Spatial interference triggered by gaze and arrows. The role of target background on spatial interference

Rafael Román-Caballero[*], Andrea Marotta, and Juan Lupiáñez

Department of Experimental Psychology, Universidad de Granada (SPAIN)

Mind, Brain and Behavior Research Center (CIMCYC), University of Granada (SPAIN)

Recent evidence with a spatial interference paradigm has shown that arrows and eye gaze yield opposite congruency effects, arrow target eliciting faster responses when their direction is congruent with their position (standard congruency effect), and gaze producing faster reaction times for incongruent conditions (reversed congruency effect). But in ecological contexts eye gaze tend to be more perceptually complex (i.e., embedded in the whole face) than simple arrows. The present study aimed to replicate this dissociation using whole faces and a comparable non-social target, formed by arrows embedded in a colored geometric background. Whereas the reversed congruency effect with gaze was replicated, the standard spatial interference with arrows was surprisingly absent. A similar outcome appeared when the contrast between the arrows and the task-irrelevant background increased. The results confirm the robustness of the reversed congruency effect with eyes, regardless of whether they are presented alone or within a face. In addition, and importantly, the unexpected absence of the spatial conflict with complex arrow targets seems to be a consequence of higher figure-ground segregation demands, which extend the processing of the task-relevant spatial dimension and, in turn, cause the decay of the location code. This pattern of results, and the provided interpretation, can explain previous unexplained findings in the spatial interference literature.

Eye gaze constitutes an important communicative signal in social interactions, conveying information about the focus of attention, private thoughts, and intentions. Along with other directional stimuli (e.g., arrows), gaze has proven to be an effective orienting signal in multiple adaptations of

[*] **Corresponding author:** Rafael Román-Caballero Departamento de Psicología Experimental, Facultad de Psicología, Universidad de Granada, Campus de Cartuja, s/n, Granada, SPAIN. E-mail: rrarroca@ugr.es.

the Posner's cueing paradigm (Posner, 1980; for reviews of gaze cueing, see Birmingham & Kingstone, 2009). The task classically involves a spatial cue preceding the target, which facilitates the response for cued compared to uncued locations (i.e., *cueing effect*). Despite their disparate social and non-social nature, both gaze and arrows produce similar cueing effects (Birmingham & Kingstone, 2009; Marotta et al., 2012) and share several orienting characteristics (Ristic & Kinstone, 2012). First, arrows and gaze elicit a fast (100 ms) and automatic shift of attention to the signaled location, even when they are uninformative or counterpredictive cues, typical of exogenous orienting (Frischen & Tipper, 2004). In addition, they trigger prolonged facilitation (for stimulus onset asynchronies, SOAs, longer than 1 s), more characteristic of endogenous orienting. Therefore, behaviorally and biologically relevant cues, such as arrows and gaze, show a complex profile of processes that do not fit well with the classic definition of exogenous or endogenous orienting (Ristic & Kinstone, 2012).

The incapability to find quantitative differences between gaze and arrows in cueing paradigms (Brignani et al., 2009; Tipples, 2002) might be due to that type of task specifically measures an orienting effect shared by gaze and arrows (Gibson & Kingstone, 2006). However, gaze might trigger additional attentional processes, which might only be uncovered by approaches aimed at investigating qualitative differences between the two types of cue. For example, it has been found that whereas arrows spread their attentional facilitation through an entire cued object, gaze selectively orients the attention to the specific location or part of the object looked at (Marotta et al., 2012; Chacón-Candia et al., 2020). Beyond cueing paradigms, other tasks have shown distinctive properties of eye cues. Cañadas and Lupiáñez (2012) used a spatial interference task in which gaze looking rightward or leftward appeared to the right or left of the fixation point. The relationship between the two spatial dimensions of the stimulus, direction and spatial location of the gaze, produced congruent and incongruent conditions, depending on whether they were the same or opposite. A reversed congruency effect was observed with faster and more accurate responses for incongruent (e.g., a face looking to the right, presented on the left) than congruent conditions (e.g., a face looking to the left, presented on the left). This surprising result was opposite to the classical spatial Stroop effect generally observed with non-social stimuli like arrows or words (e.g., faster reaction time for congruent conditions; Lu & Proctor, 1995). Other research groups have replicated this reversed congruency effect (Edwards et al., 2020; Jones, 2015), and further investigation has revealed that this effect is found both when eyes were embedded in a whole face (Jones, 2015; Torres-Marín et al., 2017) or presented alone (Cañadas & Lupiáñez, 2012), and is

modulated by the emotional expression of the face (Jones, 2015; Torres-Marín et al., 2017).

In a recent study (Marotta et al., 2018), we have directly compared spatial interference effects elicited by gaze and arrow in the same sample of participants, showing opposite congruency effects for these two types of stimuli (standard vs. reversed congruency effects respectively for arrows and gaze). Moreover, electroencephalographic evidence has shown both shared and dissociable congruency effects between gaze and no-social stimuli such as arrows, as reflected by a similar modulation of early event-related components (P1, N1, and N170), and a subsequent opposite modulation over later components (N2 and P3; Marotta et al., 2019). This suggests that, initially, eye gaze and arrows are similarly processed, leading to the same spatial conflict. However, at a later stage of processing, additional (social-specific) processes might lead to produce the reversion of the conflict with gaze stimuli.

However, no definitive explanation has been provided for the reversed congruency effect. Initially, we hypothesized that a gaze oriented inwards (i.e., on incongruent trials) might be interpreted as a face potentially making eye contact, facilitating the target processing in that type of trials (Cañadas & Lupiáñez, 2012; Marotta et al., 2018). However, in a recent study we observed no reversion with gaze in a series of experiments in which participants had to discriminate the color of the eyes (rather than gaze direction; Narganes-Pineda et al., under review). The lack of influence of the eye-gaze direction in this implicit task is inconsistent with an eye-contact hypothesis. One possible explanation is that the reversed congruency effect would be a consequence of an episode of joint attention in which both the participant and the gaze target look at the same object, at fixation cross (Edwards et al., 2020), therefore facilitating responses on incongruent trials. Alternatively, we have recently proposed that the social-specific reversion of the congruency effect could be due to the fact that a gaze looking outward (i.e., on congruent trials) might lead to a shift of attention out of the task producing behavioral distraction (Hemmerich et al., under review). We have termed this hypothesis *joint distraction*. Further studies are needed to disentangle the mechanisms behind this social attentional component.

The present study aimed to test in the same group of participants the findings of Cañadas and Lupiáñez (2012) and Marotta et al. (2018) of opposite behavioral effects for social and non-social targets. To make similar non-social and social targets, two arrows and cropped eyes were respectively used by Marotta et al. (2018), instead of using a whole face as a social stimulus, like in previous studies (Cañadas and Lupiáñez, 2012; Jones, 2015; Torres-Marín et al., 2017). In the present experiments, which were conducted

before the experiment reported by Marotta et al., the original whole faces used by Cañadas and Lupiáñez (2012) were used instead as social targets, as they represent more ecological social stimuli. One caveat is that faces are perceptually more complex than single arrows. Therefore, to control for this confound, we surrounded the arrows by a colored geometric background in which they were embedded (see **Figure 1**). Using geometric shapes of similar colors to those of their face counterparts, we tried to equal the perceptual complexity of both types of targets.

EXPERIMENT 1

We expected to replicate previous findings with comparable stimulus complexity for social and non-social stimuli. Therefore, a standard congruency effect for arrows and a reversed spatial congruency effect for gaze were anticipated.

METHOD

Participants. A total sample of 36 adults (27 women; mean age of 20.9 years, SD = 3.4) participated in the experiment, which took part in the Autumn of 2016. All of them were students from the University of Granada who signed informed consent and received partial course credit for participating. All had self-reported normal or corrected-to-normal vision and were naïve to the purpose of the experiment.

We choose the reversed congruency effect in Jones (2015) as a reference to estimate the required sample size [note that both Experiments 1 and 2 were conducted before Marotta et al., 2018]. Thus, using G*Power 3.1 (Faul et al., 2009), we found that at least 34 participants were necessary for an effect size of $d_z = 0.5$ in a paired *t*-test (i.e., for the congruency effect for each stimulus type) with an alpha of .05 and a power of .80.

The study was conducted following the ethical guidelines laid down by the University of Granada (536/CEIH/2018), in accordance with the ethical standards of the 1964 Declaration of Helsinki (last update: Seoul, 2008). Outlier detection was based on performance (i.e., mean reaction times, RTs; and accuracy) identified as poor in terms of meeting all the following indices: standard deviation from the mean (> 2.5), studentized deleted residuals (> 3), and Cook's D_i (> 4/n).

Apparatus and Stimuli. The task was programmed and administered using E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). It was run on a standard Pentium 4 PC and a 17-in. widescreen monitor with a

1,024 × 768 pixels resolution. Half of the stimuli were eight neutral Caucasian faces (four women) looking straight ahead (taken from the NimStim Face Stimulus Set; https://www.macbrain.org/resources.htm)[1]. We manipulated the direction of their gaze with Adobe Photoshop CS in order to create two versions of each face, looking leftward and rightward. The remaining half were a set of two black arrows on a geometric mosaic. Eight mosaics were created following the pattern of colors and shapes of the different faces to create a homologous background for each face (using the stained-glass texture in Adobe Photoshop CS; for an example, see **Figure 1a**; all the set of mosaics are available at https://osf.io/h3qbu/). We also included two versions of the stimuli in the arrows set, with arrows pointing leftward and rightward. All target stimuli subtended 1° × 4° degrees of visual angle at a viewing distance of 57 cm.

a)   b)
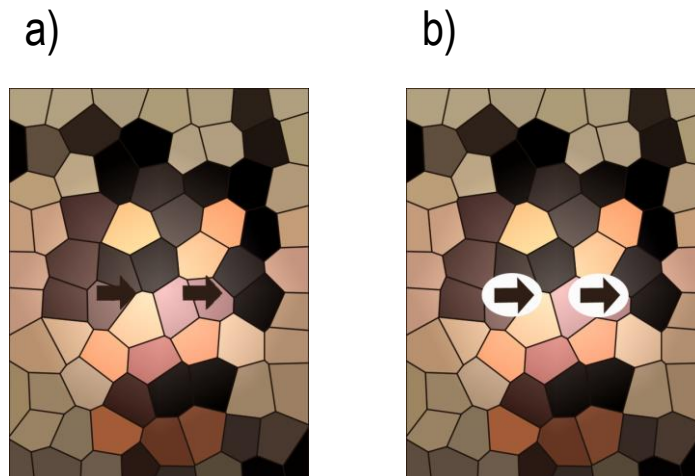
Figure 1. Examples of the arrow stimuli in Experiments 1 (a) and 2 (b).

Procedure. Apart from the stimulus used as target, the present study used the procedure as in Marotta et al., (2018). Thus, participants were seated approximately 57 cm from the computer screen in a faintly lit room to perform the experimental task. They were required to perform a discrimination task in which they had to respond as fast and accurately as possible to the direction (left or right) indicated, in different blocks of trials,

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[1] The face stimulus was drawn from the NimStim Face Stimulus Set, developed by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham, at tott0006@tc.umn.edu, for more information concerning the stimulus set.

by the eye gaze or arrows. Although similar effects have been observed when stimulus type is manipulated randomly within blocks of trials (Hemmerich et al., under review), here we manipulated it between blocks as in Marotta et al., (2018). Thus, the experiment was composed of two halves (one for each target type, with the order counterbalanced across participants), each one composed of 15 practice trials followed by two experimental blocks of 64 trials each. Target direction and target location were randomly selected within each block of trials.

Each trial (see **Figure 2**) began with a white fixation cross presented in the center of a black screen for 1 s. Participants were instructed to fixate the cross. Then a face or arrows looking/pointing to the right or the left was presented to either the left or the right of the fixation cross for 2 s, leading to either congruent or incongruent (e.g., a left-indicating target presented on the right) conditions. The distance from the center of the lateral stimulus to the central fixation cross was 5 cm. Participants were instructed to press the "z" key in response to targets indicating the left and the "m" key in response to targets indicating the right, independent of the location of the target. Since the target onset, participants were requested to discriminate stimulus direction as fast as possible but avoiding committing errors. Feedback for incorrect key presses was provided to participants, in the form of a 220-Hz tone presented for 1,500 ms.
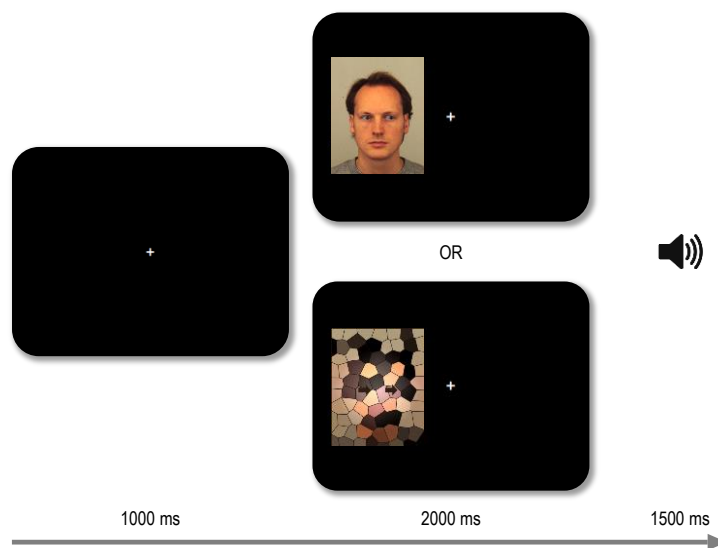
Figure 2. Schematic view of a trial sequence, moving from left to right, for both the gaze and the arrow target conditions. The examples represent incongruent trials. The speaker icon represents auditory feedback.

Design. The experiment had a two-factor repeated measures design: target type (gaze vs. arrows), congruency (congruent vs. incongruent trials). Accordingly, repeated measures ANOVAs were conducted with mean RTs and accuracy (as mean percent errors). In addition, paired *t*-tests were used for comparison between two conditions. To estimate effect size and its precision, we used η_p^2 and its 90% confidence interval for ANOVAs, and Cohen's d_z (M$_{diff}$/SD$_{diff}$ representing the mean and the standard of the difference score) and its 95% confidence interval for paired *t*-tests (for detailed discussion, see Lakens, 2013).

RESULTS

Data of one participant were not included in the analyses because of a high proportion of errors (50%). The inspection of this case allowed us to identify that the participant misunderstood the instructions and responded to stimuli location. In addition, we identified one outlier, presenting remarkably low accuracy: an average mean of 28% of errors across conditions, and, in particular, 52% of errors for congruent gaze targets. Data from the practice blocks and RTs lower (0.09%) or higher (2.84%) than 2.5 standard deviations were not analyzed. Moreover, trials with an incorrect response (4.23%) were excluded from the RT analyses.

Table 1. Mean RT and percentages of incorrect responses in Experiments 1 and 2, and the previously published study by Marotta et al. (2018) for comparison. Standard deviations are depicted in parentheses.

		Experiment 1		Experiment 2		Marotta et al. (2018)	
		Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Gaze	**RT**	637.64 (66.00)	605.32 (65.10)	674.34 (77.25)	640.55 (70.52)	596.65 (70.35)	580.13 (69.03)
	% of errors	6.18 (6.56)	4.12 (4.26)	4.49 (5.30)	3.11 (3.82)	3.71 (5.85)	2.80 (3.00)
Arrows	**RT**	601.47 (45.60)	586.90 (48.58)	641.47 (62.49)	641.96 (74.24)	496.99 (64.53)	519.00 (69.09)
	% of errors	3.59 (3.01)	3.32 (2.91)	6.69 (6.49)	7.78 (6.21)	2.11 (2.40)	4.57 (5.52)

Mean Reaction Times. A main effect of target type, $F(1, 33) = 7.36$, $p = .01$, $\eta_p^2 = .18$, 90% CI [.03, .36], indicated that participants showed overall

faster responses for arrow targets than for faces (594.19 vs. 621.48 ms). Congruency was also significant, $F(1, 33) = 35.96$, $p < .001$, $\eta_p^2 = .52$, 90% CI [.30, .65], as responses were faster for incongruent than congruent trials. Critically, the target type × congruency interaction was significant, $F(1, 33) = 7.76$, $p = .01$, $\eta_p^2 = .19$, 90% CI [.03, .37][2], due to the larger (reversed) congruency effect (*mean RTs in incongruent conditions – mean RTs in congruent trials*) observed for face stimuli than for arrows, $t(33) = -2.79$, $p = .01$, $d_z = -0.48$, 95% CI [−0.84, −0.11]. The large reversed congruency effect observed for gaze (-32.32 ms) replicated that observed by Cañadas and Lupiáñez (2012), $t(33) = -5.39$, $p < .001$, $d_z = -0.92$, 95% CI [−1.32, −0.50]. However, contrary to our predictions, the effect observed with arrows (-14.57 ms) was also significantly reversed, $t(33) = -3.78$, $p < .001$, $d_z = -0.63$, 95% CI [−1.01, −0.26] (see **Table 1** and **Figure 3**). Importantly, the reversion was observed regardless of the order in which gaze block occurred (i.e., whether gaze block was the first or the second block), as block order did not interact with any other variable ($Fs < 1$), when it was included as a between-subjects variable in the ANOVA.
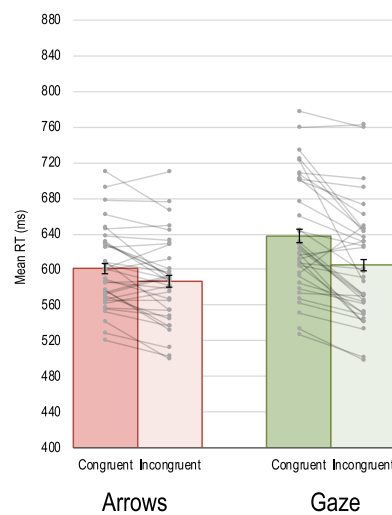
Figure 3. Mean RT for the two types of targets in congruent and incongruent conditions of Experiment 1. Across-participants mean RTs for arrow and gaze targets are depicted in red and green, whereas single-participant scores are in grey. Error bars represent standard errors of the means, with between-subjects variance removed using Cousineau-Morey method (Morey, 2008).

[2] The results were similar when data were analyzed using a linear mixed-effects model with participants and individual targets as random factors with a maximal random-effect structure, including random intercepts for such factors as well as by-participants and by-items random slopes: target type, $F(1, 44.82) = 5.68$, $p = .021$; congruency, $F(1, 33.05) = 27.29$, $p < .0001$; target type × congruency interaction, $F(1, 30.48) = 9.76$, $p = .004$.

Accuracy. Similarly to the results with meant RTs, participants exhibited fewer errors with arrows than faces (3.46 vs. 5.15%), $F(1, 33) = 4.72$, $p = .04$, $\eta_p^2 = .13$, 90% CI [.00, .30], and, in line with the reversed congruency effect, the participants numerically committed fewer errors with incongruent than congruent trials (3.72 vs. 4.88%), $F(1, 33) = 3.83$, $p = .06$, $\eta_p^2 = 0.10$, 90% CI [0, .27]. Finally, the two-way interaction was not significant, $F(1, 33) = 2.45$, $p = .13$, $\eta_p^2 = 0.07$, 90% CI [.00, .23].

DISCUSSION

Consistent with previous studies using similar spatial interference paradigms (Cañadas & Lupiáñez, 2012; Jones, 2015), the results of Experiment 1 replicated the reversed congruency effect with gaze when full faces were used as target instead of cropped eyes. The direction of this effect (faster responses and fewer errors in incongruent trials) was opposite to the typical spatial conflict observed with non-social stimuli, such as triangles in Cañadas and Lupiáñez, 2012) or a pair of arrows in Marotta et al. (2018). Unexpectedly, however, in our study arrows also produced a reversed congruency effect, although of smaller magnitude than gaze. One possible explanation is that the patterns of colors and shapes of the geometric background triggered an interpretation of these patterns as face-like stimuli. However, using a similar spatial interference task, Cañadas and Lupiáñez (2012; Experiment 3) showed that it is not easy to interpret non-social targets (i.e., triangles) as a gaze, even when it is explicitly suggested. Moreover, in the present study, we found that congruency effects were not affected by the order of the stimuli presentation. This finding is not consistent with the idea that the reversed congruency effect observed with arrows was due to their interpretation as face-like stimuli. In this case, indeed, we should have observed a greater reversed congruency effect with arrows when participants performed the face block first, making more likely to interpret arrows as face-like stimuli when following the gaze block.

Another possible explanation may be that the high perceptual complexity of the background might have made necessary first to segregate the target arrow from the background before discriminating its direction. As the irrelevant spatial code is generated when the target and background are laterally presented, the need to first select the target from the background might have delayed target selection, therefore desynchronizing the activation of the relevant spatial code and in turn reducing the conflict with the task-irrelevant spatial dimension (i.e.., target position). This would be consistent with previous unexplained reports of the absence of spatial interference by

arrows when flanked by other interfering arrows (Fan et al., 2009; Lawrence, 2018). However, the small reversed congruency effect with arrows might be a spurious effect, which calls for a replication. This was the main goal of the following experiment.

EXPERIMENT 2

To clarify the reversed congruency effect with arrow stimuli in the previous experiment, we tried to facilitate arrows selection in Experiment 2, by adding white ovals behind each arrow, to increase the contrast between targets and background. This manipulation was made to facilitate the figure-ground segregation, therefore facilitating target selection. In addition, the manipulation also increased the resemblance with faces. As a consequence, we expected that if the reversed congruency effect elicited by arrows was entirely due to a face-like interpretation of these stimuli, then the reversion should still appear or even increase in this experiment. On the contrary, if the complex figure-ground segregation in the previous experiment significantly contributed to the reversion of the congruency effect, then the higher salience of arrows should improve target selection. Therefore, if this were the relevant factor, this manipulation would eliminate the reversed congruency effect and even lead to a classic spatial interference effect for arrows in this new experiment.

METHOD

Participants. The sample was similar to the sample in Experiment 1, formed by 36 different students from the University of Granada (29 women; mean age of 19.1 years, SD = 1.7). The experiment took part in the Winter of 2016–2017. All participants signed informed consent and received partial course credit for participating. All had self-reported normal or corrected-to-normal vision and were naïve as to the purpose of the experiment. We followed the same procedure as in Experiment 1 for outlier detection.

Apparatus, Stimuli, and Procedure. The task of this study was almost identical to that of the previous experiment. The only difference was that two highly contrasting white ovals were added with Adobe Photoshop CS to the arrow stimuli, one behind each arrow (see **Figure1b**). This manipulation aimed to facilitate the figure-ground segregation. The apparatus, procedure, and design were identical to those in Experiment 1.

RESULTS

One participant was identified as an outlier, with low accuracy in conditions with gaze cues (more than 30% of errors). Similar to Experiment 1, data from the practice blocks and RTs lower (0.17%) or higher (2.78%) than 2.5 standard deviations were not analyzed. Moreover, trials with incorrect responses (5.85%) were not included in the RT analyses.

Mean Reaction Times. As in Experiment 1, the responses for arrow cues were numerically faster than for faces (641.71 vs. 653.53 ms), although the main effect of target type did not reach significance in this experiment, $F(1, 34) = 1.53$, $p = .23$, $\eta_p^2 = .04$, 90% CI [0, .19]. In addition, the main effect of congruency, $F(1, 34) = 16.31$, $p < .001$, $\eta_p^2 = .32$, 90% CI [.12, .49], and, importantly, the two-way interaction were statistically significant, $F(1, 34) = 23.34$, $p < .001$, $\eta_p^2 = .41$, 90% CI [.19, .56][3]. Whereas there was no difference between congruent and incongruent trials with arrows, $t(34) = -0.09$, $p = .93$, $d_z = -0.02$, 95% CI [−0.35, 0.31], participants were 34 ms faster in incongruent than congruent conditions with gaze, $t(34) = -6.12$, $p < .001$, $d_z = -1.03$, 95% CI [−1.44, −0.60] (see **Table 1** and **Figure 4**).
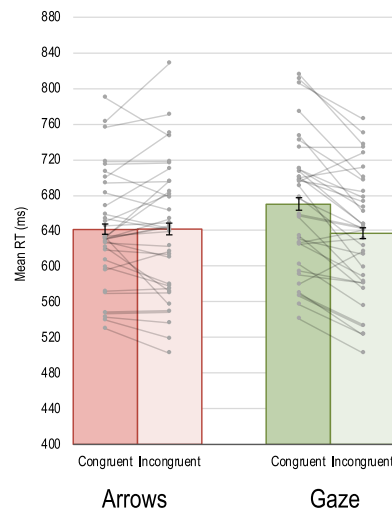
Figure 4. Mean RT for the two types of targets in congruent and incongruent conditions of Experiment 2. Across-participants mean RTs for arrow and gaze targets are depicted in red and green, whereas single-participant scores are in grey. Error bars represent standard errors of the means, with between-subjects variance removed using Cousineau-Morey method (Morey, 2008).

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[3] The results were similar when data were analyzed using a linear mixed-effects model with participants and individual targets as random factors: target type, $F(1, 40.4) = 0.22$, $p = .640$; congruency, $F(1, 33.3) = 4.81$, $p < .036$; target type × congruency interaction, $F(1, 8358.2) = 60.83$, $p < .0001$.

Accuracy. The ANOVA revealed a main effect of target type, $F(1, 34)$ = 9.75, p = .004, η_p^2 = .22, 90% CI [.05, .40], as participants made fewer errors with faces than arrows (3.80 vs. 7.23%). There was no effect of congruency, $F(1, 34)$ = 0.07, p = .80, η_p^2 = .00, 90% CI [0, .07], but the target type × congruency interaction was significant, $F(1, 34)$ = 6.64, p = .02, η_p^2 = .16, 90% CI [.02, .34]. Further analysis showed opposite numerical patterns between the two type of targets; whereas participants seemed to be more accurate in congruent trials with arrows, $t(34)$ = 1.76, p = .087, d_z = 0.30, 95% CI [−0.04, 0.63], the reversed pattern appeared with faces (i.e., more accurate for incongruent conditions), $t(34)$ = −1.66, p = .11, d_z = −0.28, 95% CI [−0.61, 0.07].

DISCUSSION

Once again, behavioral evidence of a clear reversed congruency effect was observed (i.e., faster RTs and better accuracy to incongruent relative to congruent conditions) when eye-gaze stimuli were used as targets. On the other hand, no significant difference between congruent and incongruent conditions was found with arrow targets. This finding contrasts with the idea that the reversed congruency effect elicited by arrows in the previous experiment was entirely due to a face-like interpretation of these stimuli, as in the present experiment the small reversed congruency observed in Experiment 1 completely disappeared with arrows despite the white ovals around the arrows might have increased the resemblance between face and arrow stimuli. Instead, the fact that the reversed congruency effect disappeared for arrows in this experiment seems to favor an explanation in terms of target-background segregation, as target selection was facilitated by the white ovals added behind each arrow. Nevertheless, the target still needed to be selected from its background, therefore eliminating the spatial congruency effect for arrows.

One potential limitation from our studies might be that different backgrounds were used for eyes (their faces) and arrows (artificial backgrounds similar to the faces). Although the arrow backgrounds were generated from the perceptual characteristics of the faces, there were subtle differences, such as the dark edges of the geometric figures, depicted in dark. Nevertheless, subsequent experiments using the same backgrounds for both arrows and eye gaze (cropped eyes vs. arrows embedded in the same background) have shown identical results to the present experiment (Román-Caballero et al., under review; Experiment 1), which suggests that these little differences were not relevant to explain or modulate the outcomes. The

present results are more coherent with the explanation according to which the increased difficulty of the figure-ground segregation was a key factor in the reversion of the congruency effect observed in Experiment 1 and the lack of spatial congruency effect observed in Experiment 2. This account should be explored in subsequent studies.

GENERAL DISCUSSION

Two experiments were conducted aiming to replicate in the same group of participants the findings first reported by Cañadas and Lupiáñez (2012) of opposite spatial interference effects for social and non-social targets. Instead of using the cropped eyes used by Marotta et al. (2018, 2019), the original whole faces used by Cañadas and Lupiáñez (2012) were used as social targets, as they represent more ecological social stimuli. However, faces are perceptually much more complex than single arrows. Therefore, to make more similar non-social and social targets, especially because we had in mind to later conduct an ERP study, we surrounded the arrows by a comparably complex colored geometric background.

The two conducted experiments confirmed the reversion of the interference effect elicited by eye-gaze stimuli when whole faces, instead of the eye-gaze region alone, were used as stimuli. However, with this new setup, in which arrows were embedded within a complex background, no spatial interference was observed for arrows. Given this unexpected pattern of data, in a following study (although reported previously to the current one; Martotta et al., 2018) we used a different strategy to equate perceptual complexity of social and non-social targets. Two cropped eyes were used instead of using a whole face as a social stimulus, for social targets to have a perceptual complexity comparable to that of arrows. Then, it was possible to show, with stimuli of comparable complexity and by the same participants, opposite spatial congruency effects for social (i.e., eyes) and non-social (i.e., arrows) targets.

In a later study, the planned EEG experiment was conducted, also with cropped eyes and arrows. This study showed that the spatial congruency elicited between the target location and both gaze's and arrow's direction equally modulated early event-related components (P1, N1, and N170). The reversion in the overall interference effect observed with gaze perhaps was responsible for the opposite electrophysiological modulation observed over later components (N2 and P3; Marotta et al., 2019). This observed pattern of data with shared and opposite modulations by social and non-social stimuli is very relevant to explain why some paradigms like face cueing show

virtually identical effects by arrows' and gaze's direction (Brignani et al., 2009; Tipples, 2002), whereas qualitatively different effects by social and non-social targets are shown with other paradigms (Cañadas & Lupiáñez, 2012; Gregory & Jackson, 2017; Marotta et al., 2012).

Furthermore, the fact that social orienting shares some component with non-social orienting is important as it implies that the social component triggered by gaze in our spatial interference paradigm must be strong enough to reverse the standard effect that would also be triggered by the sudden lateralized presentation of the face. Thus, any factor reducing the non-social component would increase the reversed congruency effect observed with gaze targets. Indeed, in the present paper, we analyzed one of these factors. The results of the two reported experiments are interesting as they show, for the first time, that the interference effect elicited by arrows stimuli seems to be modulated by the presence of a complex background in which the target is embedded.

These results are consistent with previous unexplained reports of the absence of spatial interference by arrows when flanked by other interfering arrows (Fan et al., 2009; Lawrence, 2018). These conditions of increased perceptual complexity added either by the perceptually complex background in our study or by the flanking arrows in the study by Fan et al. (2009) and Lawrence (2018) would make it necessary to first perceptually segregate the target from the background. This would delay the selection of the arrow target. Consequently, the conflicting spatial dimension will have decayed by the time the relevant code is formed (i.e., target direction; temporal-delay hypothesis; Hommel, 1993). This could explain the reduction or elimination of the observed spatial congruency effect in our task, as well as in several previous studies using spatial interference paradigms that pre-exposed the irrelevant target position (Botella et al., 2002; Hommel, 1993; Van der Lubbe & Woestenburg, 1999; Virzi & Egeth, 1985) or hampered the formation of the relevant code, for example by perceptually degrading the target (Hommel, 1993; Experiments 3 and 4).

Interestingly, the reversed congruency effect observed in Experiments 1 and 2 for whole faces was larger than that observed in Marotta et al. (2018, 2019) with cropped eyes of the same faces (−32 and −34 ms vs. −17 and −22 ms, respectively for the Experiments 1 and 2 in this paper and the studies of 2018 and 2019 by Marotta et al.). This serendipitous finding suggests that the presence of a complex background (i.e., facial features) might also modulate the effect with eye gaze in the same way, making it more negative. This makes sense, because eyes, as directional stimuli, seem to also trigger domain-general spatial orienting mechanisms commonly evoked by arrows, such as the spatial conflict. However, gaze cues would elicit additional social-

specific attentional components related to their social relevance. This two-effect hypothesis is consistent with our previous electroencephalographic findings above mentioned (Marotta et al., 2019) of a similar modulation of early event-related components (P1, N1, and N170) with both types of targets but an opposite pattern over later components (N2 and P3; Marotta et al., 2019). Thus, higher segregation demands with the use of a complex background would lead to the absence of the standard congruency effect with arrows (such as in the present study and in Román-Caballero et al., under review) and a subsequent greater reversion with eye gaze, as the behavioral outcome would be produced only by the action of the social-specific component (without an opposite spatial conflict component). Nevertheless, this two-effect model needs further research to be confirmed.

Some limitations of our work could also be addressed in future studies. First, the backgrounds we used for arrow targets have certain resemblance with faces, which can trigger social-related effects. However, when we increased that resemblance by adding two white ovals behind the arrows, a high contrasting visual feature typical of faces, no reversed congruency effect was observed. In a later experiment (Román-Caballero et al., under review; Experiment 2) we found similar results with a background made by randomly selecting the pixels of the faces (using Matlab). Second, it is important to highlight that the conditions of higher perceptual demands modulated the effects with both types of targets. In the case of eye gaze, the reversed congruency effect with eyes was even larger compared to simpler target displays (e.g., cropped eyes). On the contrary, our findings suggest that the spatial conflict triggered by arrows is reduced with the increase in perceptual complexity. Future studies might use different ways to controlled for the perceptual complexity of the background and manipulate it gradually, as well as it is possible to do with SOAs (e.g., 0 or 1000 ms in Román-Caballero et al., under review), to modify the segregation demands in a continuous way. Finally, although the present study collected evidence in favor of the coexistence of two attentional components with eye-gaze targets, one domain-general orienting effect triggered by their directional information, and later social-specific component responsible for the behavioral reversion, the mechanism behind the latter remains unknown. Further research will shed light on the nature of this unique social effect and will help to understand in a more fine-grained way the present findings.

RESUMEN

La evidencia reciente con un paradigma de interferencia espacial ha mostrado que las flechas y la mirada producen efectos de congruencia

opuestos. Mientras que las respuestas son más rápidas con flechas cuya posición y dirección son congruentes (efecto de congruencia clásico), con la mirada las respuestas son más rápidas para la condición incongruente (efecto de congruencia revertido). No obstante, en contextos ecológicos, la mirada aparece en contextos más complejos (esto es, una cara) que las simples flechas. El presente estudio pretende volver a hallar esa disociación, pero usando caras completas y un estímulo no social comparable en complejidad, formado por dos flechas sobre un fondo geométrico de colores. Aunque se observó de nuevo el efecto de congruencia revertida con la mirada, sorprendentemente el efecto de interferencia espacial clásico con flechas no apareció. Lo mismo sucedió cuando se incrementó el contraste entre las flechas y el fondo irrelevante. Nuestros hallazgos confirman la robustez del efecto revertido con ojos, independientemente de si se presentan solos o en el contexto de una cara. Además, es importante destacar que la ausencia del conflicto espacial con estímulos no sociales complejos parece ser consecuencia de una mayor dificultad en la segregación figura-fondo, lo cual extendería el procesamiento de la dimensión espacial irrelevante (la localización del estímulo) y provocaría la atenuación de ese código espacial. Este patrón de resultados, y la interpretación proporcionada en este trabajo, pueden explicar hallazgos anteriores en la literatura sobre interferencia espacial, que carecían de una explicación plausible.

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