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# Gaze Cuing Effect in Intentional Action: Yes, Action Matters!

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## Abstract

One of the core components of non-verbal communication and joint attention is gaze cuing – our tendency to shift attention in the direction of another's gaze. While extensively studied, little is known about whether and how internal states like the sense of agency influence sensitivity to gaze cues. In this study, we investigate whether control over action (action-outcome consistency) modulates gaze cuing effect in a color discrimination task. Participants viewed a synthetic face with lateral (left/right) pupil motion, followed by the appearance of a colored target to the left/right of the face. During each trial, participants either passively observed the gaze movement (control condition), or actively initiated it by selecting a gaze direction and pressing a corresponding button. Crucially, in active trials, the gaze direction could be consistent or inconsistent with the chosen direction. The results showed a larger in magnitude gaze cuing effect in action-outcome consistent condition; moreover, time distribution analyses suggested that the effect appeared early on, in contrast to control and action-outcome inconsistent conditions. Together, these data point towards a possible link between action control and social attentional orienting.

**Keywords:** gaze cuing; intentional action; action control; sense of agency; automaticity; RT

## Introduction

As highly social and communicative creatures, humans rely strongly on non-verbal, social cues like gaze direction, head orientation, or pointing gestures. Reported at the end of the 20th century, Gaze cueing (GC) refers to the human tendency to shift attention in the direction of another person's gaze (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999). It serves as a fundamental social cue, allowing individuals to infer the attentional focus of others and thereby engage in joint attention, a core component of human social interaction (Tomasello et al., 2005).

Originally considered a reflexive mechanism (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999), GC has been widely used to investigate attentional orienting processes. It is most commonly studied using a variant of the Posner cueing paradigm (Posner, 1980), a classic attentional task in which a presented cue (e.g., an arrow or a flash) precedes a target, and responses are typically faster when the cue validly predicts the target's location.

In the GC version, the symbolic cue is replaced by a centrally presented face whose gaze shifts left or right. Even when gaze direction is non-predictive of the target's location, participants respond faster to targets appearing in the gazed-at direction, a phenomenon known as the gaze cueing effect (GCE). This effect has been interpreted as evidence for the reflexive and automatic nature of gaze-induced attentional shifts (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999).

However, the reflexive nature of gaze cueing has since been questioned. A growing body of research suggests that, while gaze cueing may be fast and seemingly automatic, it is not purely reflexive but can be modulated by contextual, emotional, and social factors, as well as higher-order cognitive processes (for a review, see Dalmaso et al., 2020). These findings indicate that gaze cueing is deeply intertwined with social meaning, cognitive mechanisms, and various internal states, highlighting its dynamic and flexible nature and setting the stage for further exploration of its modulatory factors.

Despite the large body of research, one internal state remains notably underexplored in the gaze cueing literature: the sense of agency (SoA). Little research has been done on how transient, moment-to-moment cognitive states such as the subjective experience of control over one's own actions might modulate social attention. Investigating SoA thus represents a valuable opportunity to deepen our understanding of how volitional control interacts with mechanisms of gaze-based attentional orienting and non-verbal communication.

The sense of agency (SoA) can be understood as the feeling of being the agent of one's own actions, and the experience of controlling them and, through them, controlling events in the external world (Haggard, 2017). In other words, it is the feeling that "I am the one who is performing the action, hence I'm the one causing the effect." SoA is fundamental to motor control, self-awareness, and social interaction (Haggard, 2017).

Several theoretical frameworks have been proposed to explain how SoA arises. Predictive coding models suggest that agency stems from the match between predicted and actual sensory outcomes (Haggard, 2017). Cue integration models propose that internal motor signals and external cues are combined and taken into account for the final judgment of agency (Moore & Fletcher, 2012). Retrospective inference models, in their turn, argue that agency can also be inferred after the fact, based on contextual and temporal information (Haggard, 2017). Despite their differences, all three models converge on a central claim: congruency/consistency



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between intended actions and observed outcomes enhances the experience of agency.

Importantly, recent laboratory research shows that SoA is not limited to motor actions like button presses. For instance, Gutzeit et al. (2024) demonstrated that people can experience agency over eye movements, particularly when gaze behavior leads to predictable outcomes such as color changes. Their study revealed that gaze–outcome contingency increased both explicit agency ratings and implicit ratings (measured by temporal binding effects), extending the research of SoA to the oculomotor domain.

In the social domain, agency and attention appear to interact closely. For instance, Ulloa et al. (2019) demonstrated that eye contact not only communicates engagement but also enhances SoA. Meanwhile, Gutzeit et al. (2024) showed that even gaze-contingent effects that is, simply looking in a direction that causes an event, are sufficient to elicit SoA, particularly when the action–effect relationship is perceived as contingent and predictable.

Considering the existing literature on both gaze cueing and the sense of agency, as well as the many points of intersection between them, such as their importance for attentional allocation, their susceptibility to social influences, and their major role for social cognition and functioning, it is logical to ask whether there is an overlap between these two mechanisms, and if so, what its nature might be.

Despite its theoretical significance and centrality to volitional behavior, the influence of the sense of agency on attentional processes, specifically gaze cueing, remains poorly understood. While prior research has shown that gaze behavior can influence SoA (e.g., mutual gaze enhancing agency; Ulloa et al., 2019; Stephenson et al., 2018; Lombardi et al., 2023), the reverse relationship, that is, whether agency modulates the perceptual and attentional impact of gaze cues has not been directly tested. Our study addresses this gap by investigating whether the internal state of SoA shapes the strength of GCE. Importantly, we keep an optimal time window of the internal state of SoA (e.g., Farrer et al, 2013) to assure the occurrence of the action-effect integration process.

In this experiment, we operationalize SoA through intentional (action–outcome) consistency: whether the direction of a gaze shift aligns with the participant's intention. Participants performed a color discrimination task in which a synthetic face with dynamic pupil motion precedes target onset. In active trials, participants chose a gaze direction, which then either was consistent or inconsistent with the resulting gaze direction. In passive (control) trials, gaze direction was externally "determined" and participants had no control over it. The gaze direction itself was either valid (target appears on the same side) or invalid (opposite side), allowing us to measure whether agency/action control modulated the behavioral impact of gaze cues. Finally, we have chosen discrimination between two similar colors to make the task more difficult (hence, slow) in order to open some 'space' for the internal state of SoA to penetrate the GCE.

Drawing on predictive processing (Haggard, 2017) and cue integration framework (Moore & Fletcher, 2012), as well as empirical findings showing that congruent action–outcome relationships enhance both agency and attentional salience (e.g., Gutzeit et al., 2024), we propose that the effectiveness of gaze cues will vary systematically with perceived /internal state of agency.

Specifically, we expected enhanced gaze cueing effect in action-outcome intentionally consistent condition, where participants' chosen direction would follow by an intended gaze shift, reinforcing predictive consistency and strengthening SoA. By contrast, action-outcome intentionally inconsistent trials might weaken or disrupt cueing, as the violated expectation likely would reduce perceived agency. Passive/control trials, in which no volitional input would be involved, were expected to yield intermediate effect, reflecting no violation of expectations.

# Experiment

## Method

**Participants** Forty-three students participated in the experiment (7 males, age M(SD)=24.7(8.4) years old). They either volunteered or participated in exchange for a course credit after giving their written informed consent. All participants had normal or corrected to normal vision.

**Stimuli, Design, and Procedure** The design of the experiment was 2 (Gaze Cueing: congruent vs. incongruent) x 3 (Action-outcome consistency: consistent vs. inconsistent vs. control) within-subjects design. The face was generated by FaceGen program (Roesch et al., 2011). The face subtended around 13° of visual angle in height and 6° - in width, centered at the screen. From both sides of the face (5° to the nearest edge) squares were presented subtending 3.5°, positioned at the eye central 'line'. Target colors were violet (BlueViolet, RGB: 138, 43, 226) and magenta (Magenta, RGB: 255, 0, 255) filled in one of the squares as soon as the eye movement was completed. Figure 1 presents trial examples. Note that gaze cuing congruence refers to gaze direction towards/away from target position (a colored square).

Stimuli presentation and response collection was controlled by E-prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2002). Participants were tested individually in a sound-proof booth in front of 22-inch monitor with resolution of 1920x1080 pixels and refresh rate of 50 Hz. They were positioned at around 60 cm from the screen. Participants were asked to perform two tasks: First task was to either pressing a button of their choice (left vs right) to initiate gaze movement or to refrain from pressing a button and to observe the gaze movements to the left or to the right. Color (red/NoGo vs green/Go) of an attentional cross in the beginning of a trial would notify participants whether to wait for a gaze movement or to initiate it. To initiate gaze movement participants were asked to press either button '6' (right) or '4' (left) on an extended keyboard: that is, the buttons were positioned on the right of the keyboard. The participants were asked to press these buttons using their right hand. The second task was color discrimination: as soon as the gaze movement was over, one of the squares positioned from both sides of the face was colored. Participants were asked to discriminate between colors (violet/magenta) as fast and as accurately as possible pressing a corresponding button on the computer keyboard ("a" or "d") with their left hand.

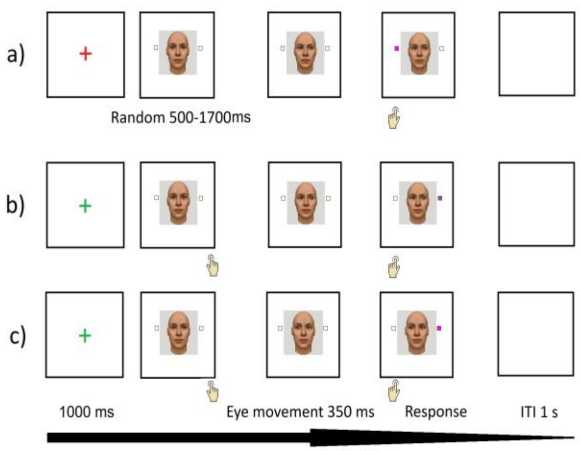


Figure 1: Trial timeline examples (not to scale). a) Control condition (red cross/NoGo: passive expectation of face appearance followed by gaze movement), incongruent gaze cuing (gaze is away from the target/colored rectangle); b) and c) green cross/Go: when a face appears, participants press a button with their *right* hand, choosing gaze direction, b) – congruent gaze cuing (gaze is towards the target/colored rectangle), c) – incongruent gaze cuing (gaze is away from the target/colored rectangle). During the response window participants discriminate between colors with their *left* hand. ITI – intertrial interval.

Response mapping to the colors was counterbalanced between participants. A trial started with a fixation cross for 1000 ms. After the cross a face would appear with two 'empty' squares positioned from each side of the face. Participants were instructed to press a left or right button with their right hand ('4' or '6') of their choice only if the cross was green. If a button press was not registered during 3 sec, then a green cross would appear again, followed by the face reminding participants to make a choice. If the cross was red, participants would wait for a face to appear and then observe the gaze movement. The face after the red cross stayed on the screen for a random time between 500 and 1700 ms. After that time the eyes moved either left or right, towards one of the squares. The movement took 350 ms. In case of movement initiation by a participant, the eye movement could be either consistent with the intended by participant gaze direction or inconsistent. After the eyes reach their ultimate left or right position, one of the side squares changed its color into violet or magenta. Participants had 1500 ms to respond to the color using their left hand. The inter-trial interval was 1000 ms. Participants first went through a practice block that consisted of 16 trials. The experimental procedure consisted of 168 trials (28 trials per condition). Trials were presented pseudorandomly so that there were no more than two consecutive trials with the same action condition and color. The experiment took around 10-15 minutes to complete.

## Results and Discussion

Data of ten participants[1] were excluded due to low accuracy (<80%) or failure to follow the instruction. Data of two participants were excluded due to them complaining of task difficulty. Finally, data of seven participants were excluded due to very long mean RT comparing to means of other participants (>700 ms, around 2SD from the overall mean). That is, we left data of only those participants for whom the color discrimination task was considerably easy. A post-hoc power analysis indicated that with the remaining sample size (24 participants) our experiment had sufficient power to detect even a small effect (power = 0.91 for an effect size f = 0.25). The post-hoc power analysis was conducted using G*Power 3.1.9.6 (Faul et al., 2007).

From the remaining data of 24 participants' erroneous responses (7.1%) and outliers (5.06%) with RT outside of ± 2SD per participant and per condition means were excluded from the RT analysis. The data were averaged by subject and then entered into repeated measures ANOVA (rANOVA) with action-outcome consistency and gaze cueing congruency as within-subject variables. Corrected Bonferroni post-hoc test was applied where appropriate. Table 1 presents descriptive statistics per condition.

Table 1: Mean RTs, standard deviations (SD) in parentheses, and 95% confidence intervals (CI) per condition, ms.

| | **Gaze Cueing** | |
|---|---|---|
| **Action** | **Congruent** | **Incongruent** |
| Consistent | 546(78), 514–579 | 594(87), 558–631 |
| Inconsistent | 560(77), 528–593 | 583(86), 547–620 |
| Control | 586(92), 547–625 | 603(93), 564–643 |

rANOVA obtained a significant main effect of gaze cueing ($F(1,23)=32.31$, $p<0.001$ $\eta_p^2=0.58$), suggesting that color discrimination was faster in congruent (564 ms) than in incongruent condition (594 ms). Main effect of action-outcome consistency was also significant ($F(2,46)=5.96$, $p=0.005$, $\eta_p^2=0.21$). A post-hoc analysis showed that the control condition (595 ms) produced slower responses than

[1] Most of participants participated for credits. Unfortunately, many of them did not cooperate, knowing that they would get the credits anyway. In our follow-up experiments we have tried to encourage participants to make less errors by assigning them more participation credits depending on the percentage of errors they make.

the consistent (570 ms, p=0.027) and inconsistent (572 ms, p=0.042) conditions. There was no difference between consistent and inconsistent conditions (p=0.776). Most importantly, a significant two-way interaction (F(2,46)=3.82, p=0.029, $\eta_p^2$=0.14) was obtained (see Figure 2). A post-hoc comparison showed a significant gaze cueing congruence effect in action consistent condition (48 ms, difference between incongruent and congruent, p=0.001, Cohen's d=0.556) as well as a congruence effect in inconsistent action-outcome condition (23 ms, p=0.036, Cohen's d=0.27). Surprisingly, there were no significant congruence effect in the control condition (17 ms, p=0.359, Cohen's d=0.20). In addition, Bonferroni post-hoc test found significant difference congruent gaze cue, consistent action-outcome, and incongruent control (p<0.001, Cohen's d=0.67). The differences between the three mean conditions in incongruent gaze cue were insignificant (all ps>0.8)[2] (cf. Figure 2).

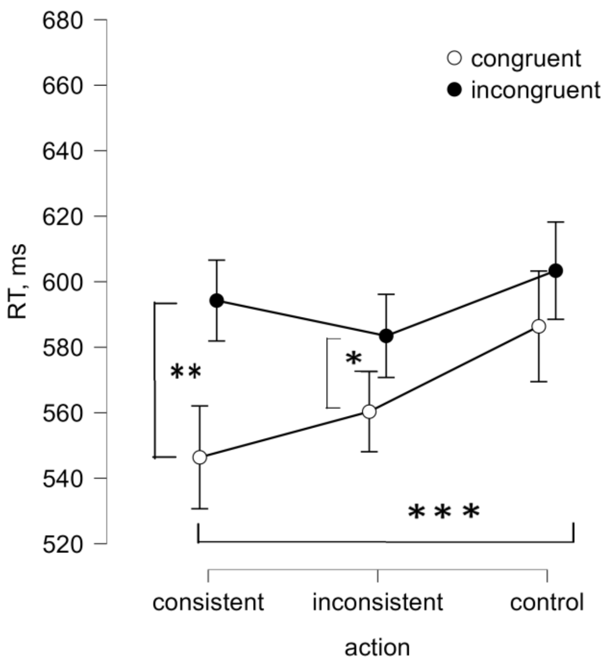


Figure 2: A gaze cuing by action consistency interaction. Vertical bars denote 95% CI.
* p<0.05; ** p<0.01, *** p<0.001.

Overall, the results suggested that the gaze cueing was affected by action-outcome consistency. In particular, the consistent action-outcome condition made the effect two times larger than in inconsistent action-outcome condition (43 vs 23 ms). This result supports our expectation of reinforced internal state of SoA in action-consistent condition and its influence on the GCE. The surprising lack of significant congruency effect in control condition partially can be explain by low expectation level and shift of attention. Since in the control condition eye movement started in a random time between 500 and 1700 ms after the red cross onset, participants would not be able to sustain their attention and would be then much less prepared to be ready in 350 ms for the color appearance. In contrast, in the action conditions, the sequence of events was quite fast and predictable, thus, making it easier to sustain the attention. To test this, we run a correlational analysis between time of participants button press (action decision, M=489 ms), random time of eye movement start in the control condition (M=1105 ms), and color discrimination time in all six conditions. The result showed significant correlations between participants' action decision time and RTs of six conditions (r varied between 0.472 and 0.712, p varied between 0.020 and <0.001). In contrast, there was no correlation between six conditions' RTs and eye moving time (all ps>0.8). Thus, the correlation analyses confirmed our assumption. In addition, it was obvious that the task of color discrimination was quite difficult. Thus, probably, both possible reasons could be attributed to the lack of GCE in the control condition.

Thus, the results showed that action control can modify GCE in gaze cuing congruent condition, suggesting facilitation in comparison with the control. To test how the effect is distributed over time, distributional analyses of RT were conducted.

## RT Distribution Analyses

RT distribution analyses were conducted on data tracing temporal dynamics of the gaze cuing effect, testing whether it occurs at earlier RTs and then decays or is developed over time. These analyses are important in that they can provide information on the level of penetrability of the effect given that the effect was influenced by action consistency.

To make the analyses clearer, the data were not reduced into the effect size as it is often done (e.g., Proctor, Miles, & Baroni, 2011) and the conditions were preserved. Individual participants' data were rank-ordered per gaze cue congruence and action-outcome consistency and then divided into five bins of 20%. Mean RTs per subject and per condition were then computed per bin. Within-subject rANOVAs with factors gaze cuing (congruent vs. incongruent), action consistency (consistent vs. inconsistent vs. control) and bins (1-5) were conducted[3]. To avoid the problem of multiple comparisons, the rANOVAs were run per action condition separately. Obviously, some results of the analyses mirrored the results presented in previous section. These were only

[2] An anonymous reviewer raised concern that the congruency effect observed might partially reflect a Simon-like effect since the responses to the color targets were from the left part of the keyboard. An additional analysis with left/right target position variable showed no interaction (p>0.6) with the key variables even though the congruency effect numerically was slightly higher when the target was presented on the left (the difference varied from 12 to 20 ms).

[3] An anonymous reviewer suggested to run the analyses separately per bin. We did perform rANOVA per bin and then, since the analyses were highly sensitive and the results were highly significant everywhere, we have decided to keep the original, more conservative and closer to 'standard' analyses in time distribution.

reported and not commented as well as natural main effects of bins. Since the key interest was the time distribution of gaze congruency across bins and action-outcome consistency, the 2-way interactions were submitted to Bonferroni post-hoc test independently of significance of the interactions. Further, to evaluate the temporal dynamics in more detail, the magnitude of congruency effect was also calculated in ms. Graphical representation of the results is shown in Figure 3 together with congruency effect size in ms and significance per bin.

Bin analysis of action-outcome consistent condition showed a significant main effect of gaze cuing ($F(1,9)=48.45$, $p<0.001$, $\eta_p^2=0.84$) and expected main effect of bins ($F(4,36)=357.79$, $p<0.001$, $\eta_p^2=0.98$). The interaction between bins and gaze cuing was also significant ($F(4,36)=2.76$, $p=0.042$, $\eta_p^2=0.24$). The post-hoc test revealed differences between congruent and incongruent conditions across all bins (p varied from 0.022 to <0.001) but the fifth one (p>0.5) (cf. Figure 3). Note that numerical variation of the effect does not change sharply across the bins – it ranges between 32 and 43 ms, showing significant effect for the first four bins and only then it doubles and loses the significance level.

Bin analysis of control condition was very similar to the previous result: it showed a significant main effect of gaze cuing ($F(1,8)=23.43$, $p=0.001$, $\eta_p^2=0.75$), main effect of bins ($F(4,32)=835.92$, $p<0.001$, $\eta_p^2=0.99$), and no interaction between bins and gaze cuing ($F(4,32)=0.48$, $p=0.750$, $\eta_p^2=0.57$). The post-hoc test on interaction revealed differences only in bins 2 (p=0.001) and 3 (p=0.002). The differences in bins 1 and 5 (p=1.0) and in bin 4 (p=0.341) were insignificant. The numerical values of the effect were similar to the values in action-consistent condition in bin 2 and 3 (34 vs 36 and 33 vs 32, accordingly). In bin 4 the effect was reduced to the effect of bin 1 (23 vs 26 ms) and increased to 51 ms, showing insignificance, similar to the pattern in action-consistent condition.

Bin analysis of action-outcome inconsistency showed a significant main effect of gaze cuing ($F(1,7)=20.28$, $p=0.003$, $\eta_p^2=0.74$), main effect of bins ($F(4,28)=334.23$, $p<0.001$, $\eta_p^2=0.98$), and no interaction between bins and gaze cuing ($F(4,28)=1.20$, $p=0.331$, $\eta_p^2=0.15$). The post-hoc test on the interaction revealed differences in bin 3 (p=0.005) and 4 (p=0.005) only. The differences in bin 1 and 5 were highly insignificant (p=1.0), and in bin 2 it was p=0.08. Here we observe small numerical changes (19-23 ms) up to a double in bin 4 (43 ms) and then undertake an abrupt reduce of the effect (11 ms).

Thus, the results suggest that the congruency effect benefited from action-consistent condition showing very early impact of action-outcome consistency observed in gaze cuing congruency effect, which was kept constant through the bins, disappearing in slow RTs (bin 5). At the same time, it was evident that action-outcome inconsistency as well as the control condition had quite weak overall GCE somewhere in the middle of RT distribution.

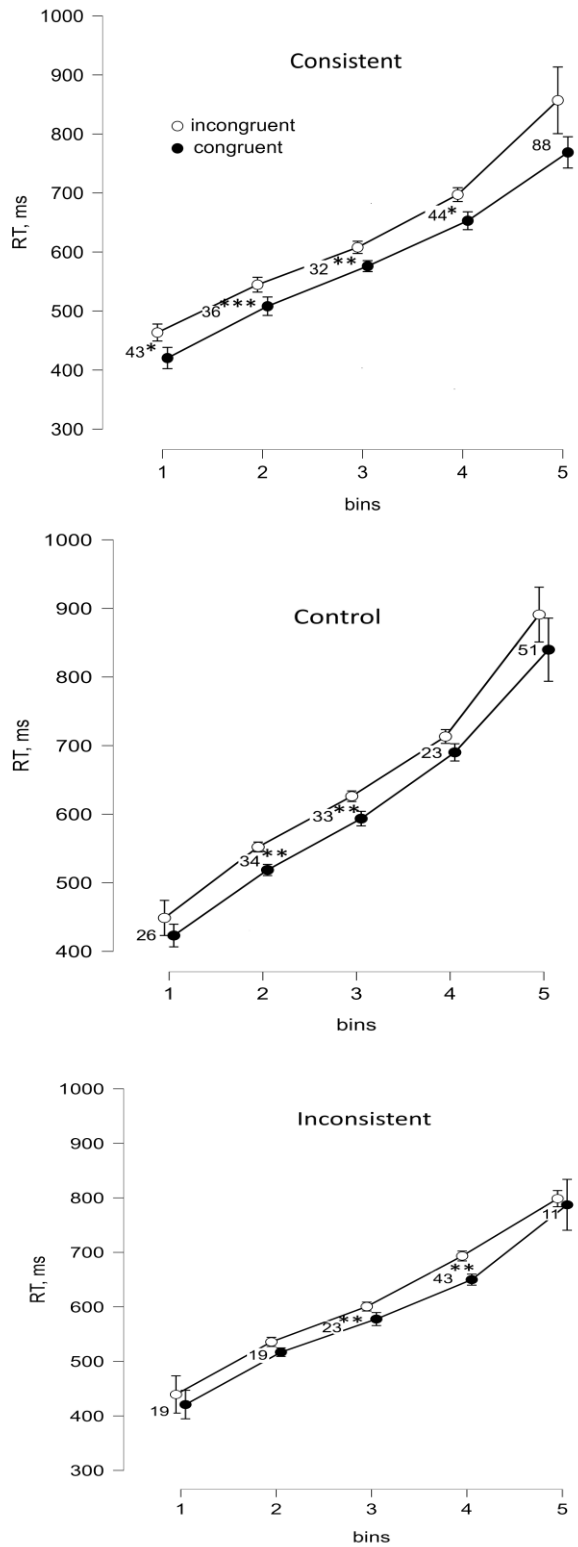


Figure 3: Time distribution across 5 bins, Horizontal line represents bins from 1 to 5. Vertical bars denote 95% CI. Numbers represent gaze congruency effect magnitude in ms per bin.
* p<0.05; ** p<0.01; *** p<0.001.

Taken together, the distribution analyses confirmed and extended the results, showing that the GCE can be influenced by action-outcome consistency, as well as suggested that the effect itself may depend on predictability of stimulus appearance and sustained attention, confirming previous findings that GCE combines both exogenous (reflexive, automatic) and endogenous (controlled, strategic) types of attentional orienting (Murray et al., 2023).

## Conclusion

The present study sought to test whether internal state of SoA can modify the GCE. Our expectations and the paradigm employed were based on previous research suggesting that both internal (SoA) and external (gaze movement) cuing have a potential to contribute to the effect (Moore & Fletcher, 2012; Dalmaso et al., 2020; Murray et al., 2023). Even though the experiment did not include any SoA measurement, either implicit or explicit, the results unambiguously suggest that our participants did experience an internal state of agency which influenced the GCE. It is clear that the results were not caused by probability of occurrence or movement direction after volitional button presses since both action-consistent and action-inconsistent conditions had the same probability. Importantly, the results suggested not only modification of the GCE, but the level of processing automaticity in each action-consistency condition. While gaze congruency in control and action-inconsistent conditions can be considered rather weak and late (less automatic), the action-consistent condition showed that combination of exogenous/external and endogenous/internal cues shaped an early and strong pattern of the gaze congruency effect. Note that one may perceive an outcome of the action in our case as a ‘doubled’ one: immediately after a button press participants observe gaze movement and then a target appearance which was still within the action-effect time window (e.g., Volosin et al., 2025). We suppose that either the target appearance played an action-effect reinforcement role or SoA has a ‘spillover’ effect on processes if they start within the action-effect window (color discrimination in our case). Both assumptions will be tested in our next experiments. In addition, we plan to reduce task difficulty by introducing discrimination between basic colors (e.g., green and blue).

Overall, the results suggest a mediating role of Sense of Agency in Gaze cuing effect which broadly connects consequences of our intentions and actions with a fundamental social cue.

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