffman, T. (2014). Age differences in conscious versus subconscious social perception: The influence of face age and valence on gaze following. *Psychology and Aging, 29*(3), 491–502. https://doi.org/10.1037/a0036249

Bompas, A., Hedge, C., & Sumner, P. (2017). Speeded saccadic and manual visuo-motor decisions: Distinct processes but same principles. *Cognitive Psychology, 94*, 26–52. https://doi.org/10.1016/j.cogpsych.2017.02.002

Bonmassar, C., Pavani, F., & van Zoest, W. (2019). The role of eye movements in manual responses to social and nonsocial cues. *Attention, Perception, & Psychophysics, 81*(5), 1236–1252. https://doi.org/10.3758/s13414-019-01669-9

Capozzi, F., & Ristic, J. (2018). How attention gates social interactions. *Annals of the New York Academy of Sciences, 1426*(1), 179–198. https://doi.org/10.1111/nyas.13854

Chacón-Candia, J. A., Román-Caballero, R., Aranda-Martín, B., Casagrande, M., Lupiáñez, J., & Marotta, A. (2022). Are there quantitative differences between eye-gaze and arrow cues? A meta-analytic answer to the debate and a call for qualitative differences. *Neuroscience & Biobehavioral Reviews, 104993*. https://doi.org/10.1016/j.neubiorev.2022.104993

Ciardo, F., Marino, B. F. M., Actis-Grosso, R., Rossetti, A., & Ricciardelli, P. (2014). Face age modulates gaze following in young adults. *Scientific Reports, 4*(1), 4746. https://doi.org/10.1038/srep04746

Cole, G. G., & Kuhn, G. (2010). What the experimenter's prime tells the observer's brain. *Attention, Perception & Psychophysics, 72*(5), 1367–1376. https://doi.org/10.3758/APP.72.5.1367

Dalmaso, M., Alessi, G., Castelli, L., & Galfano, G. (2020a). Eye contact boosts the reflexive component of overt gaze following. *Scientific Reports, 10*(1), 4777. https://doi.org/10.1038/s41598-020-61619-6

Dalmaso, M., Castelli, L., & Galfano, G. (2020b). Social modulators of gaze-mediated orienting of attention: A review. *Psychonomic Bulletin & Review, 27*(5), 833–855. https://doi.org/10.3758/s13423-020-01730-x

Dalmaso, M., Castelli, L., & Galfano, G. (2020c). Early saccade planning cannot override oculomotor interference elicited by gaze and arrow distractors. *Psychonomic Bulletin & Review, 27*(5), 990–997. https://doi.org/10.3758/s13423-020-01768-x

Dalmaso, M., Castelli, L., & Galfano, G. (2021). Increased gaze cueing of attention during COVID-19 lockdown. *iScience, 24*(11), Article 103283. https://doi.org/10.1016/j.isci.2021.103283

Dalmaso, M., Galfano, G., & Castelli, L. (2015). The impact of same- and other-race gaze distractors on the control of saccadic eye movements. *Perception, 44*(8–9), 1020–1028. https://doi.org/10.1177/0301006615594936

DeBruine, L. M. (2017). Webmorph (Version v0.0.0.9001). *Zenodo.*. https://doi.org/10.5281/zenodo.1073696

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition, 6*(5), 509–540. https://doi.org/10.1080/135062899394920

Emery, N. J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience & Biobehavioral Reviews, 24*(6), 581–604. https://doi.org/10.1016/S0149-7634(00)00025-7

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review, 5*(3), 490–495. https://doi.org/10.3758/BF03208827

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin, 133*(4), 694–724. https://doi.org/10.1037/0033-2909.133.4.694
Gayet, S., Van der Stigchel, S., & Paffen, C. L. (2014). Seeing is believing: Utilization of subliminal symbols requires a visible relevant context. *Attention, Perception, & Psychophysics, 76*(2), 489–507. https://doi.org/10.3758/s13414-013-0580-4
Hermens, F., & Walker, R. (2010). Gaze and arrow distractors influence saccade trajectories similarly. *Quarterly Journal of Experimental Psychology, 63*(11), 2120–2140. https://doi.org/10.1080/17470211003718721
Hinze, V. K., Uslu, O., Antono, J. E., Wilke, M., & Pooresmaeili, A. (2021). The effect of subliminal incentives on goal-directed eye movements. *Journal of Neurophysiology, 126*(6), 2014–2026. https://doi.org/10.1152/jn.00414.2021
Kiss, M., & Eimer, M. (2008). ERPs reveal subliminal processing of fearful faces. *Psychophysiology, 45*(2), 318–326. https://doi.org/10.1111/j.1469-8986.2007.00634.x
Kuhn, G., & Benson, V. (2007). The influence of eye-gaze and arrow pointing distractor cues on voluntary eye movements. *Perception & Psychophysics, 69*(6), 966–971. https://doi.org/10.3758/BF03193934
Kuhn, G., Benson, V., Fletcher-Watson, S., Kovshoff, H., McCormick, C. A., Kirkby, J., & Leekam, S. R. (2010). Eye movements affirm: Automatic overt gaze and arrow cueing for typical adults and adults with autism spectrum disorder. *Experimental Brain Research, 201*(2), 155–165. https://doi.org/10.1007/s00221-009-2019-7
Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Attention, Perception, and Psychophysics, 71*(2), 314–327. https://doi.org/10.3758/APP.71.2.314
Kuhn, G., Tewson, L., Morpurgo, L., Freebody, S. F., Musil, A. S., & Leekam, S. R. (2011). Developmental changes in the control of saccadic eye movements in response to directional eye gaze and arrows. *Quarterly Journal of Experimental Psychology, 64*(10), 1919–1929. https://doi.org/10.1080/17470218.2011.5925
Lakens, D., & Caldwell, A. R. (2021). Simulation-based power analysis for factorial analysis of variance designs. *Advances in Methods and Practices in Psychological Science, 4*(1), 1–14. https://doi.org/10.1177/2515245920951503
Lu, S., Liu, Y., & Fu, X. (2012). The social attention shifts triggered by supraliminal and subliminal gaze-head direction cues. *Communications in Computer and Information Science, 315*, 57–64. https://doi.org/10.1007/978-3-642-34240-0_8
Malienko, A., Harrar, V., & Khan, A. Z. (2018). Contrasting effects of exogenous cueing on saccades and reaches. *Journal of Vision, 18*, 1–16. https://doi.org/10.1167/18.9.4
McKay, K. T., Grainger, S., Coundouris, S., Skorich, D., & Henry, J. (2022). Visual attentional orienting by eye gaze: A meta-analytic review of the gaze-cueing effect. *Psychological Bulletin, 147*(12), 1269–1289. https://doi.org/10.1037/bul0000353
Mitsuda, T., & Masaki, S. (2018). Subliminal gaze cues increase preference levels for items in the gaze direction. *Cognition and Emotion, 32*(5), 1146–1151. https://doi.org/10.1080/02699931.2017.1371002
Porciello, G., Liuzza, M. T., Minio-Paluello, I., Caprara, G. V., & Aglioti, S. M. (2016). Fortunes and misfortunes of political leaders reflected in the eyes of their electors. *Experimental Brain Research, 234*(3), 733–740. https://doi.org/10.1007/s00221-015-4496-1
Reuss, H., Pohl, C., Kiesel, A., & Kunde, W. (2011). Follow the sign! Top-down contingent attentional capture of masked arrow cues. *Advances in Cognitive Psychology, 7*(1), 82–91. https://doi.org/10.2478/v10053-008-0091-3
Ricciardelli, P., Bricolo, E., Aglioti, S., & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: Exploring the tendency to imitate another individual's gaze. *Neuroreport, 13*(17). https://doi.org/10.1097/01.wnr.0000044227
Sato, W., Kochiyama, T., Uono, S., & Toichi, M. (2016). Neural mechanisms underlying conscious and unconscious attentional shifts triggered by eye gaze. *NeuroImage, 124*, 118–126. https://doi.org/10.1016/j.neuroimage.2015.08.061
Sato, W., Kochiyama, T., Uono, S., Yoshimura, S., & Toichi, M. (2017). Neural mechanisms underlying conscious and unconscious gaze-triggered attentional orienting in autism spectrum disorder. *Frontiers in Human Neuroscience, 11*, 1–13. https://doi.org/10.3389/fnhum.2017.00339
Sato, W., Okada, T., & Toichi, M. (2007). Attentional shift by gaze is triggered without awareness. *Experimental Brain Research, 183*(1), 87–94. https://doi.org/10.1007/s00221-007-1025-x
Sato, W., Uono, S., Okada, T., & Toichi, M. (2010). Impairment of unconscious, but not conscious, gaze-triggered attention orienting in Asperger's disorder. *Research in Autism Spectrum Disorders, 4*(4), 782–786. https://doi.org/10.1016/j.rasd.2010.02.002
Smith, M. L. (2012). Rapid processing of emotional expressions without conscious awareness. *Cerebral Cortex, 22*(8), 1748–1760. https://doi.org/10.1093/cercor/bhr250
Spering, M., & Carrasco, M. (2015). Acting without seeing: Eye movements reveal visual processing without awareness. *Trends in Neurosciences, 38*(4), 247–258. https://doi.org/10.1016/j.tins.2015.02.002
Strohminger, N., Gray, K., Chituc, V., Heffner, J., Schein, C., & Heagins, T. B. (2016). The MR2: A multi-racial, mega-resolution database of facial stimuli. *Behavior Research Methods, 48*(3), 1197–1204. https://doi.org/10.3758/s13428-015-0641-9
Uono, S., Sato, W., Sawada, R., Kochiyama, T., & Toichi, M. (2018). Spatiotemporal commonalities of fronto-parietal activation in attentional orienting triggered by supraliminal and subliminal gaze cues: An event-related potential study. *Biological Psychology, 136*, 29–38. https://doi.org/10.1016/j.biopsycho.2018.05.004
Xu, S., Zhang, S., & Geng, H. (2011). Gaze-induced joint attention persists under high perceptual load and does not depend on awareness. *Vision Research, 51*(18), 2048–2056. https://doi.org/10.1016/j.visres.2011.07.023
Zhang, X., Dalmaso, M., Castelli, L., Fu, S., & Galfano, G. (2021). Cross-cultural asymmetries in oculomotor interference elicited by gaze distractors belonging to Asian and White faces. *Scientific Reports, 11*(1), 1–11. https://doi.org/10.1038/s41598-021-99954-x