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Dyadic learning shapes gaze-mediated social attentional orienting

Shujia Zhang [a,b], Bin Zhan [a,b], Li Wang [a,b,*], Yi Jiang [a,b,*]

[a] State Key Laboratory of Cognitive Science and Mental Health, Institute of Psychology, Chinese Academy of Sciences, Beijing, China
[b] Department of Psychology, University of Chinese Academy of Sciences, Beijing, China

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ABSTRACT

People tend to automatically shift their attention in response to social cues, such as eye gaze—a phenomenon known as social attentional orienting, which is crucial for adaptive social behaviors and interpersonal communication. While this ability is genetically influenced and typically stable, the current research shows that it can be enhanced within a specific social context by dyadic learning. We engaged pairs of participants in a standard gaze-cuing task, during which they received instant feedback on each other's performance. Unbeknownst to the participants, the feedback was designed to create a social context in which the partner appeared to respond to the cued location faster than the participant. We found that such a social context significantly increased the magnitude of gaze cuing effect. Importantly, the observed enhancement was not attributable to confounding factors such as arousal level or overall performance difference, nor to implicit learning from the feedback structure. Instead, drift-diffusion model analysis suggested that such a social context improved both the initial attentional orienting process and the sustained allocation of processing resources to the gazed-at location, resulting in a stronger gaze cuing effect. A subsequent experiment replaced gaze cues with non-social arrow cues and observed no modulatory effect, underscoring the distinction between social and non-social attentional orienting. The current research provides compelling evidence that social attentional orienting is malleable and highlights the significant impact of dyadic learning in shaping this capability.

1. Introduction

Being social creatures, humans are always ready to detect the interactive social partners' focus of attention via various social signals. This exquisite ability, known as social attentional orienting, is fundamental to social interaction and adaptive functions because it enables us to learn about others' inner states and helps us attend to where the important events occur in the environment (Birmingham & Kingstone, 2009; Nummenmaa & Calder, 2009; Shi et al., 2010). The eye gaze, as the "window to the soul", provides the most reliable and salient cue to other's direction of attention, serving as a critical source of information for social attentional behavior (Baron-Cohen, 1995; Emery, 2000; Itier & Batty, 2009). To characterize the properties of social attentional orienting, Friesen and Kingstone (1998) introduced a central cuing task modified from the classic Posner cuing paradigm (Posner, 1980). Typically, a gaze cue is centrally presented and then a target will appear on either the left or right hemifield of the screen. People generally respond more quickly when the target appears on the gazed-at hemifield (i.e., the congruent condition) as compared to the non–gazed-at hemifield (i.e., the incongruent condition), reflecting a gaze cuing effect. Accumulating evidence suggests that social attention, which is distinct from non-social attention, is predominantly influenced by genetic factors (Wang et al., 2020), manifests early in life (Zhao et al., 2014), and tends to maintain general stability in adults (Liu et al., 2021; Prein et al., 2024).

In the past decades, research on social attentional orienting has proliferated and accumulated influential findings within social cognition. In most of the pioneering studies, the researchers generally had one participant conduct a given task each time, i.e., single-participant measure. However, a vast majority of our day-to-day activities are carried out in the concurrent presence of interactive others, and at the same time, shaped by such social contexts. Given this, there have been efforts to bridge the gap between social context and human cognition. Dyadic learning paradigm is one of the widely adopted paradigms in this field. For instance, Zhan et al. (2025) had paired participants conduct a perceptual decision task and they could monitor each other's response via feedback. Researchers found that participants' perceptual

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* Corresponding authors at: State Key Laboratory of Cognitive Science and Mental Health, Institute of Psychology, Chinese Academy of Sciences, 16 Lincui Road, Chaoyang District, Beijing 100101, China.

E-mail addresses: wangli@psych.ac.cn (L. Wang), yijiang@psych.ac.cn (Y. Jiang).

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boundaries would be biased toward their partners' boundary. Importantly, this effect decreased significantly when removing the social context. That is, participants completed the perceptual decision task independently and received partner-absent feedback, which was derived from a previous participant, rather than from a concurrent partner engaged in the same task with the participant. Similarly, compared with learning alone, learning with a concurrent interactive partner led to a greater behavioral performance improvement and a faster learning rate in visual perceptual learning task (Zhang, Bi, et al., 2023). However, social context doesn't always enhance learning performance. Several previous studies have reported that for some complex skills, dyadic learning either shows comparable or even inferior learning performance as compared with single learning (Day et al., 1997; Shebilske et al., 1992). This is particularly evident when the learning task heavily emphasizes declarative knowledge (Crook & Beier, 2010). These lines of evidence suggest that the effectiveness of dyadic learning varies with different types of learning tasks. Interestingly, the characteristics of a learning partner also modulate the learning performance. For example, learning alongside a high-aptitude partner (i.e., a partner whose responses were more likely to be correct than the participant) yielded better learning performance compared to learning with a low-aptitude partner (Zhang, Bi, et al., 2023). Besides, when it comes to cooperative learning, the partner's competence modulates the learning performance depending on the specific cooperation mode, that is, whether it involves complementary or identical information (Buchs & Butera, 2009). Based on the literature, an important question arises regarding whether social context can influence social attentional orienting, an ability generally considered to maintain general stability in adults. More importantly, if such an influence exists, how it may be modulated by the specific attributes of the partner's performance also warrants investigation. Considering the social nature of human beings, such an endeavor will provide a clearer understanding of the emergence of social attentional orienting, which is beyond the classic dichotomy of covert attention and bears great significance for daily interaction and adaptive functions.

To address the issue, we designed a dyadic learning paradigm to create a pseudo social context and investigated its influence on the magnitude of social attentional orienting through a series of experiments. Pairs of participants simultaneously carried out a gaze-cuing task, and they monitored each other's response times via instant, trial-by-trial feedback. Unbeknownst to the participants, this feedback was predetermined to convey that their partner always performed better when the target appeared on the gazed-at hemifield, that is, the congruent condition (Experiment 1). Despite this manipulation, participants were convinced that the feedback was instant and real. To detect the potential influence of such a specific social context, we measured the magnitude of gaze cuing effect before and after the dyadic learning phase using the standard gaze-cuing task. In the subsequent experiment, we further exchanged the feedback structures under congruent and incongruent conditions (Experiment 2) to make the partner respond faster to the non-gazed-at hemifield (i.e., the incongruent condition). Given that social attentional orienting is highly resistant to temporal decay (Liu et al., 2021; Prein et al., 2024), we did not anticipate a substantial reduction in gaze-cuing magnitude in this experiment. Additionally, we had another group of participants undergo the learning phase individually with partner-absent feedback (i.e., the feedback was based on the performance of a previous participant) to determine if the presence of a concurrent interactive partner was necessary for any obtained effect (Experiment 3). Null effect would highlight the necessity of partner's social presence. Finally, to investigate whether any observed modulatory effect was specific to socially gaze-mediated attentional orienting, we substituted the gaze cue with an arrow cue, which represents a type of symbolic directional cue but doesn't bear any social meanings (Experiment 4). Previous research has demonstrated that when involving more complex task (e.g., visual working memory task in Ji et al., 2022; visual mental imagery task in Zhang et al., 2025) or experimental setting (e.g., natural scenes; Hermens & Walker, 2016) other than simple standard cuing paradigm, the effects elicited by social cues tend to diminish or vanish when replaced with non-social arrow cues. Comparing social and non-social cues under a social context might be an innovative way to elucidate the longstanding dispute on the uniqueness of social attentional orienting (Friesen et al., 2004; Frischen et al., 2007; Ristic et al., 2007).

2. General method

2.1. Participants

A prior power analysis (one sample *t*-test) using G*Power in Version 3.1.9.7 (Faul et al., 2007) suggested that at least 15 participants would afford 80 % power with alpha at 0.05 (two-tailed) to detect an attentional effect induced by social or non-social cues (cohen's $d = 0.8$, which is the average effect size reported in previous relevant research, see Hietanen et al., 2006; Ji et al., 2020; Shi et al., 2010). Considering the primary aim of the study was to evaluate the potential change of attentional effect after the dyadic learning, we further increased the sample size to 24 participants per experiment, which was adequate to detecting a medium to large effect (cohen's $d = 0.6$) for the within-participant comparison between pre- and post-test phases with power of 80 % and alpha at 0.05.

A total of 98 naïve adults took part in the current research, and two participants were excluded from analysis because of quitting halfway. Therefore, the final sample size was 96 participants aged between 19 and 30 years ($M \pm SD = 23.229 \pm 2.511$). Each experiment included 24 participants (12 females in Experiment 1, 14 females in each of Experiments 2 and 3, and 13 females in Experiment 4). All participants had self-reported normal or corrected-to-normal vision and they all gave written informed consent in accordance with procedure and protocols approved by the institutional review board of the Institute of Psychology, Chinese Academy of Sciences. Participants received monetary compensation to appreciate their participation.

2.2. Apparatus and stimuli

Participants were seated on a height-adjustable chair approximately 57 cm away from a 24-in. LCD monitor (1920 × 1080 pixels, 60 Hz). Their heads were stabilized by a chin and head rest. Stimuli were generated and presented using Psychtoolbox extensions, version 3 for MATLAB (the MathWorks) (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). In Experiments 1–3, neutral face images ($4.0^\circ \times 4.6^\circ$) with gaze averted 17° to the left or right were adopted. A female face image was taken from the Ekman and Friesen's Pictures of Facial Affect (Ekman & Friesen, 1976), and this image was cropped to remove features outside the face. Gaze direction of the face image was manipulated by using Adobe Photoshop software. In Experiment 4, black arrows (RGB: 0, 0, 0; subtended $2.1^\circ \times 1.8^\circ$) were created by combining a straight line and an arrowhead attached to the leading end of the line. The Gabor patch subtended $1.1^\circ \times 1.1^\circ$ in visual angle (Gussian SD of the window = 4 pixels, contrast = 1, initial phase = 0°, spatial frequency = 9.1 cycles /degree) was used as the target in all experiments. During the cuing task, a white fixation cross ($0.5 \times 0.5^\circ$, RGB: 255, 255, 255) was centrally presented to help participants maintain central fixation. All stimuli were presented within a frame ($16.1^\circ \times 16.1^\circ$) on a neutral gray background (RGB: 128, 128, 128).

2.3. Procedure and design

2.3.1. Experiment 1

We developed a pseudo social context where a pair of participants believed that they were conducting the same task simultaneously in separate rooms, with instant comparison and feedback from the partner. In fact, the feedback was pre-determined by the computer program, allowing us to maintain the validity of social context while precisely manipulating the experimental condition. Note that creating a social context doesn't necessarily mean that the participant pair needs to be in the same experiment room (e.g., Laforest et al., 2021; Zhan et al., 2025; Zhang, Bi, et al., 2023), and the current design was referred from a recent study that also involved dyadic learning paradigm (Zhan et al., 2025). A pair of same-gender unacquainted participants arrived at the experiment place at the appointed time, and they were told that they were each other's partner in the following experiments. They signed informed consent and received experiment instructions together before the formal experiment, and then, these two participants were assigned to separate rooms. The presence of another participant and the preparation time two participants spent together effectively increased the credibility of the pseudo social context.

All participants underwent three phases: pre-test phase, dyadic learning phase, and post-test phase. They were informed that they would carry out the pre-test phase individually, then the learning phase simultaneously with their partner, and finally conduct the post-test phase individually. As shown in Fig. 1A, task in the pre-test phase was a well-established and widely-used gaze-cuing task (e.g., Friesen et al., 2004; Friesen & Kingstone, 1998; Liu et al., 2021). Each trial started with a 500 ms fixation, and then a straight eye gaze was presented as a pre-cue for 100 ms followed by a 300 ms averted gaze cue. After a 100 ms inter-stimulus interval (ISI), a Gabor patch as a target flashed for 100 ms on either the left or right visual field at a distance of 4° from the fixation. Participants were asked to localize the target by pressing the arrow keys on the keyboard, i.e., pressing the left or right arrow key if the target flashed on the left or right visual field, respectively. They had to make responses as quickly as possible on the premise of avoiding making mistakes. After the response, participants waited for a 1000 ms inter-trial interval (ITI) and then began the next trial. The pre-test phase consisted of 80 trials, taking about 5 min. Half of the trials were of congruent condition, where the target would appear at the cued location. And another half of trials were incongruent, namely the target location and the cued location were opposite to each other. After the pre-test phase was the dyadic learning phase as shown in Fig. 1B, and each trial began with the aforementioned gaze-cuing task. If the participants mistakenly indicated the target location, "*wrong*" would be presented for

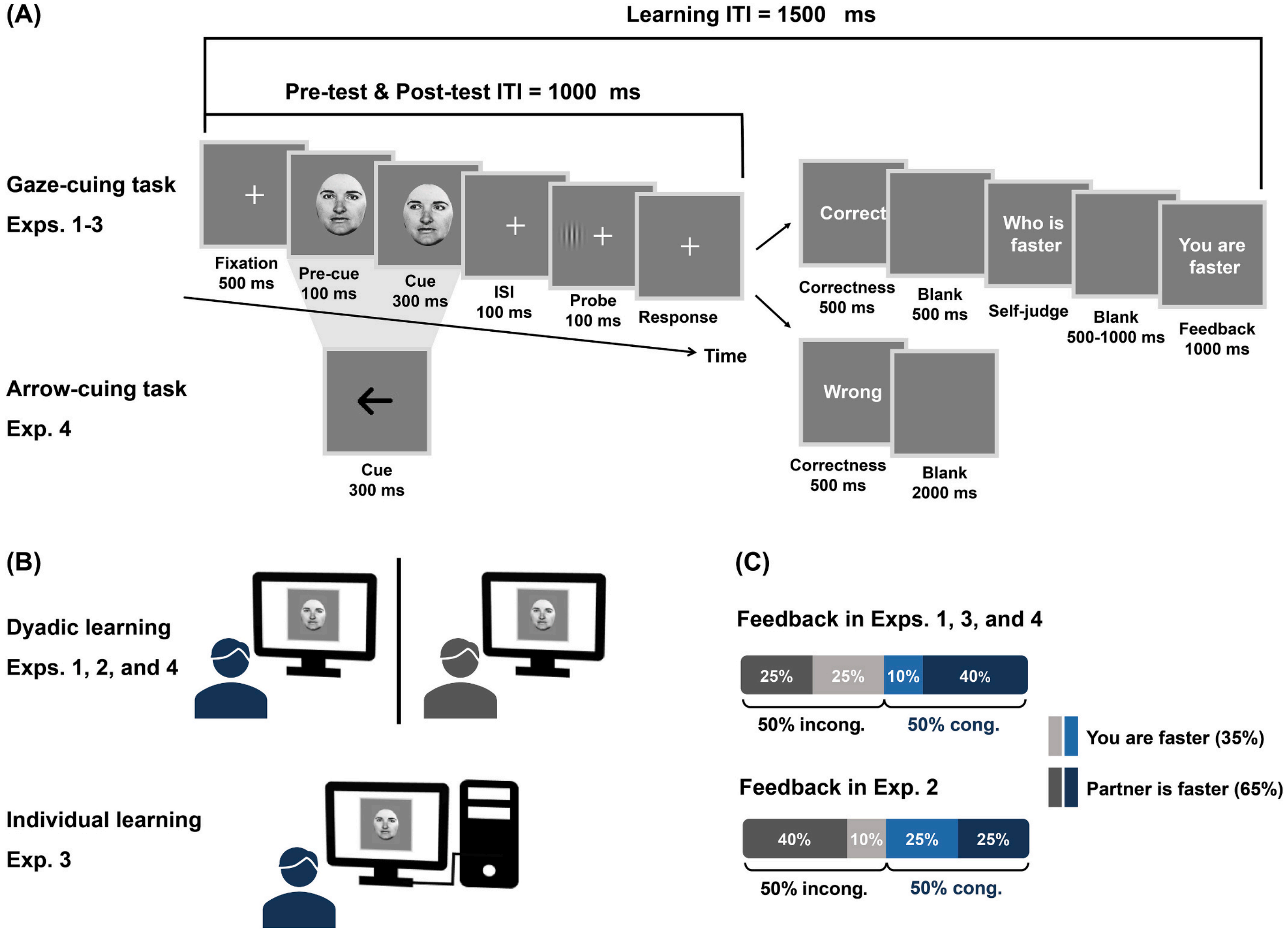

Fig. 1. Schematic illustration for a trial sequence and experimental design. (**A**) The trial illustration of Experiments 1–4. Each experiment consisted of three phases: pre-test phase, learning phase, and post-test phase. In Experiment 1, the task in pre-test and post-test phases was a standard gaze-cuing task. The same task was also conducted in dyadic learning phase, and then participants made a judgement on their performance followed by the feedback. Experiments 2–4 followed the same procedure as Experiment 1 except that Experiment 4 adopted arrow cues. (**B**) Illustration of laboratory settings for dyadic learning and individual learning in the learning phase. In Experiments 1, 2, and 4, participants underwent learning phase with a concurrent interactive partner simultaneously. In Experiment 3, participants conducted learning phase individually. (**C**) Illustration of the feedback manipulation. In Experiments 1, half trials were of incongruent condition (labeled as "incong.") and another half were of congruent condition (labeled as "cong."). In the incongruent trials, the possibility for a participant to receive "you are faster" and "partner is faster" as feedback was 50 % and 50 %, taking 25 % and 25 % of all trials respectively. In the congruent trials, there was 20 % possibility for a participant to receive "you are faster" and 80 % possibility to receive "partner is faster" as feedback, taking 10 % and 40 % of all trials respectively. The feedback structures in Experiments 2–4 are illustrated by the same token.

500 ms followed by a 2000 ms blank interval. If the participants made a correct response to the target location, "*correct*" was presented for 500 ms, and then participants were asked to judge whether it was they or their partner who made the faster response by pressing assigned keys (i.e., press left arrow key to choose themselves, and press right arrow key to choose their partner). This self judgement was designed to increase participants' sense of involvement and thus improve the credibility of pseudo social context. After a 500–1000 ms blank interval, pre-determined feedback was presented for 1000 ms to inform participants who had made the faster response in the current trial. Then after an ITI of 1500 ms, the next trial began. The learning phase included 240 trials, lasting about 30 min. Participants could have a rest for one minute per 40 trials. Half trials were congruent and the other half were incongruent. After the learning phase, participants underwent the post-test phase which was identical to the pre-test phase. Feedback was given during the learning phase, but not the pre- or post-test phases.

The structure of feedback in the learning phase is shown in Fig. 1C. Half of the trials were of congruent condition (50 %), and the other half of trials were of incongruent condition (50 %). In the incongruent trials, the possibilities for a participant receiving "you are faster" and "partner is faster" as feedback were 50 % and 50 %. In the congruent trials, there was 20 % possibility for a participant to receive "you are faster" and 80 % possibility to receive "partner is faster" as feedback. Therefore, in terms of all trials:

a) 80 % × 50 % = 40 % trials were in the congruent condition with "partner is faster";
b) 20 % × 50 % = 10 % trials were in the congruent condition with "you are faster";
c) 50 % × 50 % = 25 % trials were in the incongruent condition with "partner is faster";
d) 50 % × 50 % = 25 % trials were in the incongruent condition with "you are faster".

In this way, we created a specific social context where a concurrent interactive partner responded faster in the congruent condition than the participants themselves. In addition, we did a brief post-experiment survey to check if participants realized the different feedback structures under the congruent condition and the incongruent condition, or found the pseudo social context was "fake". Participants were asked (1) to briefly describe their feelings during the experiment, and (2) to report if they thought there existed some regularities in the experiment, and if so, to describe these regularities. Participants generally reported that they felt their partner always made the faster response, and no participant realized the difference of feedback structure under congruent and incongruent conditions. In the following debriefing session, participants were told that all the feedback was pre-determined and manipulated differently under congruent and incongruent conditions, and that their responses were not actually compared with their partner. We also asked them if they could recall the feedback structure under different conditions, but participants had no idea about this aspect. Besides, participants all reported to be convinced of the authenticity of dyadic setup.

2.3.2. *Experiment 2*

All aspects of Experiment 2 were the same as in Experiment 1 except for the manipulation of feedback structure in the learning phase. As shown in Fig. 1C, the feedback structure was exchanged between the congruent and incongruent conditions. To be more specific, in the congruent trials, the possibilities for a participant receiving "you are faster" and "partner is faster" as feedback were 50 % and 50 %. In the incongruent trials, there was 20 % possibility for a participant to receive "you are faster" and 80 % possibility to receive "partner is faster" as feedback. Therefore, for all trials:

a) 50 % × 50 % = 25 % trials were in the congruent condition with "partner is faster";
b) 50 % × 50 % = 25 % trials were in the congruent condition with "you are faster";
c) 80 % × 50 % = 40 % trials were in the incongruent condition with "partner is faster";
d) 20 % × 50 % = 10 % trials were in the incongruent condition with "you are faster".

In terms of the whole learning phase, it can be seen that 65 % of all trials would feedback "partner is faster", which is the same ratio as in Experiment 1. In the post-experiment survey and the debriefing, again, participants generally reported that they felt their partner always made the faster responses, and no participant realized different structures of feedback under the congruent and incongruent conditions. Besides, participants all reported to be convinced of the authenticity of dyadic setup.

2.3.3. *Experiment 3*

Experiment 3 were basically the same as Experiment 1 except for the laboratory settings and instructions for the learning phase (Fig. 1B). Participants were told that their response times in the gaze-cuing task would be compared with the response times yielded by a gender-matched participant, and this participant was randomly selected from the participants who had performed this same task before. Therefore, by providing partner-absent feedback, Experiment 3 manipulated the concurrent presence of a partner (i.e., social context) as compared with Experiment 1, while keeping all other aspects the same as Experiment 1. The post-experiment survey and debriefing suggested that participants generally found the randomly selected participant made the faster responses, and no participant realized different structures of feedback under the congruent and incongruent conditions.

2.3.4. *Experiment 4*

The procedure and design of Experiment 4 were the same as those of Experiment 1 except that we replaced the gaze cues with arrow cues. Again, the post-experiment survey and debriefing suggested that participants generally reported that they felt their partner made the faster responses, and no participant realized the different structures of feedback under the congruent and incongruent conditions. Besides, participants all reported to be convinced of the authenticity of dyadic setup.

2.4. *Data analysis*

2.4.1. *Data exclusion*

For each phase, we extracted the response time (RT) in each trial for each participant. Only trials with correct responses were included in analysis, and those trials with RTs shorter than 100 ms, longer than 1000 ms, or beyond three standard deviations of the mean in that phase were removed beforehand. The percentage of trials excluded was 7.0 % in Experiment 1, 7.8 % in Experiment 2, 6.3 % in Experiment 3, and 5.2 % in Experiment 4.

2.4.2. *Change of attentional orienting effect following the learning phase*

We compared the attentional effects in pre- and post-test phases to give a first glance at the change of attentional orienting effect following the learning phase. Given that participants would make generally faster responses in post-test phase than in pre-test phase due to practicing effect, we calculated the normalized attentional effect for the pre-test and post-test phases of each experiment. The normalized attentional effect index was produced by dividing the difference in the mean RTs obtained under the incongruent condition versus that in the congruent condition by their sum, expressed as $(RT_{incongruent} - RT_{congruent})/(RT_{incongruent} + RT_{congruent})$. And for each experiment, we used one sample *t*-test to see if the normalized attentional effect existed. Next, we performed a paired samples *t*-test with the independent variable of phase (pre-test vs. post-test) to investigate whether the attentional effect changed following the learning phase.

2.4.3. *Temporal dynamics in attentional orienting effect over the learning phase*

This part of analysis was to assess the changing trend during the learning phase in each experiment. In order to portray the dynamic changes of the attentional effect in each experiment, we analyzed the temporal trend of attentional effect over trials for each participant. This analysis was performed using a sliding window method which calculated the running average of the attentional effect across consecutive trials. We set 100 trials as a time bin and applied the sliding window method across trials with a step size of one trial, consequently generating 141 time bins. For instance, bin 1 included the 1st trial to the 100th trial, bin 2 included the 2nd trial to the 101st trial, and so forth. Next, we calculated the normalized attentional effect index in each time bin. Third, based on Liu et al. (2021), we fitted the obtained temporal profile of the normalized attentional effect via the function below:

$$\text{Normalized attentional effect} = \sum\nolimits_{i=1}^{2} A_i \times \sin[2 \times pi \times f_i(n + \varphi_i)] + slope \times n + intercept$$

where *n* refers to the number of the time bin. For example, trials from 1st to 100th constitute the first bin, so that $n = 1$. The *slope* parameter is of the most interest as it specifically estimates the linear change of the normalized attentional effect with the task proceeding. Particularly, a significantly positive slope value means that the attentional effect gradually increases over trials (i.e., temporal increase). Moreover, two sinusoidal functions each with three parameters A, f, and φ are used to capture the slow and fast fluctuations of the normalized attentional effect over trials, respectively. For each experiment, we performed one sample *t*-test to see if the slope was different from 0, with a slope larger than 0 indicating a rising trend of normalized attentional effect. Besides, one-way analysis of variance (ANOVA) with the between-subject variable of experiment (Experiments 1–4) was carried out to compare the slopes across these experiments, and if significant, we used LSD method to perform post-hoc pairwise comparisons.

2.4.4. *Drift-diffusion modeling*

The drift-diffusion model (DDM) is a mathematical framework widely used to explain how people make decisions between two options, modeling the process as the accumulation of evidence over time until a decision threshold is reached (Forstmann et al., 2016; Ratcliff et al., 2016). While DDM is traditionally adopted in the study of decision-making, it has been adopted to discompose and parameterize the psychological processes for gaze-cuing task (Alister et al., 2024; Parker & Ramsey, 2024) as well as perceptual detection task (van Vugt & van den Hurk, 2017; Zhang, Ye, et al., 2023) in recent years. To further explore the cognitive mechanism underlying the enhancement of social context on gaze-mediated attentional orienting effect (Experiment 1) and compare it with arrow-mediated attentional orienting effect (Experiment 4), we utilized DDM framework to decompose behavioral performance (RT distributions and response accuracy) into distinct cognitive processes. Shown in Fig. 2, the model fitting was performed using accuracy coding such that the upper and bottom boundaries corresponded to those for correct and incorrect choices, respectively. This approach explicitly links decision boundaries to attentional processing dynamics (drift rate for post-target evidence accumulation; non-decision time for initial orienting) rather than spatial response biases (e.g., automatic motor tendencies to respond to left/right locations), thereby avoiding theoretical conflations between cue-driven spatial expectations and sustained attentional allocation (Alister et al., 2024; Zhang, Ye, et al., 2023). We fitted a regression model that allowed two key DDM parameters varied with cue-target congruency (congruent vs. incongruent): 1) the drift rate *v*, which indicates the average speed and quality of evidence accumulation from the target onset (Alister et al., 2024; Zhang, Ye, et al., 2023), with faster drift rate reflecting faster target detection and more accurate response;

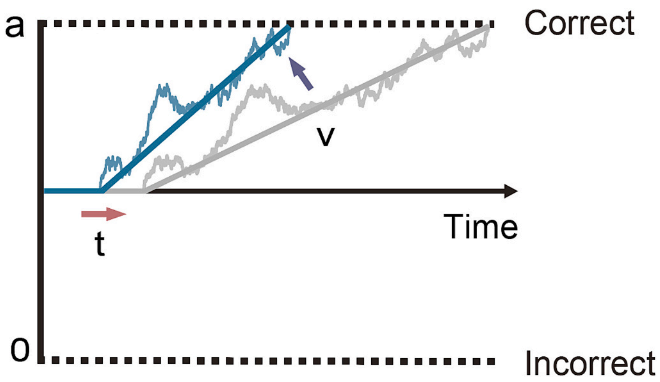

Fig. 2. The illustration for the drift-diffusion model (DDM). DDM describes how individuals accumulate noisy evidence over time to make a response between two alternatives, i.e., "a" for correct response, "0" for incorrect response. The noisy evidence is sampled until sufficient evidence reached one decision boundary over another. The drift rate (*v*) describes the average speed of accumulation. A faster drift rate reflects a sustained boost in information processing in congruent trials (blue line) compared to incongruent trials (gray line). The larger non-decision time (*t*) reflects the delayed onset of target processing in incongruent trials compared to congruent trials. The purple and pink arrows represent the cue-target congruency effects on drift rate (β_{v1}) and non-decision time (β_{t1}), respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

$$v = \beta_{v1} \times \text{Congruency} + \beta_{v0}$$

2) the non-decision time *t*, which captures the duration of sensory encoding and response execution. During the gaze-cuing and arrow-cuing tasks, non-decision time is associated with initial attentional orienting process (Alister et al., 2024; Price et al., 2019; Zhang, Ye, et al., 2023), with less non-decision time reflecting faster attention orientating to the target location.

$$t = \beta_{t1} \times \text{Congruency} + \beta_{t0}$$

Here, β_{v1} and β_{t1} denote the weight assigned to cue-target congruency in drift rate and non-decision time parameters, respectively, and both weights are assumed to be independent for pre-test and post-test. Both β_{v0} and β_{t0} are intercepts that accounted for individual variance in choices and response times that was irrespective to the cue-target congruency. These two parameters were also allowed to differ between pre-test and post-test phases. Furthermore, the decision boundary (*a*), which reflects response caution, is used to reflect speed-accuracy trade-off theoretically. To be more specific, wider boundaries lead to more accurate but slower responses, while narrower boundaries allow for less accurate but faster responses (Forstmann et al., 2016; Ratcliff et al., 2016). However, this trade-off is not compatible with the notion of attentional orienting effect, where the congruent condition yields faster and/or more accurate responses (Driver et al., 1999; Frischen et al., 2007). Therefore, we expected the decision boundary to remain the same between congruent ad incongruent conditions (see also Parker & Ramsey, 2024; Zhang, Ye, et al., 2023). Further, decision boundary was assumed to vary between pre-test and post-test phases, due to that the boundary may be different after learning. The starting point related with prior bias or response bias was set to 0.5, as accuracy coding ($correct = 1$, $incorrect = 0$) was applied and the correct response for target location was equally likely to be on the left or the right. To make a brief summary for the current DDM, the drift rate and non-decision time were allowed to vary with cue-target congruency, and the decision boundary and starting point were assumed to remain consistent across congruent and incongruent conditions.

The model fitting was performed in Python 3 using hierarchical drift-diffusion model (HDDM) toolbox (Wiecki et al., 2013). In the HDDM, subject parameters were drawn from a group-level distribution, and the posterior distribution of each parameter at both subject and group levels was simultaneously estimated using Markov-Chain Monte-Carlo (MCMC) methods. To ensure adequate posterior estimation, we ran 12,000 sampling iterations and discarded the first 2000 samples. The outlier probability was conservatively set to 5 %.

For analysis, we calculated the $\Delta\beta_{v1}$ and $\Delta\beta_{t1}$ with the following formulas to clearly illustrate the change of β_{v1} and β_{t1} between the pre-test and post-test phases:

$$\Delta\beta_{v1} = \beta_{v1\_\mathrm{post}} - \beta_{v1\_\mathrm{pre}}$$

$$\Delta\beta_{t1} = \beta_{t1\_\mathrm{post}} - \beta_{t1\_\mathrm{pre}}$$

A positive $\Delta\beta_{v1}$ and a negative $\Delta\beta_{t1}$ may give rise to an increase in attentional orienting effect, with the former representing a stronger sustained allocation of information processing resources to the cued location, and the latter meaning faster attentional orienting to the cued location. All statistical tests were two-tailed, with the alpha criterion set at 0.05.

2.4.5. *Transparency and openness*

We report how we determined the sample size, the data exclusion, all manipulations, and all measures in the study. Data were analyzed using G-power Version 3.1, JASP Version 0.18.3, and the hierarchical drift-diffusion model toolbox in Python 3. The original data and analytic codes for the current study are publicly accessible at Science Data Bank (ScienceDB) via the link: https://doi.org/10.57760/sciencedb.16711. Experimental instructions for Experiments 1–4 are also available at https://doi.org/10.57760/sciencedb.16711. Other materials used in our research are widely available. There is not a preregistration for the current study.

3. Results

3.1. *Enhancement of gaze-mediated attentional effect through dyadic learning*

Experiment 1 examined whether participants could learn from a social context where a partner who responded faster to the cued location than the participants. We constructed such a social context by manipulating the feedback structure (please see the section *Procedure and design* for details). RTs under congruent and incongruent conditions (Table. 1) were used to calculate the normalized attentional effect index (please see the section *Data analysis* for details). As shown in Fig. 3, in Experiment 1, one sample *t*-test revealed significant attentional effects in the pre-test and post-test phases (pre-test: $M \pm SD$ = 1.1 % ± 2.2 %, $t(23) = 2.410$, $p = 0.024$, cohen's $d = 0.492$, 95 % CI for mean difference = [0.2 %, 2.0 %]; post-test: $M \pm SD$ = 2.4 % ± 2.2 %, $t(23) = 5.177$, $p < 0.001$, cohen's $d = 1.057$, 95 % CI for mean difference = [1.4 %, 3.3 %]). Importantly, such a social context evoked an increase in attentional effect as indicated by the comparison between the pre-test and post-test phases, $t(23) = 2.607$, $p = 0.016$, cohen's $d = 0.532$, 95 % CI for mean difference = [0.3 %, 2.3 %]. Although the participants were not aware of the pre-determined feedback structure, they implicitly learned from the social context where a concurrent interactive partner responded faster in the congruent condition than the participant, resulting in a stronger gaze cuing effect through dyadic learning. This finding demonstrated a significant impact of the partner's relative response speed advantage in the congruent condition on facilitating the gaze-mediated attentional orienting.

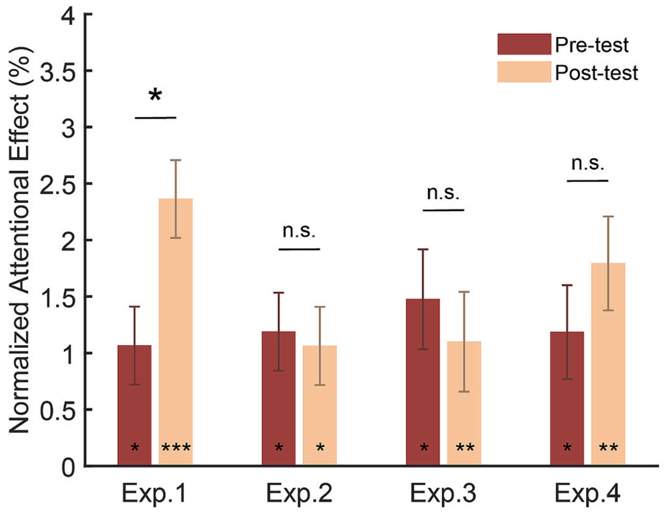

Fig. 3. The normalized attentional effects in pre-test and post-test phases of Experiments 1–4. Attentional effects were stably observed in the pre- and post-test phases across these four experiments. And only in Experiment 1, normalized attentional effect was significantly increased in post-test phase compared to pre-test phase. Error bars indicate the standard errors following Cousineau-Morey corrections. **p* < 0.05; ***p* < 0.01; ****p* < 0.001; n.s., not significant.

While an increase in the gaze cuing effect has been observed in Experiment 1, it remains unclear whether this enhancement was driven merely by the concurrent presence of a partner (regardless of the partner's performance), or by the specific attributes of this partner's performance. To answer this question, in Experiment 2, we exchanged the feedback structure between the congruent and incongruent conditions (Fig. 1C). Such a manipulation retained the presence of a partner, but shifted the partner's relative response speed advantage from the congruent condition to the incongruent condition. If the mere presence of a partner was sufficient to elicit the effect, results would be similar to those of Experiment 1. By contrast, if the specific attributes of the partner's performance were critical, we should observe a different result pattern from Experiment 1. Beyond this primary aim, Experiment 2 also helped to examine two possible confounding factors. The first one is the overall performance difference. It refers to that participants perceived their partner to be more likely to respond faster, as 65 % of all trials in the learning phase provided feedback indicating "partner is faster". The overall performance difference was a by-product of feedback manipulation, and it gave rise to an alternation that as long as 65 % trials were

Table 1
The response times (in ms) under congruent and incongruent conditions at pre-test and post-test phases, and the comparison of RTs between pre-test and post-test phases for congruent and incongruent conditions, respectively.

Experiment	Congruency	$RT_{\text{pre-test}}$	$RT_{\text{post-test}}$	$\Delta RT_{\text{pre-post}}$	*p* value
Experiment 1	Incongruent	372.86 (59.81)	355.02 (49.89)	17.84	0.098
	Congruent	364.21 (53.05)	337.78 (40.72)	26.43	0.005**
Experiment 2	Incongruent	390.98 (101.52)	353.60 (62.82)	37.38	0.001**
	Congruent	382.45 (101.81)	345.98 (62.48)	36.47	0.002**
Experiment 3	Incongruent	418.62 (78.37)	379.62 (45.26)	39.00	0.004**
	Congruent	405.23 (67.86)	371.43 (44.74)	33.80	0.004**
Experiment 4	Incongruent	379.11 (59.92)	352.67 (41.72)	26.44	< 0.001***
	Congruent	369.74 (55.26)	339.95 (38.73)	29.79	< 0.001***

Note. Standard deviations in parentheses. The *p* values represent the results of *t*-tests conducted between $RT_{\text{pre-test}}$ and $RT_{\text{post-test}}$. ***p* < 0.01; ****p* < 0.001.

with “partner is faster” feedback, regardless of the learning conditions, the gaze-mediated social cuing effect would be enhanced after learning. The second potential factor is the arousal level, due to the feedback manipulation as well as the presence of others. On the one hand, the overall performance difference might lead to participants’ increased arousal level as they noticed their own responses were not as fast. On the other hand, the presence of a concurrent interactive learning partner could also enhance arousal level. These factors may result in the alternation that arousal level mainly contributed to the effects observed in Experiment 1. Exchanging the feedback structure between the congruent and incongruent conditions remained both the overall performance difference and the arousal level the same as in Experiment 1.

We first used one sample *t*-test and found significant attentional effects in both the pre-test and post-test phases (pre-test: $M \pm SD = 1.1$ % $\pm$ 2.0 %, $t(23) = 2.792$, $p = 0.010$, cohen’s $d = 0.570$, 95 % CI for mean difference = [0.3 %, 1.9 %]; post-test: $M \pm SD = 1.1$ % $\pm$ 2.5 %, $t(23) = 2.177$, $p = 0.040$, cohen’s $d = 0.444$, 95 % CI for mean difference = [0 %, 2.2 %], shown in Fig. 3). However, in sharp contrast to Experiment 1, no statistical difference was found between the pre-test and post-test phases, $t(23) = 0.022$, $p = 0.983$, cohen’s $d = 0.004$, 95 % CI for mean difference = [−1.0 %, 1.1 %], suggesting that it was the partner’s relative response speed advantage in the congruent condition that elicited the effect in Experiment 1. Such a result also excluded the performance difference and arousal level as the confounding factors of Experiment 1.

Still, there remained a possibility that participants just implicitly learned from the certain feedback structure in Experiment 1, and the presence of a concurrent interactive learning partner was not necessary. The aim of Experiment 3 was to further clarify whether participants indeed learned from the social context where a concurrent interactive partner responded faster to the gazed-at hemifield than the participant, instead of just implicitly learning from a specific feedback structure. To this end, we let participants undergo the learning phase individually and provided them with partner-absent feedback, with all the other aspects remaining the same as in Experiment 1. As shown in Fig. 3, gaze cuing effects were observed in the pre-test and post-test phases (pre-test: $M \pm SD = 1.5$ % $\pm$ 2.8 %, $t(23) = 2.552$, $p = 0.018$, cohen’s $d = 0.521$, 95 % CI for mean difference = [0.3 %, 2.7 %]; post-test: $M \pm SD = 1.1$ % $\pm$ 1.7 %, $t(23) = 3.124$, $p = 0.005$, cohen’s $d = 0.638$, 95 % CI for mean difference = [0.4 %, 1.8 %]). Despite a decreasing trend reflected by the mean values, there was no statistical difference in the magnitude of gaze cuing effect between these two phases, $t(23) = 0.588$, $p = 0.562$, cohen’s $d = 0.120$, 95 % CI for mean difference = [−0.9 %, 1.7 %]. Therefore, the increase in gaze cuing effects observed in Experiment 1 cannot be simply attributed to the feedback manipulation, and importantly, these results highlight the key role of social context (i.e., the concurrent presence of others) in shaping the gaze-mediated attentional orienting.

Former experiments have clearly demonstrated that dyadic learning with a concurrent partner who responded to the gazed-at hemifield faster than the participant enhanced participants’ gaze-mediated social attentional orienting. However, it remains an open question whether this effect was specific to cues with social relevance, or whether it can be generalized to non-social cues (e.g., arrow). Despite lacking social relevance, directional arrow cues can also direct spatial attention (e.g., Tipples, 2002), similar with the gaze cues. This discovery has led to an ongoing debate about whether the attentional effects induced by gaze cues are inherently different from those induced by arrow cues (Friesen et al., 2004; Frischen et al., 2007; Ristic et al., 2007). As a result, researchers have frequently employed gaze and arrow cues to ascertain whether social attentional orienting is unique and distinct from non-social attentional orienting. A recent meta-analysis suggested that the intrinsic distinction between gaze and arrow cues may only become pronounced in specific contexts where higher-order cognitive functions are engaged (Chacon-Candia et al., 2023). Given the social context created by dyadic learning, the current design offered a promising opportunity to probe the difference between gaze and arrow cues.

Therefore, the aim of Experiment 4 was to further explore if enhancement in attentional effect could be extended to non-social arrow cues. As shown in Fig. 3, both the pre-test and post-test phases demonstrated significant arrow cuing effects (pre-test: $M \pm SD = 1.2$ % $\pm$ 2.7 %, $t(23) = 2.150$, $p = 0.042$, cohen’s $d = 0.439$, 95 % CI for mean difference = [0 %, 2.3 %]; post-test: $M \pm SD = 1.8$ % $\pm$ 2.9 %, $t(23) = 3.022$, $p = 0.006$, cohen’s $d = 0.617$, 95 % CI for mean difference = [0.6 %, 3.0 %]). After learning with a partner who responded faster to the arrow-cued location than the participant, the mean magnitude of arrow cuing effect in the post-test phase was numerically larger than that under pre-test phase, but this difference didn’t reach statistical significance, $t(23) = 1.013$, $p = 0.322$, cohen’s $d = 0.207$, 95 % CI for mean difference = [−0.6 %, 1.9 %]. Taken together, the facilitating effect of social context failed to be generalized on arrow-mediated non-social attentional orienting, accentuating the demarcation between social and non-social attentional effects.

3.2. Temporal dynamics in attentional orienting effect over the learning phase

We fitted the normalized attentional effects over trials for each participant to portray the dynamic changes of the attentional effect in each experiment (please see the section *General method* for details). Fitted plots at individual level are provided at https://doi.org/10.57760/sciencedb.16711. The R^2 values of the fitted curves for Experiments 1 to 4 were $M \pm SD = 0.888 \pm 0.093$ (min = 0.616, max = 0.988), 0.859 $\pm$ 0.105 (min = 0.592, max = 0.970), 0.852 $\pm$ 0.096 (min = 0.610, max = 0.973), and 0.867 $\pm$ 0.101 (min = 0.649, max = 0.982), respectively. That is, the fitted curve on average could explain more than 85 % variance of the normalized attentional effect. One-way ANOVA found no significant effect of experiment for the fitted R^2, $F(3, 92) = 0.618$, $p = 0.605$, $\eta_p^2 = 0.020$, indicating comparable goodness of fitting across Experiments 1–4.

As expected, the mean slope was significantly larger than 0 in Experiment 1, $M \pm SD = 3.3$ % $\pm$ 4.7 %, $t(23) = 3.419$, $p = 0.002$, cohen’s $d = 0.698$, 95 % CI for mean difference = [1.3 %, 5.3 %], illustrating a rising trend of normalized attentional effect during the dyadic learning phase (Fig. 4–5). In contrast, the mean slope was neither significantly different from 0 for Experiments 2–4, suggesting a stable effect (Experiment 2: $M \pm SD = 0.4$ % $\pm$ 3.5 %, $t(23) = 0.524$, $p = 0.605$, cohen’s $d = 0.107$, 95 % CI for mean difference = [−1.1 %, 1.8 %]; Experiment 3: $M \pm SD = 0.2$ % $\pm$ 2.8 %, $t(23) = 0.423$, $p = 0.676$, cohen’s $d = 0.086$, 95 % CI for mean difference = [−0.9 %, 1.4 %]; Experiment 4: $M \pm SD = 0.2$ % $\pm$ 2.4 %, $t(23) = 0.487$, $p = 0.631$, cohen’s $d = 0.100$, 95 % CI for mean difference = [−0.8 %, 1.3 %]).

In order to compare the temporal trends of attentional orienting effect in different experiments, we entered the slopes of Experiments 1–4 into a one-way ANOVA (Fig. 5). A significant effect was obtained, $F(3, 92) = 4.494$, $p = 0.005$, $\eta_p^2 = 0.128$, and post-hoc pairwise comparison (LSD Method) suggested that the mean slope in Experiment 1 was significantly larger than that in Experiment 2 ($p = 0.005$), Experiment 3 ($p = 0.003$), and Experiment 4 ($p = 0.003$). No other significant pairwise differences between experiments were found ($ps > 0.8$). These lines of evidence demonstrated that only in Experiment 1 participants exhibited increasing attentional effects as the learning phase proceeded, which echoed the results revealed by the comparison of normalized attentional orienting effect between the pre-test and post-test phases, and together highlighted the distinct facilitation effect of social context created by the concurrent presence of a partner who responded faster in the congruent condition than the participant on gaze cuing effect.

3.3. Cognitive mechanisms underlying the enhancement of attentional orienting effect

To further explore the cognitive mechanisms underlying the

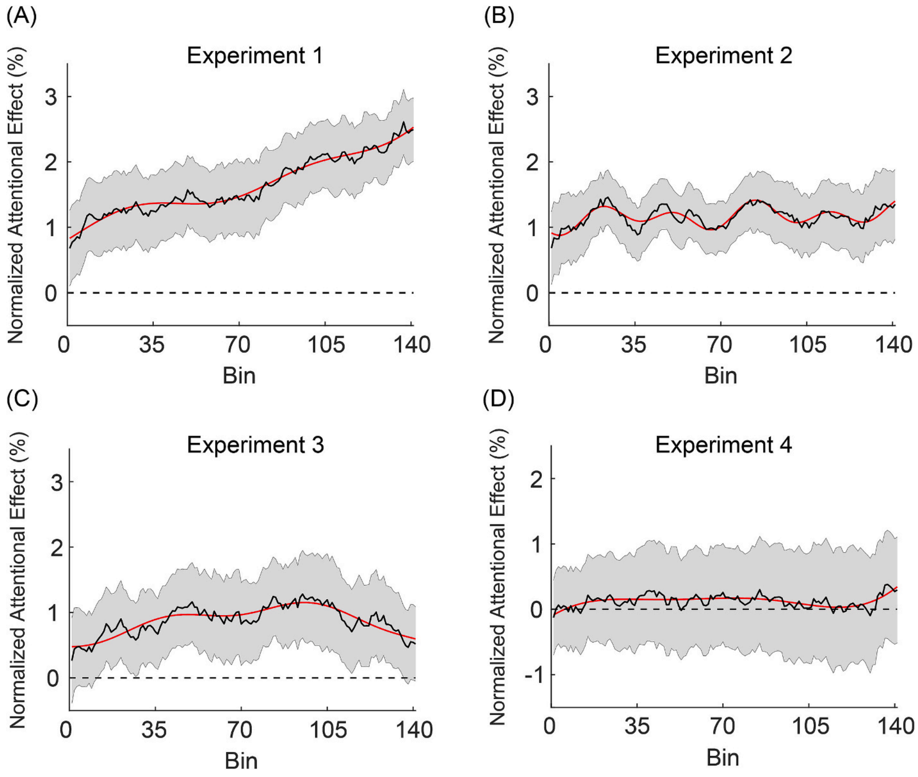

Fig. 4. The temporal dynamics of the normalized attentional effect across participants in Experiments 1–4, corresponding to panels (A)-(D), respectively. In each panel, the observed attentional effect over trials was plotted in black, and the fitted curve was plotted in red. The shaded areas represent standard errors. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

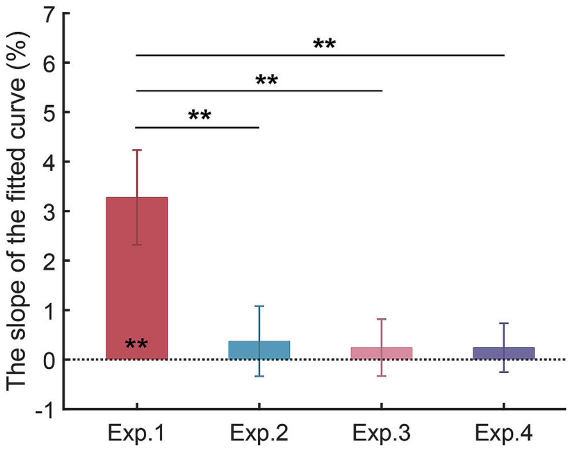

Fig. 5. The mean slopes of the curves fitted in Experiments 1–4. Only the mean slope of Experiment 1 was significantly different from zero, in sharp contrast with the mean slopes of Experiments 2–4. Error bars indicate standard errors. $^{**}p < 0.01$.

enhancement of the attentional orienting effect, we applied DDM analysis to decompose attentional orienting effect into distinct cognitive processes. Specifically, we considered two potential processes that could plausibly clarify the change of attentional orienting effect: 1) the drift rate v, which reflects the quality and efficiency of information processing, and 2) the non-decision time t, which occurs before (e.g., stimulus encoding) and after (e.g., motor execution) a probe decision is made. In accounting for cuing effect, drift rate v reflects a sustained allocation of information processing resources to the gazed-at location, implying that the target located at the cued location are processed more efficiently than those at the non-cued location (Alister et al., 2024; Zhang, Ye, et al., 2023). Non-decision time t represents the time individuals take to initially orient attention to the cued location, with additional time required to reorient attention to the target if the target appears at the non-cued location, resulting in the delayed commence of target processing in the incongruent trials compared to the congruent trials (Alister et al., 2024; Price et al., 2019; Zhang, Ye, et al., 2023). We fitted the cue-target congruency effects on drift rate (β_{v1}) and non-decision time (β_{t1}) in the pre-test and post-test phases respectively, and then calculated $\Delta\beta_{v1}$ and $\Delta\beta_{t1}$ to represent their change.

In Experiment 1, DDM obtained a positive $\Delta\beta_{v1}$ ($M \pm SD = 0.250 \pm$

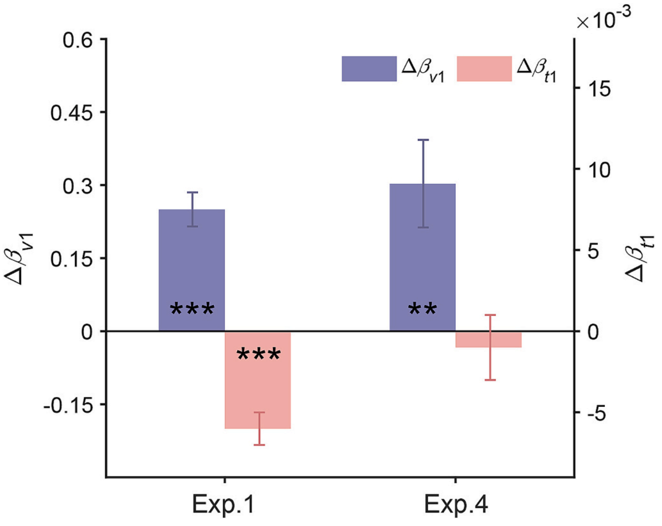

Fig. 6. The change of cue-target congruency effects on drift rate ($\Delta\beta_{v1}$) and non-decision time ($\Delta\beta_{t1}$) in Experiment 1 and Experiment 4. Error bars indicate standard errors. $^{**}p < 0.01$; $^{***}p < 0.001$.

0.174, $t(23) = 7.055$, $p < 0.001$, cohen's $d = 1.440$, 95 % CI for mean difference = [0.177, 0.323]) and a negative $\Delta\beta_{t1}$ ($M \pm SD = -0.006 \pm 0.003$, $t(23) = 8.202$, $p < 0.001$, cohen's $d = 1.674$, 95 % CI for mean difference = [0.004, 0.007]), as shown in Fig. 6. These results suggested that the partner's relative response speed advantage in the congruent condition enhanced (1) the attentional orienting processes to the gazed-at location as compared to the non-gazed-at location, reflected by $\Delta\beta_{t1}$, and (2) the boost in information processing resources allocated to the gazed-at location as compared to the non-gazed-at location, reflected by $\Delta\beta_{v1}$. Both processes contributed to faster responses under the congruent condition compared with the incongruent condition, resulting in a significant enhancement in the magnitude of the gaze cuing effect.

Apart from Experiment 1, DDM analysis was also applied to Experiment 4, where the gaze cues were replaced with arrow cues and no modulatory effect of social context was found (though a seemingly increasing trend). The average $\Delta\beta_{v1}$ was positive, $M \pm SD = 0.303 \pm 0.440$, $t(23) = 3.369$, $p = 0.003$, cohen's $d = 0.688$, 95 % CI for mean difference = [0.117, 0.488]. This result was similar with Experiment 1, suggesting that learning with a concurrent interactive partner who responded faster to the arrow-cued hemifield enhanced the sustained boost in information processing resources at the arrow-cued location as compared to the non-arrow-cued location. However, the initial attentional orienting process was unchanged as reflected by the $\Delta\beta_{t1}$ which was not statistically different from 0, $M \pm SD = -0.001 \pm 0.009$, $t(23) = 0.382$, $p = 0.706$, cohen's $d = 0.078$, 95 % CI for mean difference = [−0.005, −0.003]. Considering that all aspects in Experiment 4 were identical to Experiment 1 except for the cue type, it's reasonable to infer that $\Delta\beta_{t1}$ only tunes to gaze cuing effect. As a result, the initial attentional orienting process (reflected by $\Delta\beta_{t1}$) serves as a main contributor in accounting for the divergent effects obtained with social and non-social cues in above behavioral analyses.

To sum up, DDM illustrated that the enhancement of gaze cuing effect in the context of dyadic learning (Experiment 1) is fundamentally supported by both the initial attentional orienting process and the sustained allocation of information processing resources. For Experiment 4, the alteration in one process alone seemed insufficient to provoke a noticeable change in the magnitude of arrow-mediated non-social attentional effect, indicating that a significant modulation relies on the co-contribution from both the attentional orienting and sustained information processing allocation processes.

4. Discussion

Being social creatures, humans are endowed with the ability to direct attention according to social cues (Farroni et al., 2004; Hood et al., 1998; Wang et al., 2020). Such a social attention ability has been one of the central focuses of research in the past decades. Building on previous research using single-participant measure, the current research endeavored to advance understanding by examining the impact of the presence of a concurrent interactive partner (i.e., social context) as well as the specific attributes of the partner's performance on such a special form of attention. In this study, pairs of participants underwent a gaze-cuing task simultaneously, during which they received instant, trial-by-trial feedback regarding who made the faster response. We found that a concurrent interactive partner who responded faster in the congruent condition than the participant increased the participant' magnitude of gaze cuing effect, as reflected by the direct comparison between the pre- and post-test phases as well as the temporal trend during the dyadic learning phase. This enhancement was neither due to confounding factors such as arousal level and overall performance difference, nor because participants implicitly learned from a certain structure of feedback. Instead, as suggested by the drift-diffusion model analysis, social context created by the presence of a concurrent interactive partner who responded faster in the congruent condition than the participant enhanced the initial attentional orienting process and the sustained allocation of information processing resources to the gazed-at location. These two processes worked together and contributed to the stronger gaze cuing effect. Importantly, such an enhancement effect from the certain social context on attentional orienting was specific to socially gaze cuing effect and cannot be extended to non-social arrow cues, mainly because the initial orienting process remained unchanged after dyadic learning in the arrow-cuing task as indicated by drift-diffusion model. Taken together, our research reports a specific modulation on the gaze-mediated attentional orienting effect, providing compelling evidence that social attentional orienting is malleable and highlighting the significant impact of dyadic learning in shaping social attention ability.

Social context created by the concurrent presence of others has been found powerful in shaping human cognition and behavior as suggested in many aspects (e.g., Kampis & Southgate, 2020; Markus, 1978; Schwenke et al., 2022; Zhang, Bi, et al., 2023). The current study is in line with previous literature on this point with novel evidence, as we find a facilitation of specific social context (i.e., the partner responded faster to the gaze-cued hemifield) on a special form of attention, i.e., social attentional orienting. It is a key part of human cognition, and this exquisite attentional ability helps people to learn about other's inner mental state and key events occur around them (Birmingham & Kingstone, 2009; Nummenmaa & Calder, 2009; Shi et al., 2010). Despite the significance of social attention ability and the inherent ultrasocial disposition of human (Tomasello, 2014), few research has endeavored to intertwine these two concepts and investigate the potential role of social context, especially the specific attributes of the partner's performance, in shaping social attentional orienting. The current research strived to bridge this gap and demonstrated that social attention ability remains malleable in adults and can be further enhanced by a social context demonstrating the partner's relative response speed advantage in the congruent condition, although it is predominantly influenced by genetic factors (Wang et al., 2020) and shows a tendency to stabilize after emerging early in life (Liu et al., 2021; Zhao et al., 2014).

Recently, it has been shown that factors including the attributes of the cuing faces (e.g., emotional expression; Yuan et al., 2023) and the relationship between the observer and the cuing faces (e.g., familiarity; Deaner et al., 2006) are able to modulate the magnitude the gaze cuing effect (for a recent review, see Dalmaso et al., 2020). However, distinct from changing the different aspects of the cuing faces, the current study, for the first time, demonstrated that dyadic learning could alter the way the same gaze cues were utilized. Importantly, we went further by adopting drift-diffusion modeling and revealed that the facilitation in socially gaze cuing effect originated from the enhanced initial attentional orienting as well as the sustained boost of information processing resources to the gazed-at location. The insights gained from our study could be particularly valuable for interventions aimed at enhancing social attention skills. As has been suggested, social attention ability appears to underpin the development of complex social-cognitive skills (e.g., language acquisition, theory-of-mind; Baron-Cohen, 1995; Hood et al., 1998; Nuku & Bekkering, 2008) and its deficits are closely linked with socio-cognitive disorders (e.g., autistic spectrum disorder, ASD; Bruinsma et al., 2004). Therefore, our research stands at the foundation of applying the dyadic learning paradigm developed here to individuals with ASD, which may have profound clinical implications.

Notably, we observed a remarkable dissociation between social and non-social attentional orienting with regard to how social context influenced them, corroborating the perspective regarding the specificity of social attentional orienting. In the past decades, research in support of this perspective suggested social attentional orienting to be more reflexive and independent of cognitive control (Friesen et al., 2004; Ristic et al., 2007), shows faster disengagement (Wang et al., 2024) and has different neural substrates compared with non-social attentional orienting (Hietanen et al., 2006; Kingstone et al., 2000). However, other studies reported opposite findings as similar gaze cuing effect and arrow cuing effect were widely reported, especially with the standard perceptual cuing paradigm (e.g., Galfano et al., 2012; Ristic et al., 2002;

Tipples, 2002). Therefore, the specificity of social attentional orienting is equivocal and still under discussion. The current research lends support for the specificity of social attentional orienting with novel evidence, showing that social context facilitates the magnitude of social attentional orienting effect but not non-social attentional orienting effect. Moreover, insights from drift-diffusion modeling suggested that the process of initial attentional orienting could be influenced by social context in social gaze-cuing task, whereas such an effect is absent in the non-social arrow-cuing task. Given that eye gaze cues induce complex social cognitive processes beyond what is elicited by non-social symbolic arrows, their qualitative distinction might only be observed with more specific experimental procedures where high-level socio-cognitive factors are involved (Chacon-Candia et al., 2023). In this sense, the current research, by introducing a social context created by the presence of the partners, also contributes a novel paradigm which will provide insights regarding the qualitative difference between social and non-social cues.

What is the potential neural basis underlying the observed facilitation in gaze cuing effect? A recent study that adopted a similar dyadic learning paradigm may provide some hints. It has been suggested that the facilitation in orientation discrimination after dyadic learning was likely underpinned by enhanced functional links between social cognition areas (e.g., dorsolateral prefrontal cortex, dlPFC) and the early visual cortex, the area responsible for orientation representation (Zhang, Bi, et al., 2023). In a similar manner, the dyadic learning for a gaze-cuing task in the current research is likely to be supported by the functional interplays between social cognition areas (i.e., dlPFC) and the social attention areas, especially those areas implicated in gaze-mediated social attentional effect but not arrow-mediated non-social attentional effect, such as the temporoparietal junction (TPJ) and the posterior superior temporal sulcus (pSTS) (Salera et al., 2023). Importantly, all these brain sites are the core regions of “social brain” network that stands at the foundation of social cognition (Adolphs, 2009; Blakemore, 2008; Li et al., 2018; Wang & Jiang, 2023), suggesting their intimate connections. Besides, it has been shown that dysfunction of the dlPFC-STS network may underlie the abnormal social-cognitive functioning (Shin et al., 2015). It should be noted that these nodes and connectivity are still hypothesized to be involved in the current findings. Future studies adopting neuroimaging and neuromodulation techniques are encouraged to identify the neural network dedicated to the enhancement of gaze-mediated social attentional orienting induced by dyadic learning.

To sum up, the present study reported a modulatory effect of social context on a special form of attention. A social context where a concurrent interactive partner responded faster to the gaze-at hemifield than the participant increased the participants’ magnitude of gaze cuing effect. Drift-diffusion modeling analysis implied that such a facilitation stemmed from promotion in two key processes, i.e., the initial attentional orienting process and the sustained allocation of information processing resources to the gazed-at location compared with non-gazed-at location. Furthermore, this modulatory effect couldn’t be extended to non-social arrow cues, pointing to a distinction between social and non-social attentional effects. In short, our inquiry sheds new light on the long-standing dispute on the specificity of social attentional orienting, and takes a further step in providing innovative insights into how the social environment shapes human cognitive capabilities.

Data repository

https://doi.org/10.57760/sciencedb.16711.

Open practices statement

We report how we determined the sample size, the data exclusion, all manipulations, and all measures in the study. Data were analyzed using G-power Version 3.1, JASP Version 0.18.3, and the hierarchical drift-diffusion model toolbox in Python 3. The original data and analytic codes for the current manuscript can be publicly accessible via the link: https://doi.org/10.57760/sciencedb.16711. Other materials used in our research are widely available. There is not a preregistration for the current study.

CRediT authorship contribution statement

Shujia Zhang: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation. **Bin Zhan:** Writing – review & editing, Methodology, Formal analysis. **Li Wang:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Funding acquisition. **Yi Jiang:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

All authors have no competing interests to declare, and approved the final manuscript for submission.

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Data availability

Original data and analytic codes can be publicly accessible via the link: https://doi.org/10.57760/sciencedb.16711.

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