

**Is the Reversed Congruency Effect Observed with Gaze due to its Social Nature? Analysis of
Non-Social Stimuli with Similar Asymmetrical Contrast Features of Eye-Gaze Stimuli**

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All hypotheses, experimental design, and analysis plans were preregistered (Ponce et al., 2024). The preregistrations, together with the data, experimental materials, and analysis scripts that support the findings of this study, are publicly available at the Open Science Framework (OSF) and can be accessed at <https://osf.io/wzkqb/>.

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Abstract

The reversed congruency effect (RCE), typically observed with gaze stimuli, reflects slower and less accurate responses to congruent than incongruent trials, in contrast to the standard congruency effect (SCE; faster for congruent than incongruent trials) observed with arrows. This phenomenon has been interpreted as evidence that gaze engages unique social and perceptual mechanisms. The present study examined whether the RCE could also be elicited with non-social stimuli designed to mimic the asymmetric contrast between pupil and sclera. Across two preregistered experiments, we manipulated the contrast polarity of arrow targets: in gaze-similar arrows, a darker arrowhead and lighter tail paralleled the pupil-sclera configuration, whereas in gaze-opposite arrows this relation was reversed. We also varied perceptual context by embedding stimuli in complex backgrounds. Both manipulations influenced response speed and accuracy, eliciting the SCE, with complex backgrounds producing slower, less accurate performance and reduced SCEs. Distributional analyses further revealed modulations of early response dynamics but no evidence of an RCE. Target-specific effects also emerged, with gaze-similar arrows harder to process yet eliciting smaller SCEs than gaze-opposite arrows. These findings suggest that contrast polarity and perceptual complexity alone are insufficient to reproduce gaze-induced RCEs, underscoring the unique role of gaze in spatial conflict resolution.

Key words: Reversed congruency effect, Spatial Stroop, Gaze and Arrows, Distributional analyses, Cognitive control

Public significance statements: This study examined whether the unique effects of gaze on attention could be reproduced with non-social stimuli that mimic the contrast between the dark pupil and the white sclera of the eye. Across two preregistered experiments, we manipulated the contrast polarity of arrow targets and increased visual complexity by embedding them in patterned backgrounds. Although both manipulations influenced performance, they did not reproduce the “reversed congruency effect” typically observed with

gaze. This suggests that gaze cues engage additional processes that go beyond visual complexity, highlighting their special role in guiding attention and behavior. Understanding this unique contribution of gaze to spatial conflict has broader implications for theories of attention and for explaining why gaze plays such a central role in human communication.

Is the Reversed Congruency Effect Observed with Gaze due to its Social Nature? Analysis of Non-Social Stimuli with Similar Asymmetrical Contrast Features of Eye-Gaze Stimuli

Gaze is one of the most fundamental cues in social cognition, conveying critical information about others' attention, intentions, and emotional states. Across development and cultures, humans exhibit a remarkable sensitivity to gaze direction (Emery, 2000; Farroni et al., 2004) supporting key processes such as joint attention, theory of mind, and social learning (Baron-Cohen et al., 1994; Mundy, 2018; Stephenson et al., 2021).

In attentional research, gaze cues are often compared to non-social directional stimuli such as arrows (e.g., Kingstone et al., 2003), which share certain functional features but lack inherent social meaning. Both types of cues effectively reorient attention in variants of the Posner cueing paradigm (Posner, 1980), typically producing comparable cueing effects (i.e., faster responses to validly than invalidly cued targets), despite their different nature (for a review, see Chacón-Candia et al., 2023a). This functional similarity has led some researchers to propose that both gaze and arrow cues engage common, domain-general attentional processes (Cole & Millett, 2019; Santiesteban et al., 2014).

However, it remains debated whether these similarities reflect shared mechanisms or whether gaze additionally engage social-cognitive processes such as mental state attribution (Apperly & Butterfill, 2009; Shepherd, 2010).

Evidence from modified cueing paradigms (Chacón-Candia et al., 2020, 2023b; Marotta et al., 2012) and spatial interference tasks (Cañadas & Lupiáñez, 2012; Marotta et al., 2018) suggests that the traditional Posner paradigm is not able to capture social-domain-specific processes underlying attentional orienting.

To address this limitation, researchers have increasingly adopted spatial interference paradigms (Lu & Proctor, 1995; Viviani et al., 2024), especially gaze adaptations of the spatial Stroop task (Marotta et al., 2018), first introduced by Cañadas and Lupiáñez (2012).

In this task, participants respond to the direction indicated by a lateralized target (e.g., a face looking left or rightward) while ignoring its spatial location. Trials are congruent when the target's direction matches its location on the screen (e.g., a face looking left presented on the left), and incongruent when they conflict (e.g., a face looking right presented on the left). Notably, Cañadas and Lupiáñez (2012) observed that gaze stimuli produced a reversed congruency effect (RCE), with faster responses on incongruent trials, which is opposite to the usual effect elicited by arrows, that is, a standard congruency effect (SCE), with faster responses on congruent trials (Marotta et al., 2018).

This dissociation has been replicated across various labs and task variations (e.g., Edwards et al., 2020; Ishikawa et al., 2021; Jones, 2015), with the RCE consistently observed for different types of gaze stimuli, ranging from isolated eyes to full faces, and even including some domestic animals (but not other animals) or inverted faces (Hemmerich et al., 2022; Ishikawa et al., 2024; Tanaka et al., 2023). In contrast, the effect is typically absent with other directional cues such as pointing hands or words with spatial meaning (Bonventre & Marotta, 2023; Dalmaso et al., 2023; Hemmerich et al., 2022). Moreover, the RCE is modulated by factors such as emotional expression (Torres-Marín et al., 2017; Marotta et al., 2022), stimulus familiarity (Ishikawa et al., 2024), and social anxiety (Ishikawa et al., 2021).

These findings initially inspired socially based interpretations of the RCE. One proposal suggested that inward-directed gaze on incongruent trials elicits an episode of direct eye contact, facilitating faster responses (Cañadas & Lupiáñez, 2012; Marotta et al., 2018). Another suggested that incongruent gaze enhance *joint attention* by aligning the participants' focus of attention with the direction of gaze (Edwards et al., 2020), both focusing at the fixation point.

Alternatively, the *joint distraction* hypothesis posits that congruent gaze (i.e., outward looking gaze, as a right looking gaze presented to the right) may misdirect attention away from the task-relevant location, thereby slowing responses when the participant has to reorient back to the task space (Hemmerich et al., 2022).

However, several findings challenge these social interpretations. Narganes-Pineda et al. (2022) showed that explicit processing of gaze direction is required to elicit the RCE, inconsistent with a purely automatic eye-contact account. Developmental studies by Aranda-Martín et al. (2022) showed that children under 12 exhibit an SCE with gaze, similar to that observed with arrows. It is not until adolescence that participants (12 years old and older) begin to show the RCE with gaze. This developmental trajectory is inconsistent with the early emergence of joint attention mechanisms, typically observed around the age of four (Mundy et al., 2007). Furthermore, attempts to reduce distraction in congruent trials by adding contextual elements (e.g., a colored frame) did not modulate the RCE (Aranda-Martín et al., 2023), undermining the joint distraction hypothesis.

A more integrative framework combines domain-general and domain-specific mechanisms. Hemmerich et al. (2022) proposed that the RCE results from the interaction of three “vectors”: the task-relevant direction and the task-irrelevant spatial location (both shared by social and non-social targets), and a uniquely “looking vector” tied to the perceived gaze direction. This framework suggests that gaze-specific processes can override the SCE, producing the overall reversed pattern observed (Hemmerich et al., 2022; Ponce et al., 2025a).

Neurophysiological evidence supports this view, showing early overlap in spatial conflict processing between gaze and arrows, but later divergences consistent with social-cognitive involvement (Marotta et al., 2019; Narganes-Pineda et al., 2023).

From a behavioral standpoint, Román-Caballero et al. (2021a, 2021b) demonstrated that embedding stimuli in complex, face-like backgrounds, simulating the perceptual

complexity of faces, reduced the SCE observed with arrows, while enhancing the RCE observed with gaze was enhanced when gaze stimuli were used instead of cropped eyes. They attributed this to the *temporal-delay* hypothesis by Hommel (1993): increased background complexity delays extraction of directional information, allowing the spatial code to decay. For gaze, once the SCE is reduced, an additional gaze-related component reverses the typical pattern. These findings suggest that the SCE must be reduced in order for the RCE to emerge, or that any factor reducing the shared SCE increases the RCE.

However, some findings challenge the notion that the RCE is specific to gaze stimuli. Tanaka et al. (2024) observed an RCE using tongue stimuli, targets unlikely to trigger gaze related processes, which led to the proposal of the dual-stage account grounded in the *activation-suppression* hypothesis (Ridderinkhof, 2002a, 2002b). In this view, delayed access to the direction code (Román-Caballero et al., 2021a) allows the spatial code to decay (Hommel, 1993), after which inhibition acts on any remaining conflict. On congruent trials, inhibition may suppress the correct response as it overlaps with the irrelevant code, resulting in a delay. In contrast, on incongruent trials, inhibition facilitates performance by suppressing the incorrect, location-based response, leaving the appropriate response free to proceed. With highly discriminable stimuli like arrows, conflict resolves too quickly for this reversal to emerge, but with more difficult stimuli, even non-social targets may elicit RCEs.

The extent to which perceptual difficulty alone can produce the reversed effect remains debated. Non-social stimuli have occasionally elicited reversed effects, but their magnitude tends to be smaller and less consistent than those observed with gaze targets (Román-Caballero et al., 2021a; Tanaka et al., 2025). Moreover, recent findings suggest that conflict effects elicited by social and non-social stimuli may also differ in their temporal dynamics, as revealed by distributional analyses (Ponce et al., 2025a, 2025b; Tanaka et al., 2025), indicating that gaze stimuli may elicit distinct temporal patterns.

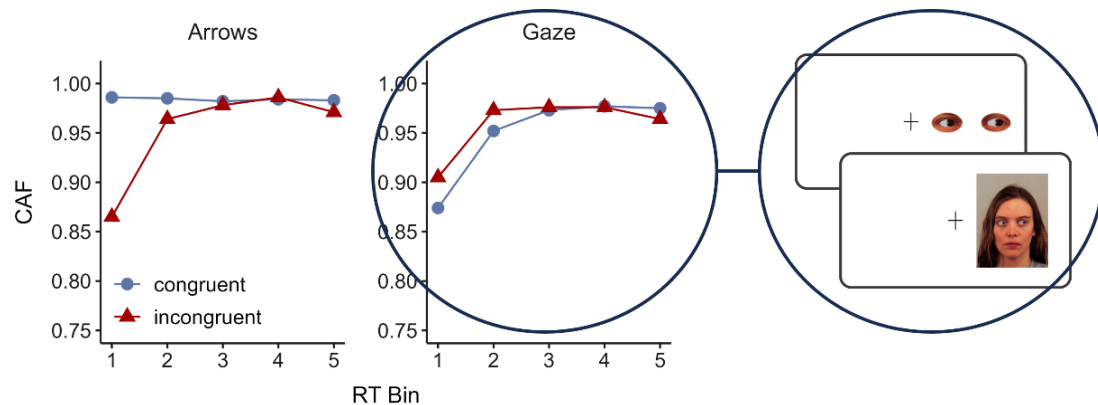
Importantly, Conditional Accuracy Function (CAF) analyses, which examines accuracy as a function of response speed (Heitz, 2014), revealed a dissociation within the fastest responses (Ponce et al., 2025a). With non-social stimuli, early responses show reduced accuracy for incongruent trials, converging over time (Torres-Quesada et al., 2022; van Campen et al., 2014, 2018). With gaze stimuli, however, two notable deviations appear: (1) reduced accuracy for both congruent and incongruent trials among the fastest responses, and (2), more errors for congruent than incongruent trials (see **Figure 1**).

Typical CAF pattern has been attributed to response capture (Salzer et al., 2019; van Campen et al., 2014, 2018; van Maanen et al., 2018), grounded in the dual-route framework, where task-relevant information is processed through controlled mechanisms, and task-irrelevant codes through a transient automatic route (Banich, 2019; Braver, 2012; Cohen et al., 1990; De Jong et al., 1994; Luo & Proctor, 2019; Ridderinkhof, 2002a, 2002b; Ulrich et al., 2015). Response capture reflects early activation based on spatial location, information carried by the automatic route. This activation occurs prior to the onset of inhibitory mechanisms (Burle et al., 2016; Mittelstadt et al., 2023b; Ridderinkhof, 2002a, 2002b), the decay of the irrelevant spatial code (Hommel, 1993), or both (White et al., 2018).

With gaze, reduced accuracy on fast congruent trials suggests interference from additional factors beyond location-based responses (Ponce et al., 2025a). This cannot be explained by automatic allocation of attention toward gaze direction (Cañadas & Lupiáñez, 2012; Marotta et al., 2018; Edwards et al., 2020; Hemmerich et al., 2022), since congruent gaze should facilitate correct response selection. Instead, the interference likely arises from the perceptual configuration inherent to gaze stimuli. What needs to be explained is why fast responses to congruent gaze (e.g., a right looking gaze presented to the right) results in pressing the opposite, incorrect key (i.e., left key in this example) in a substantial proportion of trials.

Figure 1

CAFs for Arrow and Gaze Stimuli (adapted from Ponce et al., 2025a), and Illustration of the Pupil–Sclera Contrast



Note. On the left, CAFs for arrows show the typical pattern: reduced accuracy for incongruent trials (red) compared to congruent trials (blue-purple) among the fastest responses. In contrast, gaze stimuli show reduced accuracy for both conditions, with congruent trials dropping even further. On the right, examples of gaze-congruent trials are shown for isolated eyes and faces. In these cases, the white sclera points toward the incorrect response, which may account for the accuracy drop observed in the CAF.

The only possibility is that the RCE may not arise from high-level social cognitive processing, but rather from low-level perceptual features specific to gaze, which would add some additional conflict. Gaze acts both as a socially relevant cue and as a directional signal (Chacón-Candia et al., 2023; Jarick & Kingstone, 2015), and the human eye's distinctive morphology facilitates its processing (Batki et al., 2000; Itier & Batty, 2009; Maurer et al., 2002; Shi et al., 2025). The uniquely exposed sclera, thought to have evolved to enhance gaze signaling (Kobayashi & Kohshima, 1997), supports processes such as gaze following, automatic attentional capture, and attentional orienting (Driver et al., 1999; Emery, 2000; Gobbin & Haxby, 2007; Morrisey et al., 2019; Theeuwes & van der Stigchel, 2006; Ulloa et al., 2018). These effects likely depend on the high-contrast relation between pupil and sclera, which enables efficient extraction of directional information.

Following this rationale, errors on incongruent trials can be attributed to spatial interference, while errors on congruent trials may result from the visual salience of the sclera,

which is positioned closer to the central fixation point in these trials (i.e., the participant's focus area). Specifically, when the sclera appears on the side opposite the correct response direction, its high contrast may trigger response capture toward the incorrect side. If participants initially rely on this salient feature, it could account for the drop in accuracy on fast congruent trials, thereby producing the reversed CAF pattern observed with gaze stimuli. A fast response automatically triggered by the more visually prominent part of the face—the sclera—might be the source of the additional conflict hypothesized above, as it would activate the response opposite to the correct pupil's direction response (**Figure 1**).

Furthermore, the RCE in RTs may partly arise from these perceptual characteristics. According to the dual-route framework, information conveyed by the automatic route is either inhibited (Ridderinkhof, 2002a), or dissipates quickly over time (Hommel, 1993) during response selection. Once the initial spatial code and that triggered by sclera salience are inhibited or decay, response selection may instead be guided by the pupil, which conveys clearer directional information due to its contrast with the surrounding sclera (Kobayashi & Kohshima, 1997; Ulloa et al., 2018).

The emergence of the RCE would thus depend on the interaction between the asymmetrical contrast of the pupil-sclera configuration and the task-irrelevant spatial code. Accordingly, congruent trials may involve an initial automatic response capture triggered by the salient sclera, which must first be inhibited or allowed to decay before the correct response to the pupil side can be executed. This delay in response selection may lead to slower response latencies on congruent trials, thereby producing RCE.

The two experiment presented in this paper, pre-registered at Open Science Framework (OSF; **Transparency and Openness** section), aimed to test this hypothesis by designing two types of non-social targets that mimicked the asymmetrical contrast properties of gaze stimuli and their inverse counterpart. This manipulation was intended to isolate the

contribution of low-level perceptual contrast while avoiding the influence of socially driven processes.

Experiment 1

Experiment 1 tested whether the RCE could be elicited using non-social stimuli that mimic the sclera-pupil contrast polarity of gaze. Specifically, participants performed a spatial Stroop task with two types of arrow targets (**Figure 2**): one designed to simulate the contrast between the sclera and pupil (*gaze-similar* arrows), and another with the opposite contrast pattern (*gaze-opposite* arrows). Based on the assumption that contrast polarity might facilitate the reversed effect, we expected gaze-similar arrows to elicit an RCE.

It was also hypothesized that if the sclera modulates the automatic response capture mechanism, gaze-similar arrows would reproduce the CAF pattern previously observed with gaze stimuli: reduced accuracy for both congruent and incongruent trials, with lower accuracy for congruent trials in the fastest responses.

In contrast, gaze-opposite arrows were expected to produce a standard SCE, along with CAF patterns typically associated with non-social stimuli like standard arrows.

Method

Participants

Thirty-six adults (27 females; mean age = 21.8 years, $SD = 3.4$) participated in the study. All were students from the University of Granada who provided informed consent and received compensation in the form of either 6 euros or partial course credit, according to their preference. Participants were naïve to the purpose of the experiment. The study was conducted in accordance with the ethical guidelines of the University of Granada (3232/CEIH/2023) and the 1964 Declaration of Helsinki. Data collection took place during April and May 2024. Outlier detection was based on participants' mean accuracy scores, with any

participant falling more than 3 *SDs* below the group mean across conditions being excluded from the analysis.

Power analyses were conducted to assess whether a sample of 36 participants, based on Marotta et al. (2018), was sufficient to detect the expected effects (the script and dataset are available in OSF, see **Transparency and Openness**). Focusing on the gaze congruency effect with an estimated effect size of $d_z = 0.49$, a paired-sample *t* test using the *pwr* package (Champely et al., 2022) indicated a power of .81. Additionally, an ANOVA-based simulation using the *Superpower* (Lakens & Caldwell, 2021) estimated a power of .99 for the interaction between target type and congruency, based on Marotta et al.'s dataset, with an effect size of Cohen's $f = 1.08$.

Apparatus and Stimuli

The task was programmed in OpenSesame (Mathôt et al., 2012) and run locally using JATOS (Lange et al., 2015), although the experiment was conducted in person. It was run on a standard Intel Core i5 PC with an 18.5-inch widescreen monitor (resolution: 1366 × 768 pixels, aspect ratio: 16:9, refresh rate: 59.79 Hz, color depth: 8-bit).

Two types of arrow stimuli were created (**Figure 2**). Gaze-similar arrows replicated the contrast polarity found in pupil-sclera configurations, featuring a darker less salient arrowhead and lighter tail. In contrast, gaze-opposite arrows inverted this pattern, with a lighter head and darker less salient tail. Both stimulus types were designed using a linear gradient fill with four gradient stops transitioning from dark grey to white. The background against which the arrows were presented was a uniform grey.

Procedure

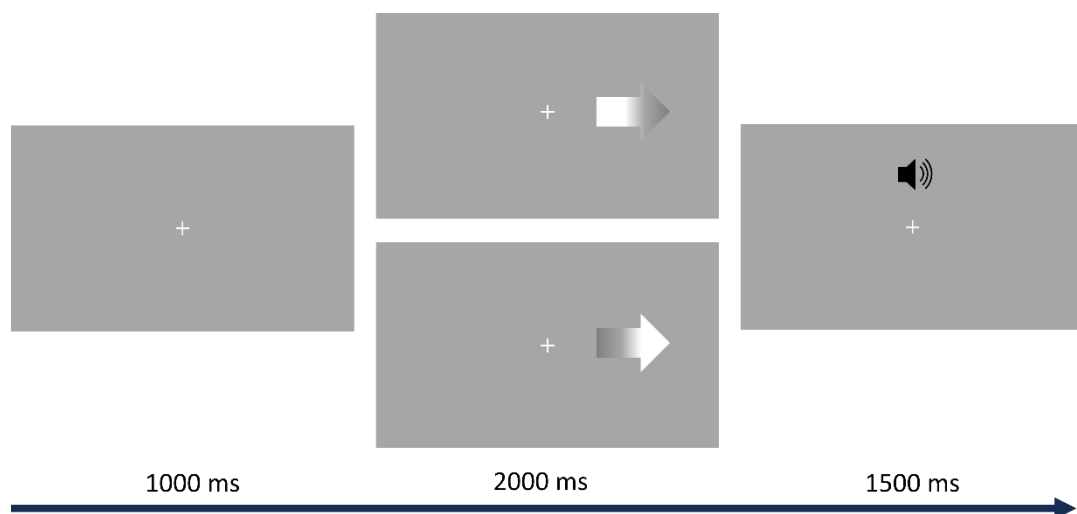
The procedure was adapted from Marotta et al. (2018). Participants were seated approximately 60 cm from the computer screen in a dimly lit room. After completing 15 practice trials, they proceeded to four experimental blocks with a short break between each. A

total of 256 experimental trials were presented, 64 trials per condition (congruency, \times target type). The four conditions were intermixed within each block.

Participants performed a spatial Stroop task in which they were instructed to respond as quickly and accurately as possible to the direction indicated by the arrow (left or right), while ignoring its spatial location. Each trial began with a central fixation cross presented for 1000 ms, followed by a lateralized arrow target (pointing left or right), which remained onscreen until the participant responded or for a maximum of 2000 ms (**Figure 2**). Incorrect responses triggered auditory feedback lasting 1500 ms. Participants were instructed to maintain fixation on the central cross and to press the “C” key for left-pointing arrows and the “M” key for right-pointing arrows, regardless of the stimulus’s spatial position.

Figure 2

Schematic Representation of Trial Sequence



Note. Schematic representation of trial sequence. The example depicts congruent trials for both target types: gaze-similar arrows (top) and gaze-opposite arrows (bottom). The speaker icon indicates the auditory feedback presented after incorrect responses.

Design and Statistical Analysis

The study employed a 2×2 within-participants design with the factors target type (gaze-similar vs. gaze-opposite) and congruency (congruent vs. incongruent trials). To examine temporal dynamics, CAF analyses were conducted by sorting RTs from fastest to slowest and

dividing them into five equal-sized bins (20% each), following prior procedures (e.g., Hübner & Töbel, 2019; Ponce et al., 2025a). Accuracy was calculated for each participant across all combinations of target type, congruency, and bin, yielding a $2 \times 2 \times 5$ structure. Repeated-measures ANOVAs were used to test for interaction effects: a 2×2 model for the RT and accuracy analyses, and a $2 \times 2 \times 5$ model for the CAF analysis. Post-hoc contrasts were conducted where appropriate, with Bonferroni adjustment to control for multiple comparisons.

In addition to the preregistered analyses, one exploratory (non-preregistered) analysis was conducted. Delta function analyses were used to assess whether an RCE might emerge at slower response latencies, as previously reported with non-social stimuli (Tanaka et al., 2025). To compute delta values, quantile averaging was employed (Ratcliff, 1979). Correct RTs were sorted and quantile values were extracted at the .1, .3, .5, .7, and .9 probabilities using R's quantile function with the type 8 estimator (Hyndman & Fan, 1996), following the same procedures as in previous studies (e.g., Grange, 2016; Ponce et al., 2025b). For each target type and quantile, delta values were computed by subtracting the mean RT on congruent trials from that on incongruent trials. This resulted in a 2×5 design (target type \times quantile). Bonferroni-adjusted post-hoc contrasts were applied, along with one-sample t tests against zero to test whether Stroop effects at each quantile differed from zero.

Transparency and Openness

We reported how we determined our sample size, as well as all data exclusions, manipulations, and measures. All hypotheses, experimental design, and analysis plans were preregistered prior to data collection. The preregistrations, along with task materials, stimuli, datasets, and analysis scripts, are publicly available on OSF (<https://osf.io/wzkqb/>). Data were analyzed using R (Version 4.3.2; R Core Team, 2023) in RStudio (Version 2025; Posit Team, 2025). For statistical analyses we used *rstatix* (Version 0.7.2; Kassambara, 2023), for confidence

intervals we used *papaja* (Version 0.1.2; Aust & Barth, 2023), and for data processing and visualization we used the *tidyverse* collection (Wickham et al., 2019).

Results

Following the preregistered plan of analysis, the data from one participant were excluded due to low accuracy (i.e., more than 3 *SDs* below the group mean). Practice trials were omitted from all analyses. Consistent with the criteria used by Marotta et al. (2018), trials with RTs below 200 ms (0.01%) or above 1300 ms (0.25%), as well as incorrect responses (2.75%), were excluded from the RT analyses. The same trimming procedure was applied to the distributional analyses (i.e., CAF and delta functions). Greenhouse-Geisser corrections were applied where violations of the sphericity assumption occurred. **Table 1** showed mean RTs for condition and experiment.

Table 1. Mean Reaction Times (RT, in milliseconds) and Percentages of Incorrect Responses (IR) by condition and experiment.

		Experiment 1		Experiment 2			
		congruent	incongruent	Absent		Present	
				congruent	incongruent	congruent	incongruent
Gaze-similar	RT	458 (57)	484 (68)	467 (89)	501 (91)	634 (71)	637 (84)
	IR	1.79 % (2.15)	3.75 % (4.61)	1.49 % (1.76)	5.80 % (4.80)	5.57 % (5.13)	8.43 % (11.88)
Gaze-opposite	RT	450 (59)	486 (70)	451 (80)	497 (89)	601 (81)	610 (88)
	IR	1.03 % (1.61)	4.17 % (4.94)	1.32 % (1.67)	5.44 % (4.19)	2.62 % (4.27)	3.74 % (3.94)

Note. Standard deviations of RTs and IRs are reported in parentheses. In Experiment 2, the labels “Absent” and “Present” refer to the absence or presence of background in which the stimuli were embedded.

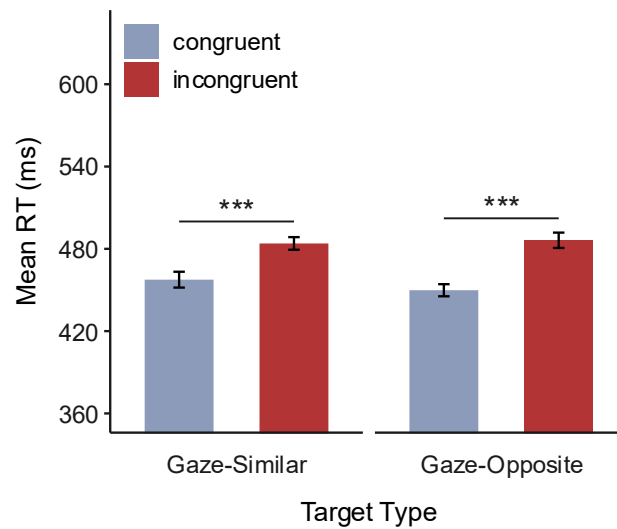
Reaction Time

The ANOVA on RTs revealed a main effect of congruency, $F(1, 34) = 79.35, p < .001, \eta_p^2 = .70$, with faster responses on congruent trials (454 ms) than on incongruent trials (485 ms). A significant interaction between target type and congruency was also found, $F(1, 34) = 5.99, p = .020, \eta_p^2 = .15$. A direct comparison across target types indicated that gaze-opposite arrows

elicited significantly faster responses on congruent trials than gaze-similar arrows, $t(34) = 2.97$, $p = .005$, $d_z = 0.50$, whereas no difference was observed on incongruent trials. Nevertheless, and importantly, both gaze-similar, $t(34) = -6.34$, $p < .001$, $d_z = -1.07$, and gaze-opposite arrows, $t(34) = -9.13$, $p < .001$, $d_z = -1.54$, elicited an SCE, with faster responses on congruent than incongruent trials (**Figure 3**).

Figure 3

Mean RTs by Congruency for each Target Type



Note. Mean RTs (in milliseconds) are shown by congruency for each target type (congruent trials in blue-purple, incongruent in red). Error bars indicate 95% confidence intervals computed with the Cousineau–Morey adjustment method (Morey, 2008). Asterisks indicate significance levels: $p < .05$ *, $p < .01$ **, $p < .001$ ***.

Accuracy

The accuracy analysis revealed a main effect of congruency, $F(1, 34) = 11.58$, $p = .002$, $\eta_p^2 = .25$. Participants made fewer errors on congruent trials (1.41%) than on incongruent trials (3.96%). No other effects reached statistical significance.

Distribution Analysis

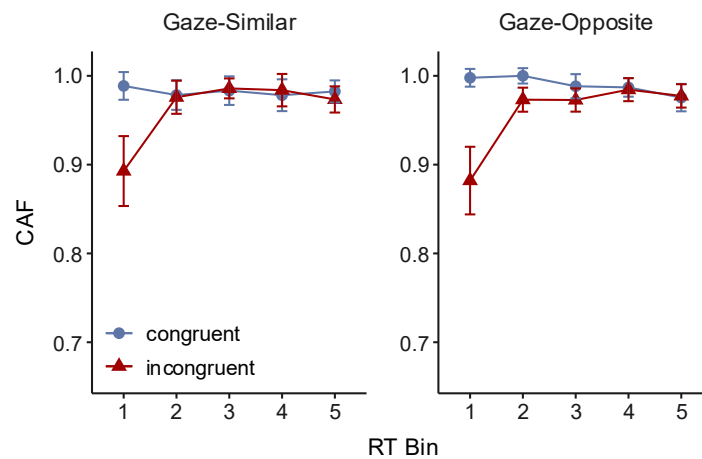
The three-way interaction in the CAF analyses did not reach significance, $F(2.79, 94.97) = 0.84$, $p = .469$, $\eta_p^2 = .02$. However, there was a significant two-way interaction between

congruency and bin, $F(2.08, 70.69) = 25.32$, $p < .001$, $\eta_p^2 = .43$. Follow-up comparisons revealed that accuracy was lower on incongruent compared to congruent trials in bin 1, $t(69) = 6.98$, $p < .001$, $d_z = 0.83$, and bin 2, $t(69) = 2.05$, $p = .044$, $d_z = 0.25$. In addition, bin 1 showed significantly lower accuracy than subsequent bins only for incongruent trials (**Figure 4A**).

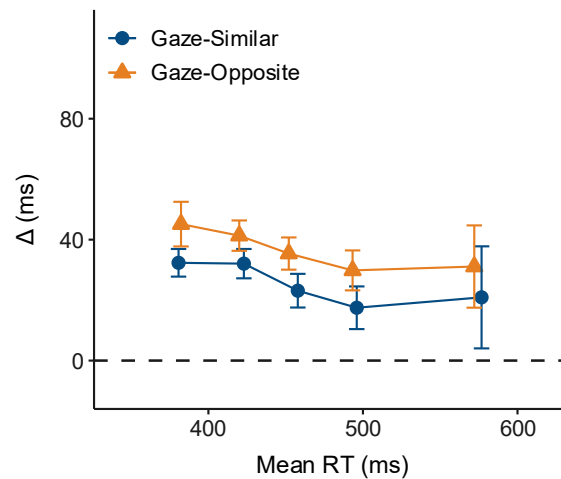
For the delta function analysis, the interaction between target type and quantile was not significant. However, a main effect of target type was observed, $F(1, 34) = 34.00$, $p = .011$, $\eta_p^2 = .18$, indicating a larger spatial Stroop effect for gaze-opposite targets (37 ms) compared to gaze-similar targets (25 ms). A main effect of quantile was also found, $F(1.65, 58.13) = 5.55$, $p = .010$, $\eta_p^2 = .14$, showing that the Stroop effect was larger at earlier quantiles (first and second) than at middle quantiles (third and fourth), suggesting a slight decrease in interference with increasing response times, from 38ms at the highest point to 24 ms at the lowest. Nevertheless, one-sample t tests against zero confirmed that the SCE differed from zero across all quantiles ($ps < .05$; **Figure 4B**).

Figure 4*Distributional Analysis from Experiment 1*

A)



B)



Note. Distributional results from the experiment 1: A) CAF showing accuracy across five RT bins as a function of congruency and target type (congruent trials in blue-purple circles, incongruent in red triangles). B) Delta plot depicting the spatial Stroop effect across quantiles by target type (gaze-similar in blue circles, gaze-opposite in orange triangles), plotted against the average RT for each quantile point. The dashed line at zero indicates the absence of a congruency effect. Error bars indicate 95% confidence intervals computed with the Cousineau–Morey adjustment method (Morey, 2008).

Discussion

Experiment 1 examined whether simulating gaze-like contrast polarity (i.e., pupil-sclera contrast asymmetry) would elicit an RCE or reproduce the distributional patterns typically

observed with gaze stimuli. The results did not support this hypothesis: both gaze-similar and gaze-opposite arrows produced SCEs, with faster and more accurate responses on congruent trials.

Distributional analyses supported these findings, no reversal was observed in either distributional analysis. CAF results showed reduced accuracy for fast incongruent responses, a pattern typically observed with non-social stimuli (Ponce et al., 2025a; Torres-Quesada et al., 2022), consistently across both arrow types. Delta plots revealed a consistent SCE across the distribution, with interference slightly decreasing at slower quantiles. This pattern aligns with temporal-decay (Hommel, 1993) or active suppression accounts (Ridderinkhof, 2002a, 2002b). However, unlike other location-based tasks such as the visual Simon task results (Luo & Proctor, 2019; Mittelstädt & Miller, 2020; Zhong et al., 2020), the interference persisted even at the slowest quantiles, suggesting that spatial interference may be stronger in the spatial Stroop task (see **General Discussion**). Interestingly, the smaller Stroop effect for gaze-similar arrows was driven by faster congruent responses in the gaze-opposite condition, suggesting a facilitation effect when the white arrowhead matched the spatial location. This is interesting as it shows that our manipulation was somehow successful in speeding up responses when the contrast polarity was congruent with the arrow direction. In other words, on congruent trials, when contrast polarity asymmetry was incongruent with the arrow direction (i.e., more salient in the opposite side of the target arrowhead, as with the pupil-sclera, responses were 8 ms slower). Nevertheless, a SCE was still observed, opposite to the predicted RCE in case this was due to pupil-sclera contrast asymmetry.

Thus, these findings suggest that contrast asymmetry alone is insufficient to reproduce the behavioral and temporal dynamics of gaze-related interference. However, such features may still play a role under conditions where spatial interference is reduced. As noted earlier, increasing background complexity has been shown to reduce the SCE in arrow stimuli (Román-

Caballero et al., 2021a, 2021b; Tanaka et al., 2024), potentially by delaying access to directional information and allowing the spatial code to decay (Román-Caballero et al., 2021a, 2021b) and/or by enhancing or accelerating the activation of inhibitory mechanisms (Ponce et al., 2025b; Tanaka et al., 2025). Building on this, Experiment 2 tested whether embedding contrast-manipulated arrows within a complex background would reduce spatial interference and enhance the influence of perceptual contrast, enough to elicit an RCE.

Experiment 2

To further investigate whether low-level perceptual contrast can drive RCEs under reduced spatial interference, Experiment 2 introduced a background manipulation to the same task and stimuli used in Experiment 1. While contrast asymmetry alone did not elicit an RCE, previous studies suggest that visual complexity may reduce spatial interference by delaying access to directional information and/or enhancing early inhibition processes (Román-Caballero et al., 2021a, 2021b; Tanaka et al., 2024, 2025; Ponce et al., 2025b). Under such conditions, perceptual features like contrast polarity may exert a stronger influence on response selection.

To test this, arrow targets were presented either without background, as in Experiment 1 (background-absent condition), or embedded within a visually complex rectangular background (background-present; **Figure 5**). This within-participants manipulation allowed us to assess whether background presence modulates congruency effects and facilitates the emergence of an RCE with contrast-manipulated arrows.

In the background-absent condition, we expected to replicate the results of Experiment 1, in both mean-level and distributional analyses (i.e., SCE in RT and accuracy, typical CAF and delta patterns). In the background-present condition, we hypothesized that gaze-similar arrows would elicit an RCE, while gaze-opposite arrows would produce a reduced or absent SCE. At the distributional level, for gaze-similar stimuli, we anticipated a drop in accuracy for fast

congruent and incongruent trials in CAFs, the former reflecting early interference from the salient, task-irrelevant scleral-like feature, and a reversed pattern in delta functions emerging at the medium and slowest quantiles. In contrast, gaze-opposite stimuli were expected to show a diminished conflict effect, potentially leading to flat delta functions across the distribution.

Method

Participants

A total of 40 adults participated in this experiment (30 female; mean age = 22.5 years, $SD = 3.0$). All participants were undergraduate students at the University of Granada and received partial course credit for their participation. Data collection took place in June 2024. The study adhered to the same ethical guidelines as Experiment 1, and the outlier detection procedure was also identical.

Power analyses were conducted using the same approach as in Experiment 1, given that the primary design elements and critical comparisons (e.g., target type and congruency) remained unchanged. Although an additional factor was introduced (background condition: absent vs. present), it was not expected to substantially affect the required sample size. Nonetheless, the sample was increased to 40 participants to account for potential measurement noise in the online data collection.

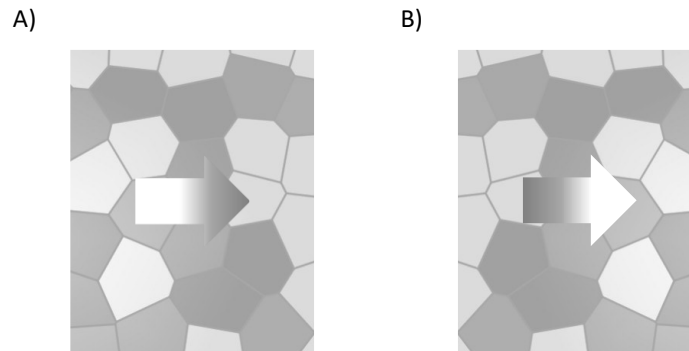
Apparatus and Stimuli

The study was conducted online. The task was programmed using OpenSesame (Mathôt et al., 2021) and administered via JATOS (Lange et al., 2015). The task structure and arrow stimuli were identical to those in Experiment 1, with the addition of the background manipulation. The background-absent condition replicated the procedure from Experiment 1, while in the background-present condition, targets were embedded within a visually complex background. Two types of backgrounds were used, adapted from the stimuli of Román-

Caballero et al. (2021a) and modified to avoid face-like configurations and employ a greyscale palette. One background was a mirrored version of the other (**Figure 5**).

Figure 5

Arrow stimuli used in Experiment 2 under the Background-Present Condition



Note. Examples of the arrow stimuli used in Experiment 2 under the background-present condition. A) Gaze-similar arrows (darker arrowhead, lighter tail) shown with one version of the background. B) Gaze-opposite arrows (lighter arrowhead, darker tail) shown with the mirrored version of the background.

Procedure

The procedure was identical to that of Experiment 1 (see **Figure 2**), with the exception of the added background condition. The task consisted of two main blocks: one comprising background-absent trials, and one with background-present trials. Block order was counterbalanced across participants. Each block was preceded by 10 practice trials and consisted of two sub-blocks of 128 trials each, with a brief pause in between, resulting in 256 experimental trials per block (i.e., 64 trials per experimental condition, as in Experiment 1).

Design and Statistical Analysis

The experiment employed a within-participants $2 \times 2 \times 2$ design, which the factors background (absent vs. present), target type (gaze-similar vs. gaze-opposite), and congruency (congruent vs. incongruent). RT trimming criteria were applied as in Experiment 1.

Distributional analyses, including CAFs and delta functions, followed the same procedures used

in the previous experiment, with the background factor incorporated into the analytical framework. Post-hoc contrasts were conducted where appropriate, with Bonferroni adjustment to control for multiple comparisons.

Transparency and Openness

We followed the same guidelines regarding transparency and openness as in Experiment 1. For this experiment, all analyses, including delta functions, were preregistered. The preregistration, task materials, stimuli, datasets, and analysis scripts are also available on OSF (<https://osf.io/wzkqb/>). Data were analyzed using the same software and R packages as in the previous experiment.

Results

Data from one participant was excluded due to consistently low accuracy (i.e., more than 3 *SDs* below the sample mean). Practice trials were not included in any analyses. Following the same trimming criteria used in Experiment 1, trials with RTs faster than 200 ms (0.03%) and slower than 1300 ms (1.55%) were removed, along with incorrect responses (4.79%), for all RT-based analyses. The trimming procedures were also applied to the distributional analyses (CAF and delta functions). When the assumption of sphericity was violated, Greenhouse-Geisser corrections were applied.

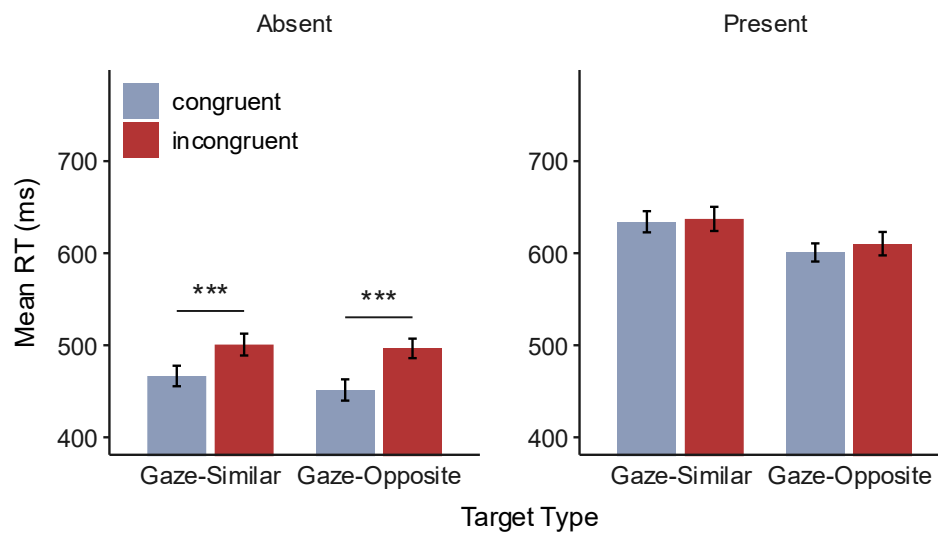
Reaction Time

The RT analysis revealed a significant main effect of background, $F(1, 38) = 267.90, p < .001, \eta_p^2 = .88$, with faster responses observed in the background-absent condition (479 ms) compared to the background-present condition (621 ms). A main effect of target type also emerged, $F(1, 38) = 59.12, p < .001, \eta_p^2 = .61$, reflecting slower responses for gaze-similar arrows (560 ms) than for gaze-opposite arrows (540 ms). As in Experiment 1, a main effect of

congruency was found, $F(1, 38) = 43.26, p < .001, \eta_p^2 = .53$, with faster responses on congruent (539 ms) than incongruent trials (561 ms).

The three-way interaction between background, target type and congruency was not significant. However, all two-way interactions reached significance. Of particular interest, the background \times congruency interaction was significant, $F(1, 38) = 48.35, p < .001, \eta_p^2 = .56$. Post-hoc comparisons showed that when the background was absent, congruent trials were significantly faster than incongruent ones, $t(77) = -10.67, p < .001, d_z = -1.21$, replicating the congruency effect observed in Experiment 1. In contrast, when the background was present, no significant difference was found between congruent and incongruent trials ($p = .098$), suggesting the absence of the spatial interference effect (**Figure 6**).¹

¹ For completeness, we also tested the congruency effect within each target type, represented in **Figure 6**. When the background was absent, both gaze-similar, $t(38) = -6.01, p < .001, d_z = -0.96$, and gaze-opposite targets, $t(38) = -9.62, p < .001, d_z = -1.54$, showed significant SCEs. In the background-present condition, neither target type showed a significant effect, gaze-similar, $t(38) = -0.54, p = .60, d_z = -0.09$, and gaze-opposite, $t(38) = -1.96, p = .058, d_z = -0.31$.

Figure 6*Mean RTs across Congruency by Target Type and Background condition*

Note. Mean RTs across congruency conditions for each combination of target type and background condition (absent vs. present), congruent trials in blue-purple, incongruent in red. Error bars represent standard errors of the mean, adjusted using Cousineau-Morey method (Morey, 2008). Error bars indicate 95% confidence intervals computed with the Cousineau–Morey adjustment method (Morey, 2008). Asterisks denote significance levels: $p < .05$ *, $p < .01$ **, $p < .001$ ***.

Additionally, the interaction between background and target types was significant, $F(1, 38) = 21.12$, $p < .001$, $\eta_p^2 = .36$. Although gaze-similar arrows elicited slower RTs in both background conditions, the difference was larger in the background-present condition (30 ms), $t(77) = 8.37$, $p < .001$, $d_z = 0.95$, than in the background-absent condition (10 ms), $t(77) = 3.24$, $p = .002$, $d_z = 0.36$. Finally, the target type \times congruency interaction was also significant, $F(1, 38) = 5.73$, $p = .022$, $\eta_p^2 = .13$, as in Experiment 1. Both target types elicited an SCE, but it was larger for gaze-opposite arrows, mainly due to faster responses on congruent trials, $t(77) = 7.33$, $p < .001$, $d_z = 0.83$; the difference in incongruent trials was smaller yet still significant, $t(77) = 4.29$, $p < .001$, $d_z = 0.49$.

Importantly, an additional analysis including block order (i.e., whether participants began with the background-absent or background-present block) as a between-participants factor revealed no significant main or interaction effects involving block sequence (all $ps > .06$), indicating that the observed results were not influenced by block presentation order.

Accuracy

A main effect of background was observed, $F(1, 38) = 5.28$, $p = .027$, $\eta_p^2 = .12$, with participants making fewer errors in the background-absent condition (3.51 %) compared to the background-present condition (5.09 %). A significant main effect of target type also emerged, $F(1, 38) = 13.05$, $p < .001$, $\eta_p^2 = .26$, with gaze-similar producing higher error rates (5.33 %) than gaze-opposite stimuli (3.28 %). Additionally, there was a main effect of congruency, $F(1, 38) = 19.49$, $p < .001$, $\eta_p^2 = .34$, indicating that congruent trials elicited fewer errors (2.75 %) than incongruent trials (5.85 %).

Similar to RT analysis, the three-way interaction (background \times target type \times congruency) was not significant. However, a significant interaction between background and congruency was observed, $F(1, 38) = 4.43$, $p = .042$, $\eta_p^2 = .10$. Although both background conditions elicited more errors on incongruent than congruent trials, the difference between congruent and incongruent trials was smaller in the background-present condition, *diff.* = 1.99%, $t(77) = 2.11$, $p = .038$, $d_z = 0.24$, compared to background-absent condition, *diff.* = 4.21%, $t(77) = 8.16$, $p < .001$, $d_z = 0.92$. Additionally, a significant interaction between background and target type emerged, $F(1, 38) = 9.56$, $p = .004$, $\eta_p^2 = .20$, with gaze-similar producing more errors than gaze-opposite targets in the background-present condition (7.00 % vs. 3.18 %), but not in the background-absent condition.

Distribution Analysis

CAF analyses (**Figure 7A**) did not reveal a significant four-way interaction (background \times target type \times congruency \times bin). However, a significant three-way interaction between background, congruency and bin was found, $F(1.72, 65.46) = 5.47$, $p = .009$, $\eta_p^2 = .13$. Follow-up comparisons indicated an SCE in the first, $t(77) = 8.98$, $p < .001$, $d_z = 1.02$, and second bins, $t(77) = 2.91$, $p = .005$, $d_z = 0.33$, when the background was absent. A smaller but still significant

SCE was also observed in the first bin when the background was present, $t(77) = 2.17$, $p = .033$, $d_z = 0.25$. Additionally, in the background-absent condition, incongruent trials showed reduced accuracy in the first bin compared to later bins. In the background-present condition, both congruent and incongruent trials exhibited reduced accuracy in the first bin relative to the subsequent bins. Nevertheless, a similar pattern was observed for both gaze-similar and gaze-opposite targets (see **Figure 7A**).

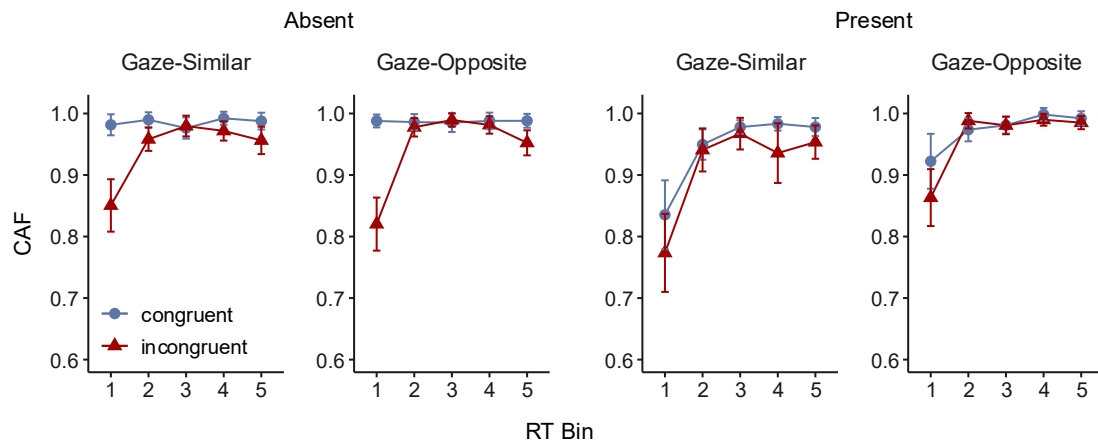
Moreover, a significant interaction between background, target type, and bin was observed, $F(2.34, 88.89) = 7.79$, $p < .001$, $\eta_p^2 = .17$. Post-hoc comparisons revealed that differences between target types were present only in the background-present condition, where gaze-similar targets elicited higher error rates across most bins (except the third), than gaze-opposite. In contrast, no significant differences between target types were observed in any bin in the background-absent condition, replicating the pattern observed in Experiment 1.

Delta plot analysis (**Figure 7B**) revealed a main effect of background, $F(1, 38) = 40.60$, $p < .001$, $\eta_p^2 = .52$, with larger congruency effects observed in the background-absent condition (39 ms) compared to the background-present condition (7 ms), as expected. A main effect of target type also emerged, $F(1, 38) = 8.12$, $p < .007$, $\eta_p^2 = .18$, showing that gaze-opposite targets (29 ms) elicited a larger effect than gaze-similar targets (17 ms). Neither the three-way interaction nor the two-way interactions were significant.

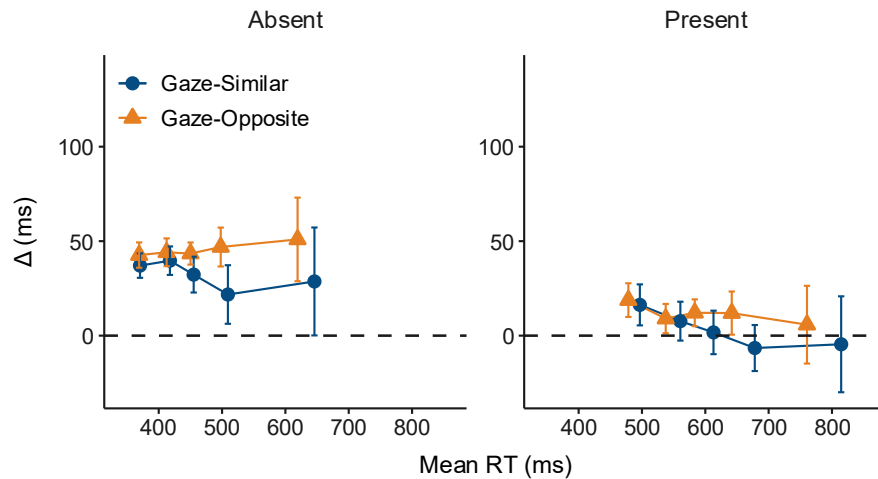
Planned one-sample t tests against zero in the background-absent condition confirmed the presence of an SCE across the entire distribution ($ps < .05$), with a marginal effect for gaze-similar targets in the fifth quantile ($p = .06$). In the background-present condition, an SCE was only evident in the first quantile for both target types, and in the third quantile for gaze-opposite targets. However, in no case was a significant reversed effect observed.

Figure 7*Distributional Analysis from Experiment 2*

A)



B)



Note. Distributional results from the Experiment 2. A) CAF showing accuracy across five RT bins for congruent and incongruent trials, separated by target type and background condition (congruent trials in blue-purple circles, incongruent in red triangles). B) Delta plot depicting the spatial Stroop effect as a function of mean RT quantiles, plotted by target type and background condition (gaze-similar in blue circles, gaze-opposite in orange triangles). Error bars reflect standard errors of the mean, adjusted using Cousineau-Morey method (Morey, 2008).

Discussion

Experiment 2 aimed to test whether embedding the contrast-manipulated arrows from Experiment 1 within a visually complex background (**Figure 5**), could reduce spatial interference and facilitate the emergence of an RCE for gaze-similar arrows. The results did not

support this hypothesis: the RCE did not emerge neither at the mean level nor in the distributional analyses.

On the one hand, the results of Experiment 1 were successfully replicated in the background-absent condition. A robust SCE was observed regardless of target type, both in RT and accuracy. Distributional analyses also confirmed a typical non-social pattern: reduced accuracy for incongruent trials in the fastest responses (CAF) and a consistent SCE across the entire RT distribution (delta plot).

On the other hand, and consistent with prior findings (Román-Caballero et al., 2021a, 2021b; Tanaka et al., 2024, 2025), the presence of a complex background effectively reduced the magnitude of the SCE. At the mean level, the congruency effect was no longer evident, and at the distributional level it was restricted to specific quantiles.

Interestingly, the CAF patterns revealed a significant drop in accuracy not only for incongruent trials, but also for congruent trials in the first bin compared to later bins, a pattern previously associated with social stimuli (Ponce et al., 2025a), although no reversion was observed across any point of the CAF distribution. Such modulation may reflect increased difficulty in extracting directional information in combination with automatic response capture. However, the fact that no reversion was ever observed indicates that sclera-pupil asymmetrical contrast is not responsible for the RCE observed with gaze.

General Discussion

Across two preregistered experiments, we tested whether low-level contrast polarity—designed to mimic the asymmetric pupil-sclera configuration of human eyes (Itier & Batty, 2009; Shi et al., 2025; Kobayashi & Kohshima, 1997; Yang et al., 2015)—can account for the RCE typically observed with gaze targets in spatial Stroop tasks. The results are straightforward: contrast asymmetry alone did not elicit an RCE. Both in the absence of background

(Experiment 1) and when stimuli were embedded in visually complex background (Experiment 2), arrows with “gaze-similar” contrast produced SCEs or, at most, a marked reduction of interference, but never a reversal at the mean or distributional levels.

In Experiment 1, where arrows were presented without a background, both target types elicited robust SCEs in RTs and accuracy. Distributional analyses supported this typical non-social pattern, showing reduced accuracy for fast incongruent responses and an SCE across the RT distribution. Crucially, gaze-similar arrows neither produced an RCE nor reproduced the reversed CAF pattern previously associated with gaze stimuli. These results indicate that contrast polarity alone is not sufficient to account for the RCE observed with gaze.

Experiment 2 introduced a complex background to test whether increased visual complexity would reduce spatial interference (Román-Caballero et al., 2021a, 2021b; Tanaka et al., 2024), and allow contrast polarity to exert a stronger influence. As expected, the background manipulation attenuated the SCE. However, no reversal emerged at either the mean level or in distributional analyses.

Despite the absence of an RCE, our manipulations uncovered additional patterns that shed light on how perceptual features and background complexity affect performance and its temporal dynamics. In turn, these findings contribute to a better understanding of the extent to which gaze-related effects might be shaped by perceptual and task-related factors.

The background manipulation was originally introduced to equate the perceptual complexity between gaze and arrow stimuli (Román-Caballero et al., 2021a). As in previous studies, embedding targets in complex backgrounds elicited slower and less accurate responses compared to no backgrounds conditions (Román-Caballero et al., 2021a; Tanaka et al., 2024, 2025). This pattern parallels findings that gaze stimuli generally produced slower RTs (Dalmaso et al., 2023; Ishikawa et al., 2021; Marotta et al., 2018, 2019) and higher error rates (Aranda-

Martín et al., 2023; Hemmerich et al., 2022; Ishikawa et al., 2024; Marotta et al., 2019; Narganes-Pineda et al., 2022) compared to arrows.

From a social account perspective, the slowing of RTs has often been attributed to the social significance and complexity of gaze stimuli, which may induce greater exploration of their features (Marotta et al., 2018; Román-Caballero et al., 2021a). However, the same pattern can also reflect a more general perceptual mechanism: when task-relevant information is harder to extract due to surrounding visual complexity, responses slow and accuracy decreases. Consistent with this, studies on location-based tasks show that targets with reduced discriminability leads to slower and less accurate responses (Ellinghaus, 2024; Hommel, 1993). Recent research suggests that perceptual demands contribute to gaze-related effects (Tanaka et al., 2024), potentially pointing to a mechanism that gaze may share with other complex stimuli.

At the distributional level, the background manipulation also revealed notable conflict dynamics. In the background-present condition, the CAF showed reduced accuracy for the fastest responses in both congruent and incongruent trials, a pattern previously linked to gaze stimuli (Ponce et al., 2025a). Typically, the drop in accuracy for incongruent trials within the fastest responses has been explained by an automatic response capture (Salzer et al., 2019; Torres-Quesada et al., 2022; van Campen et al., 2014, 2018): responses are more likely to be selected based on spatial location information before inhibition takes place (Ridderinkhof, 2002a, 2002b), and/or before the spatial code has decayed (Hommel, 1993).

However, this account does not explain why, in the background-present condition, congruent trials also showed reduced accuracy. Even if responses were selected on the basis of target location, congruent trials should have yielded higher accuracy, as location and direction match. Instead, the results suggest that under increased perceptual difficulty, automatic

capture may be shaped by additional stimulus- or task-related factors producing early costs across both trial types.

In this sense, the pattern partially resembles that observed with gaze stimuli (Ponce et al., 2025a), although without the additional process that gaze stimuli may recruit to produce a reversed CAF.

Delta function analyses provided complementary insights, capturing how interference evolves across the RT distribution (De Jong et al., 1994; Pratte et al., 2010; Speckman et al., 2008). Decreases in delta values are typically interpreted as reflecting either stronger inhibitory control or the decay of spatial codes (Mittelstädt & Miller, 2020; Mittelstädt et al., 2023a; Ridderinkhof, 2002a, 2002b).

In the background-present conditions, the conflict effect was already reduced at the very first quantiles compared to the background-absent condition (about 22 ms less at Q1, and 34 ms less at Q2). This early reduction cannot be explained by passive decay alone, which would predict at least similar early interference (Hommel, 1993; Ulrich et al., 2015), or stronger interference given the high saliency of complex stimuli (Dolk et al., 2013; Ellinghaus et al., 2024; Rubichi et al., 1997; Stoffer, 1991). Instead, our results support a rapid engagement of inhibitory control mechanisms. Consistent with prior work, reduced target discriminability seems to modulate conflict dynamics beyond the fading of distractor activation (Ellinghaus et al., 2024).

Recent studies propose similar dynamics for gaze (Ponce et al., 2025b; Tanaka et al., 2025): both gaze, and arrows in complex contexts, appear to trigger earlier inhibitory control. Where gaze differs, however, is in the subsequent dynamics: although reversals with arrows in complex backgrounds have been occasionally reported (Román-Caballero et al., 2021a, experiment 1; Tanaka et al., 2025, supplemental material), gaze stimuli have consistently shown a robust reversal across the remainder of the distribution (Ponce et al., 2025b). This

interpretation aligns with active inhibitory accounts that describe inhibition as a flexible, adaptive, top-down process (Burle et al., 2016; Meynier et al., 2009; Mittelstädt et al., 2023a; Scorolli et al., 2015), that can vary in strength, onset time, and build-up rate (Ridderinkhof, 2002a, 2002b).

Our results also highlight task-related characteristics of the spatial Stroop. In both Experiment 1 and the background-absent condition of Experiment 2, spatial Stroop interference persisted throughout the RT distribution, except for a small reduction at the last quantile for gaze-similar targets in Experiment 2. This contrasts with other location-based tasks, such as the visual Simon task, where conflict typically diminishes over time or disappears at slower responses (Luo & Proctor, 2019; Mittelstädt & Miller, 2020; Zhong et al., 2020).

Persistence has been observed before in the spatial Stroop task (e.g., Castel et al., 2007, figure 2; Juncos-Rabadán et al., 2008, see *t* tests performed with the youngest group; Ponce et al., 2025b; Tanaka et al., 2025, see experiment 1) and likely reflects the dual overlap characteristic of this task: spatial location (i.e., task-irrelevant information) interferes both with the response mappings (S–R overlap) but also with the relevant dimension (S–S overlap), namely the stimulus's direction (Kornblum, 1992; Viviani et al., 2024). Such layered interference may explain the robustness of SCEs and their persistence across the RT distribution in the background-absent condition, potentially reflecting interference arising at multiple loci and stages (Banich, 2019; De Houwer, 2003; Parris et al., 2022). Indeed, evidence seems to suggest that S–S and S–R overlaps differ in how they elicit and resolve conflict (Li et al., 2014; Lou & Proctor, 2017; Scerrati et al., 2017; Torres-Quesada et al., 2022).

This distinction may also be important for understanding differences between gaze and arrow effects. Spatial location can trigger automatic response activation that competes with directional information not only during response selection but also at motor execution (Burle et al., 2016; Miller & Rouast, 2016; Treccani et al., 2018), potentially modulating arrows effects.

Yet the RCE elicited by gaze has also been observed with verbal responses (Narganes-Pineda et al., 2022), suggesting that motor components are not strictly necessary. Future research should therefore examine whether motor factors provide an additional modulation of the RCE and how this interferes with the S-S vs. S-R distinction, which appears particularly relevant to gaze versus arrow research.

Beyond background effects, the contrast pupil-sclera manipulation appears to interact with spatial interference asymmetrically across congruency. In both experiments, gaze-similar targets gaze-similar targets were harder to process (slower and less accurate), but they yielded a smaller SCE than gaze-opposite targets. This difference was largely due to faster congruent responses for gaze-opposite arrows, broadening the congruency gap. These patterns suggest that perceptual contrast interacts with congruency asymmetrically, possibly adding an extra layer of conflict. Similar effects have been reported when target discriminability is low or perceptual load is high, which may shift attentional resources toward target processing and reduce distractor interference (Ellinghaus et al., 2024; Lavie, 1995). Future studies should directly test how contrast-specific features modulate congruency.

Taken together, our findings contribute to the debate about whether gaze-induced RCEs reflect a social specific component or can be explained by domain-general mechanisms. Perceptual manipulations such as background complexity modulated conflict dynamics in ways partly resembling gaze stimuli, implying that non-social factors play an important role. Yet, the absence of an RCE in our experiments underscores that these manipulations are not sufficient. Additional mechanisms, potentially linked to the unique perceptual configuration of eyes and/or their social meaning, are required to reproduce gaze's distinctive effects. This supports integrative accounts where the RCE emerge from the interaction of domain-general and domain-specific processes (Hemmerich et al., 2022; Marotta et al., 2018, 2019; Ponce et al., 2025a).

Nevertheless, two considerations should be kept in mind for future studies. First, although our contrast manipulations approximate pupil–sclera asymmetry, they may not capture the full complexity of gaze processing. Our aim, however, was to model this asymmetry while minimizing any social-related component. Second, while our background manipulation successfully increased task difficulty, other forms of perceptual complexity (e.g., mosaic patterns, varied color palettes, etc.) may interact differently with target contrast features.

Overall, the present study highlights the value of distributional analyses for disentangling perceptual, task-related, and social contributions. By capturing early response dynamics that mean-level analyses may miss, these tools offer a more precise framework for understanding the conditions under which gaze effects and their absence emerge. This aligns with previous work recommending distributional approaches for examining subtle cognitive control dynamics (Balota & Yap, 2011; De Jong et al., 1994; Mittelstädt & Miller, 2020; Speckman et al., 2008).

Conclusion

The present study tested whether non-social stimuli mimicking the pupil–sclera contrast of human eyes could reproduce the RCE typically observed with gaze. Across two preregistered experiments, contrast polarity alone proved insufficient: both in simple displays and under increased perceptual complexity, arrows with gaze-like contrast produced standard congruency effects or reduced interference, but never a reversal. Distributional analyses confirmed the typical non-social conflict patterns, with no evidence of the reversed dynamics consistently observed with gaze.

These findings suggest that while perceptual complexity modulates conflict dynamics, the RCE with gaze cannot be explained by contrast asymmetry alone and likely emerges from the interaction of task dynamics and target characteristics with gaze-specific processes. Thus, gaze appears to engage both domain-general interference mechanisms and additional

mechanisms unique to its perceptual and social significance, underscoring its special role in spatial conflict resolution.

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