Affective priming enhances gaze cueing effect

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Abstract

Other's gaze direction triggers a reflexive shift of attention known as the gaze cueing effect. Fearful facial expressions are further reported to enhance the gaze cueing effect, but it remains unclear whether this facilitative effect is specific to gaze cues or the result of more general increase in attentional resources due to affective arousal.

We examined the effects of affective priming on the cueing effects of gaze and arrow stimuli in the Posner cueing task. Participants were primed with two types of briefly presented affective stimuli (neutral, threatening), and the target location was cued either by an arrow or a gaze cue in a neutral face. Gaze cues were preceded by the same face with its eyes closed or directed to the viewer. Study 1 (n = 26) assessed the cueing effect using manual key press, and Study 2 (n = 30) employed gaze-contingent eye tracking techniques to assess the cueing effect using time to first fixate the cued target location. Both studies found that threatening priming significantly enhanced the cueing effects of eye gaze but not arrow stimuli. The results therefore suggest that affective priming does not facilitate general attentional orienting, but the facilitation is more specific to social cues such as eye gaze.

Key words: Gaze cueing; Eye contact; Affective priming; Posner cueing task

Public significance statement

Gaze cueing has been one of the major topics in experimental psychology. However, only a limited number of studies have been reported on the affective mechanisms which could influence this social phenomenon. Our empirical studies provide a convincing case that affective priming selectively facilitates attentional orienting to social cues such as eye gaze, contributing theoretical advances of researches in social attention and cognition.

Introduction

Direction of eye gaze is a crucial signal for human social interaction and communication, and can be used to infer mental states such as attention, perception, and intention (Frith & Frith, 2007). Several studies have found that humans shift their attention in response to another person’s gaze direction, even when eye gaze direction is not informative or when participants were instructed to ignore or attend to the opposite direction of eye gaze (Driver et al., 1999; Friesen & Kingstone, 1998, 2003; Friesen et al., 2004; Hietanen, 1999; Kingstone et al., 2000; Ristic et al., 2002). This demonstrates that the shift of attention toward the direction of another person's gaze (i.e., the gaze cueing effect) may be reflexive.

As Frischen et al. (2007) summarised, previous studies have reported that facial cues, such as facial expressions depicted in the stimuli, can modulate the gaze cueing effect in humans. For instance, compared to neutral faces, the gaze cueing effect was larger for fearful but not happy faces suggesting fearful facial expressions can enhance attentional orienting in response to eye gaze (Tipples, 2006; Mathews et al., 2003). Pecchinenda et al. (2008) examined gaze cueing effects for disgusted, fearful, happy, and neutral faces. They showed that negative facial expressions (disgusted and fearful) have stronger cueing effects than happy or neutral faces when participants performed/engaged in affective judgments during the task. Kuhn and Tipples (2011) found identical levels of cueing effects between fearful and happy faces when searching for a pleasant target. When searching for a threatening target, the gaze cueing effect was stronger for fearful faces than happy faces.

Thus, it was suggested that contextual factors such as the target item affect the influence of facial expressions on gaze cueing effects. From a theoretical perspective, Mathews et al. (2003) argued that an enhanced gaze cueing effect followed by a presentation of fearful expression may provide a significant advantage to an individual. Specifically, the combination of averted gaze and a fearful facial expression may facilitate orienting to the source of a potential threat, which requires immediate detection for one's safety.

It is widely known that animals automatically respond to a threatening stimulus (e.g., fight or flight response; Roelofs, 2017). Aston-Jones et al. (1999) proposed that animals tend to be more responsive and sensitive to changes in external stimuli, with high levels of arousal in threatening situations. Relatedly, it has been proposed that the attentional state can be regulated by changes in physiological arousal (Reynolds et al., 2013). For instance, heart rate response, which is an index of arousal state, is associated with the participants' looking durations on the stimuli (Courage et al., 2006).

Perception of fearful faces could induce an emotional experience of fear (Hariri & Holmes, 2006; Hariri et al., 2002; Lau et al., 2009; Pine et al., 2005), as well as the perception of threat (Mogg et al., 2007; Stein et al., 2009). For example, several neuroimaging studies demonstrated that perception of fearful faces activates the amygdala, a subcortical structure that plays a vital role in experiencing fear (Felmingham et al., 2010; Hariri & Holmes, 2006; Hariri et al., 2002). Since the amygdala is involved in physiological arousal (Adolphs, 2003; Pfaff et al., 2008) and individuals experiencing a fearful emotional state exhibit high levels of arousal (Globisch et al., 1999), these studies support the view that perception of fearful expression induces heightened arousal, possibly as a result of the induced experience of fear. Thus, modulation of fearful expressions on gaze cueing may be mediated by high levels of arousal induced by the threatening stimuli.

Previous studies compared the cueing effects between gaze and arrow cues. Overall, studies often show identical levels of cueing effects (Tipples, 2002; Kuhn & Kingstone, 2009). On the other hand, some studies found increased difficulties in inhibiting gaze cues compared to arrow cues (Friesen et al., 2004), suggesting functional differences between gaze cues and arrow cues. Functional differences between gaze and arrow cues may be due to differences in social significance. It has been argued that directional cues with social significance may drive the modulation of reflexive shifts in spatial attention (Kingstone et al.,2003). Gaze cues would have more social significance than arrow cues, thus it may be difficult to inhibit gaze cues compared to arrow cues. Also, if the social significance of cues affected reflexive shifts in spatial attention, gaze cues preceded by direct gaze might have stronger cueing effects than gaze cues preceded by closed eyes. Direct gaze is one of the most important signals to engage communicative partners (Senju & Johnson, 2009). Neurophysiological studies have shown that direct gaze increased amygdala activation and physiological arousal, suggesting direct gaze modulates attentional states (Adolphs, 2009; Helminen et al. 2011). It has been argued that gaze direction preceded by direct gaze modulates neurophysiological state because other’s gaze direction will play a critical role in the detection of potential threat sources in social situations (Richeson et al., 2008). Gaze cues preceded by direct gaze would have more social significance than gaze cues preceded by closed eyes.

In previous studies on gaze cueing, the use of affective stimuli was limited to facial expressions, which makes it impossible to dissociate whether the effect is a response to the communicative signal conveyed by fearful facial expressions or due to general affective arousal induced by the fearful faces. Moreover, it is not clear whether the influence of affective stimuli is general to attentional orienting, or specific to social attention such as gaze cueing. To address this issue, we used non-facial threatening stimuli, which can elicit affective responses in both central and autonomic nervous systems consistent with fear arousal even when the stimuli are presented subliminally (Hedger et al., 2015). For example, subliminal threatening stimuli increase amygdala activity (Morris et al., 1999) and autonomic skin conductance responses (Esteves et al., 1994) even in the absence of awareness of the stimuli. The use of brief presentation of (non-facial) threatening stimuli as affective priming allows us to compare the effect of affective priming on eye gaze cueing, as well as attentional cueing for non-social directional cues such as an arrowhead.

In the current study, we introduced three types of cueing stimuli (arrow, eye gaze followed by closed eyes, or eye gaze followed by direct gaze) that were presented after a brief presentation of affective priming images (neutral or threatening). There were two conditions of cue validity with the same probability (valid, *i.e.* the target appeared in the cued location, or invalid, *i.e.* the target appeared in the direction opposite to the cue) to examine cueing effects of eye gaze and arrow stimuli in a Posner cueing task. In this task, spatial cueing facilitates stimulus detection at the cued location relative to uncued locations (Posner, 1980). There were three alternative hypotheses. Firstly, if affective priming influences general attentional orienting in the cueing task, it is predicted that affective priming will shorten response time irrespective of the validity or social nature of cue. As Aston-Jones et al. (1999) suggested, participants will be sensitive and responsive to external stimulus change and show rapid response to the target regardless of cueing direction, if they have high levels of arousal after threatening priming. Secondly, if affective priming increases attention for socially relevant cues only, it is predicted that response times will be shorter for congruent gaze cues only, and longer for incongruent gaze cues due to the increased difficulty of shifting away from the gaze cue. Finally, according to the threat-related hypothesis, only gaze cues followed by direct gaze will result in decreased response times for congruent gaze cues and increased response times for incongruent gaze cues. As Mathews et al. (2003) suggested, gaze direction of another person can be an important source of threat perception. Also, some studies have suggested that eye contact directly activates arousal systems in the brain including amygdala (Hood et al., 2003; Adolphs, 2009), and direct gaze plays a critical role in the detection of potential threat sources (Richeson et al., 2008). It was predicted that cueing effects would be larger when the gaze cue was following a period of direct gaze compared to closed eyes.

Study 1

Method

Participants

A total of 26 adults (of which 12 were female) participated in Study 1. The experiment was conducted in Japan. The mean age was 22.0 years (range: 19–29 years, Standard Deviation (SD) = 2.68 years). We estimated the required sample size as follows. The main effects of cue validity for gaze and arrow cues in a similar study by Blai et al. (2017) had effect sizes of $\eta_p^2 = .53$. To obtain a desired statistical power of .90 for main effects, with an alpha value of .05, a minimum sample size of 12 individuals was required. Another study examined affective priming effects during a Stroop task with 14 adult participants with sufficient effect sizes of affective priming ($\eta_p^2 = .95$; Hart et al., 2010). We recruited a larger number of participants than estimated from power analysis to account for possible inflation of effect sizes due to a small number of participants included in some of the previous studies. Using the effect size from the current study ($\eta_p^2 = .226$), we conducted a *post–hoc* power analysis with G*Power (Erdfelder et al., 1996). The result indicated that with the present sample we have achieved above 95% power with alpha at .05 to find three-way interaction between affective priming, type of cueing sequence, and validity. All participants had normal or corrected-to-normal vision. The experimental protocol was approved by the Research Ethics Review Board of the Department of Psychology, Kyoto University, Kyoto, Japan. The participants provided written informed consent before they participated in this study.

Apparatus

The experiment was performed using PsychoPy 1.90.1 (Peirce, 2007) on an EPSON Endeavor MR-8000 PC with a BenQ GW2470H 23.8-inch LCD monitor (60 Hz refresh rate). The participants were seated at a distance of approximately 60 cm from the monitor. Reaction times (RT) and accuracy were measured on the basis of their keyboard responses.

Stimuli

All trials were preceded by a fixation cross placed at the screen center (about 3°). For the affective priming stimuli, threatening (36 snakes, 36 spiders) and neutral stimuli (72 everyday objects) were selected from the Geneva Affective PicturE Database (GAPED) (Dan-Glauser & Scherer, 2011), which is available for use in non-commercial research projects. The GAPED has been employed previously for a subliminal visual priming study (Maureira et al., 2015), and priming stimuli were presented in the center of the screen (6°in height and 8° in width).

For the facial stimuli, we used images of two different adult female faces. In a pilot study, these female faces were perceived to be equally attractive. Gaze cues were preceded by the same face with its eyes closed (eyes closed condition) or directed (direct gaze condition) to the viewer. For the cueing stimuli, the faces were presented with eyes gazing either at the left or right side. All faces were presented in greyscale and measured approximately 16° in height and 10° in width.

The arrow cueing stimulus was preceded by a black horizontal line (arrow condition). The arrow cues were black arrows that pointed to the left or right, and measured about 3° in height and 9° in width.

The target stimulus, presented after the cueing stimuli, was an asterisk (approximately 1°) positioned on the left or right side of the screen at 15° eccentricity from the fixation point.

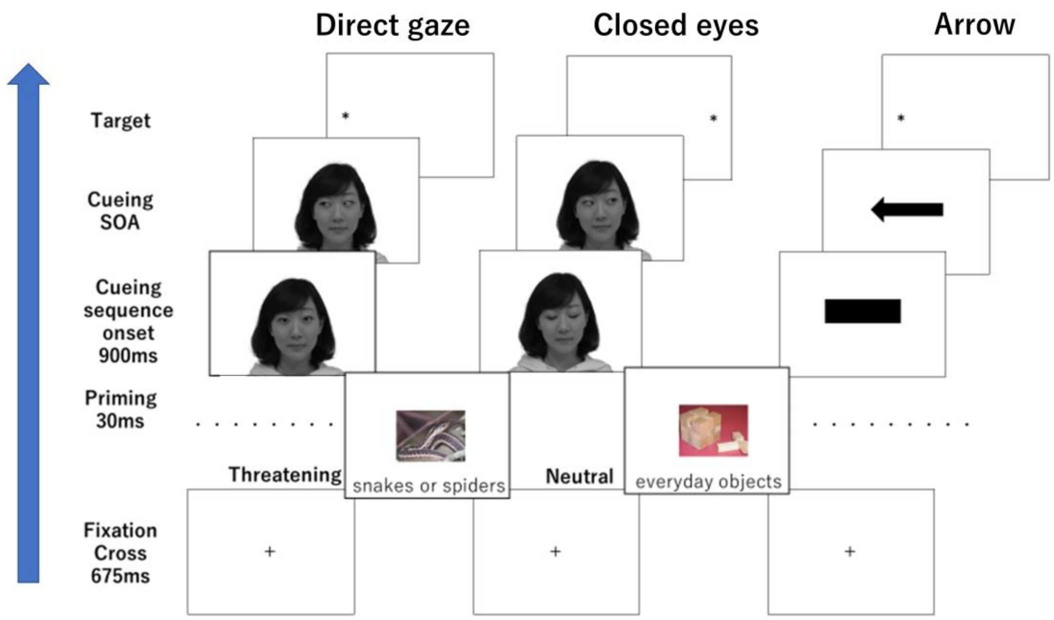

Figure 1. Sequence of events for each of the three cueing sequence conditions (*Direct gaze*, *Closed eyes*, *Arrow*) SOA: stimulus onset asynchrony

Procedure

The experiment consisted of three types of cueing sequence: arrow cueing preceded by a black horizontal line (arrow condition), gaze cueing preceded by closed eyes (closed eyes condition), and gaze cueing preceded by direct gaze (direct gaze condition). A task consisted of four practice trials (without affective priming) followed by 144 experimental trials. The number of trials was selected to retain the effects of affective priming (72 trials with affective priming and 72 trials with neutral priming), as it has been shown that repeated subliminal exposure to affective stimuli leads to habituation in 72 trials

(Dijksterhuis & Smith, 2002), which could reduce effect sizes with a larger number of trials. Three within-participant factors were fully crossed in the experiment: affective priming (threatening, neutral), type of cueing sequence (arrow, closed eyes, direct gaze), and cue validity (valid, invalid). All combinations of stimuli were presented in a random order and with equal probability.

In each trial, a fixation cross was centrally displayed for 675 ms, followed by an affective priming stimulus presented for 30 ms (see Figure 1). The presentation time was decided so that the visual stimulus cannot reach visual consciousness. In previous studies, physiological and behavioural threat responses were observed with ~30 ms presentation durations, and it has been suggested that these responses are concomitants of "unconscious" processing (Carlson et al., 2009; Morris et al., 1999). After the affective priming image (threatening or neutral), a cueing sequence (arrow, closed eyes, or direct gaze) was started and a black horizontal line, closed eyes, or direct gaze was presented for 900 ms, followed by a cueing stimulus (arrow or eye gaze) pointing either to the right or to the left, presented for either 100, 300, or 700 ms. It was emphasized during the instruction that the direction of the cueing stimuli was not relevant to the target position. The target was presented immediately after the offset of the cueing stimuli. Participants were required to press, as quickly as possible, the "Z" key when the target appeared on the left and the "M" key when the target appeared on the right. The target was displayed until the participant responded. After recording the participants' responses, they were given feedback, which was displayed for 500 ms ("O" represented a correct response, and "X" represented an incorrect response).

Data Analysis

The mean accuracy was 99.65% (SD = 0.56). There were only 12 trials with incorrect responses, so these were excluded from the analyses. Since the number of incorrect responses was so small, we did not compare accuracy across conditions. Furthermore, almost all participants responded correctly in all the trials. RTs above and below 2.5 SDs from the individual mean for each condition were excluded, which was 1.6% of all trials.

For the analysis of response time, we used individual mean response times for each condition, affective priming (threatening, neutral), type of cueing sequence (arrow, closed eyes, direct gaze), and validity (valid, invalid) as independent variables. The values for skewness and kurtosis between -2 and +2 are considered acceptable to assume normal univariate distribution (George & Mallery, 2010). The distributions of RTs for each condition showed the skewness and kurtosis within the range of normal distribution (skewness range: 0.35 ~ 1.48; kurtosis range: -.881 ~ 1.94).

Results

Figure 2 shows the mean manual RTs in each condition.

An ANOVA revealed a significant three-way interaction between affective priming, type of cueing sequence, and validity ($F(2, 50) = 3.506$, $p = .046$, $\eta_p^2 = .226$). No other interactions reached significance (validity×cueing sequence: $F(2, 50) = 1.422$, $p = .261$, $\eta_p^2 = .106$; priming×cueing sequence: $F(2, 50) = .1092$, $p = .352$, $\eta_p^2 = .083$; priming× validity: $F(2, 50) = 0.337$, $p = .567$, $\eta_p^2 = .013$). There was a significant main effect of validity ($F(1, 25) = 7.478$, $p = .011$, $\eta_p^2 = .230$; Valid mean RT = 414.28 ms vs. Invalid mean RT = 428.71 ms). No other main effects approached significance (priming: $F(1, 25) = 3.286$, $p=.082$, $\eta_p^2 = .116$; Neutral mean RT = 418.86 ms vs. Threatening mean RT = 424.13 ms; cueing sequence: $F(2, 50) = 2.200$, $p =.133$, $\eta_p^2 = .155$; Direct gaze mean RT = 421.14 ms, Closed eyes mean RT = 417.80 ms, Arrow mean RT = 425.56ms). To explore the three-way interaction more, a series of Bonferroni-corrected follow-up pairwise comparisons were performed.

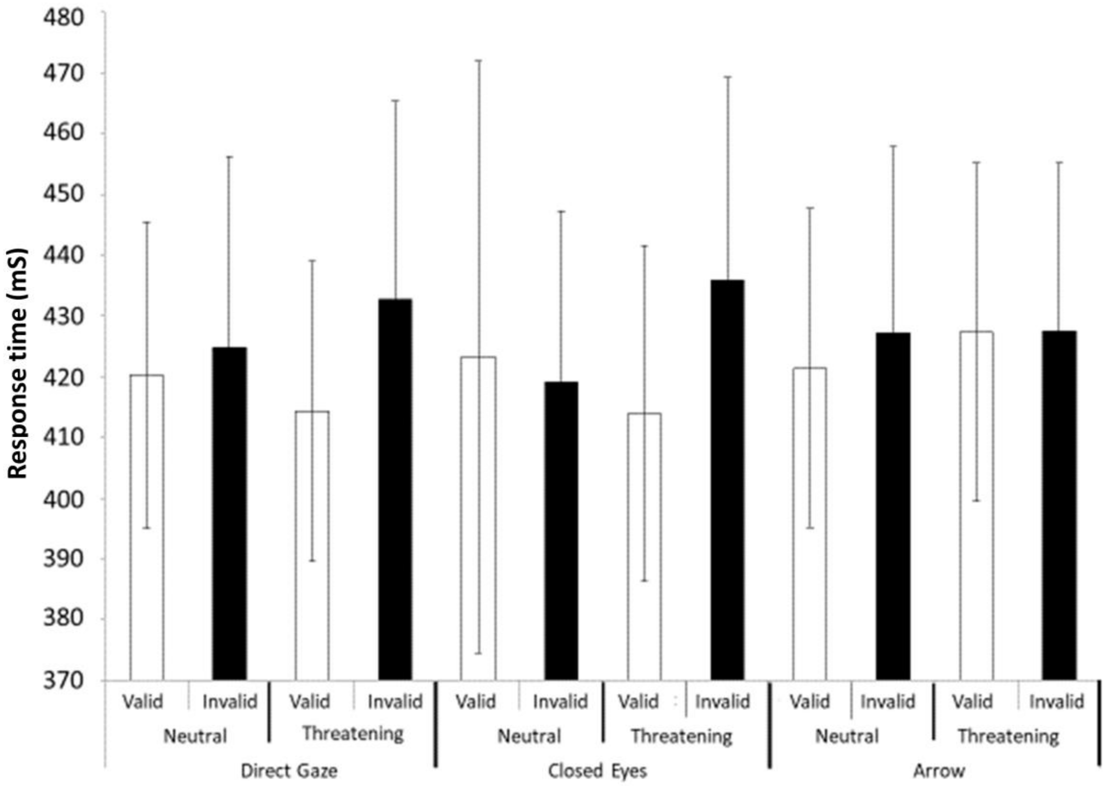

Figure 2. Mean manual RTs as a function of cueing sequence (direct gaze, closed eyes, and arrow), affective priming (neutral, threatening), and cue validity (valid, invalid). Error bars show standard deviations.

Firstly, to examine how affective priming influenced attentional orienting, we compared each priming condition across the conditions in the cueing sequence and validity factors with Bonferroni-corrected post-hoc analyses. For valid cue trials, threatening priming stimuli induced faster response times than neutral stimuli within the direct gaze condition (p = .021, η_p^2 = .196). Similarly, for invalid cue trials, threatening priming stimuli showed longer response times than neutral stimuli within the closed eyes condition (p = .012, η_p^2 = .226). There were no significant differences between neutral and threatening conditions within the arrow condition (valid: p = .106, η_p^2 = .101; invalid: p = .945, η_p^2 = .000). Thus, affective priming with threatening stimuli affected attentional orienting only in the direct gaze and closed eyes conditions.

Secondly, another series of Bonferroni-corrected post-hoc analyses examined the simple main effect of cue validity within each condition of the affective priming and cueing sequence factors. For threatening priming stimuli, direct gaze and closed eyes conditions showed significant effects of validity (i.e. cueing effect) in the closed eyes (p = .002, η_p^2 = .324) and the direct gaze (p = .010, η_p^2 = .235) conditions, but not in the arrow condition (p = .663, η_p^2 = .008). By contrast, for neutral priming stimuli, the effect of validity was not significant in any of the cueing sequence conditions (closed eyes: p = .319, η_p^2 = .040; direct gaze: p = .190, η_p^2 = .068), although it is worth noting that arrow cueing showed a marginal, but still not significant, effect (arrow: p = .095, η_p^2 = .107).

Finally, we compared RTs for each cueing sequence condition across the conditions in the affective priming and validity factors, but this did not reach significance apart from the difference with shorter RTs in the closed eyes and direct gaze than arrow conditions for valid threatening priming stimuli (closed eyes: p =.012; direct gaze: p =.011).

Comparing cueing effects

To probe the effects of affective priming on cueing effects, we calculated the mean cueing effect (mean invalid RT minus mean valid RT) for each priming and cueing sequence, and conducted an ANOVA with affective priming and type of cueing sequence. There was a significant main effect of affective priming ($F(1, 25) = 6.946$, $p = .014$, $\eta_p^2 = .217$; Neutral mean cueing effect = 6.273 ms vs. Threatening mean cueing effect = 16.513 ms). No main effect of cue approached significance ($F(1, 25) = 1.249$, $p=.296$, $\eta_p^2 = .048$). A significant interaction between affective priming and type of cueing was found ($F(2, 50) = 5.564$, $p = .007$, $\eta_p^2 = .182$).

Series of Bonferroni-corrected post-hoc analyses showed that threatening priming enhanced cueing effects than neutral priming in the closed eyes ($p = .001$, $\eta_p^2 = .346$; Neutral mean cueing effect = 0.622 ms vs. Threatening mean cueing effect = 22.791 ms) and the direct gaze ($p = .026$, $\eta_p^2 = .183$; Neutral mean cueing effect = 7.832 ms vs. Threatening mean cueing effect = 23.802 ms) conditions, but not in the arrow condition ($p = .305$, $\eta_p^2 = .042$; Neutral mean cueing effect = 10.364 ms vs. Threatening mean cueing effect = 2.947 ms). Thus, affective priming with threatening stimuli increased cueing effects only in the direct gaze and closed eyes conditions.

Discussion

This study tested whether affective priming enhances the cueing effect in general or only for gaze cues. As predicted, the results suggest that affective priming only enhances a cueing effect for gaze stimuli, but not arrow stimuli. However, we did not observe the predicted differences in gaze cueing effect between the direct gaze and closed eyes conditions. Only the direct gaze condition revealed a consistent trend for both neutral and threatening priming stimuli, with shorter response times for valid compared to invalid cue trials. This is consistent with the claim that direct gaze can modulate attentional orienting to gaze cues, though our initial prediction on the effect of direct gaze could not be fully supported.

The results in Study 1 did not show significant cueing effects after neural priming, nor did arrow cues show cueing effects in the threatening condition. Although it is unclear why the cueing effects in these conditions could not be replicated cueing effects in these conditions, particularly for arrow cues, one could argue that relatively lower saliency of cues used in the current study, compared to other studies which found significant gaze and arrow cueing effects, may have contributed to less robust cueing effects. We used the images of real faces for gaze cueing and the arrows with one arrowhead for arrow cueing. Previous studies used pictures of schematic faces and double arrowheads (Tipples, 2002; Kuhn & Benson, 2007; Kuhn & Kingstone, 2009). Another possibility was that the behavioural measurement used in this study, namely manual response time in a localization task, may not have been sensitive enough to detect cueing effects in some conditions. This issue was explored in Study 2 as described below.

Study 1 measured participants' reaction times using manual key presses to assess attentional orienting in the Posner cueing task (Posner & Cohen, 1984). In Study 2, we aimed to replicate Study 1 with an oculomotor measurement, namely the latency of overt orienting, mainly because this measurement showed larger effect sizes and better reliability in previous studies (Friesen & Kingstone, 2003; Smith & Casteau, 2019). It has been shown that emotions and mood states influence the spatiotemporal course of overt attention (Kaspar et al., 2013). We used eye tracking techniques to measure overt shifts of attention (gaze-dependent shifts in attention) in a reliable and unobtrusive manner (Kaspar et al., 2015).

Study 2

In Study 2, we examined how affective priming influences orienting time, i.e. the time to first fixations to targets (Van Rooijen et al., 2018), in a gaze-contingent Posner cueing task. We replicated the experimental paradigm used in Study 1 except for (a) the measurement of overt orienting with eye tracking techniques instead of the measurement of covert orienting with manual key press, and (b) the use of gaze-contingent stimulus control. The details of these changes are described below.

Method

Participants

A total of 30 adults (of which 22 were female) participated in Study 2. The experiment was conducted in the UK and Japan. The mean age was 22.76 years (range: 19–30 years, SD = 4.43 years). All participants had normal vision or wore contact lenses to correct their vision. The number of participants in this study is greater than the sample size in many previous studies of gaze cueing (e.g., Driver et al., 1999; Jones et al., 2009). Hietanen and Leppanen (2003) have previously shown that findings for gaze cueing in samples of this size generalize to much larger samples. Using the effect size from the current study (η_p^2 = .214), we conducted a *post-hoc* power analysis in G*Power (Erdfelder et al., 1996). The result indicated that with the present sample we have achieved above 95% power with alpha at .05 to find three-way interaction between affective priming, cueing sequence, and validity. Informed consent was obtained from participants before the study was conducted. The experimental protocol was approved by the Research Ethics Review Board of the Department of Psychology, Kyoto University, Kyoto, Japan, and Department of Psychology, Birkbeck, University of London, London, UK. The participants provided written informed consent before they participated in this study.

Apparatus

The experiment was controlled through MatLab (R2013a, MathWorks) using the Psychophysics toolbox (Version 3) on a Tobii TX300 eye tracker (Tobii Technology, Sweden; screen resolution: 1920 x 1080; refresh rate: 60Hz) at a sampling rate of 120 Hz. The participants were seated at a distance of approximately 60 cm from the monitor. Positions of left and right eye centres were calculated. Fixation was defined as gaze recorded within a 50 pixel diameter for a minimum of 50 ms. Saccadic RTs were coded as the time to first fixate target stimuli after target presentation onset (gaze RT).

Stimuli

The cueing and affective priming stimuli were the same as those of Study 1. To allow for gaze-contingent targets, we used a red circle (120-pixel diameter, 2°) as the target stimulus positioned on the left or right of the screen at approximately 13° eccentricity from the fixation point.

Procedure

It was emphasized during the instruction that the direction of the cueing stimuli was not relevant to the target position. Also, participants were asked to fixate the centre of the screen until the target appears. We excluded extremely short gaze RTs (RTs less than 100ms) for the analysis to account for instances when participants had shifted their eyes in the expected target location in advance. The presentation of the visual stimuli followed the same paradigm as Study 1. Participants were seated at a distance of approximately 60 cm from the monitor, and a five-point calibration was conducted prior to recording.

A task consisted of four practice trials (without affective priming) followed by 144 experimental trials. Three within-participant factors were fully crossed in the experiment: affective priming (threatening, neutral), type of cueing sequence (arrow, closed eyes, direct gaze), and cue validity (valid, invalid). All combinations of stimuli were presented in a random order and with equal probability.

On each trial, a fixation point was centrally displayed for 1.5s, followed by the brief presentation of an affective priming stimulus (30 ms). After the affective priming stimulus, a cueing sequence (arrow, closed eyes, or direct gaze) was started and a black horizontal line, closed eyes, or direct gaze was presented (900 ms), followed by a cueing stimulus, pointing either left or right, for either 100, 300, or 400 ms. The changes in the

SOAs from Study 1 were introduced based on Kuhn et al. (2010), who have shown that a shorter SOA of less than 600 ms has stronger cueing effects in eye tracking paradigms. Given the non-significance of cueing effects in some conditions in Study 1, we shortened the range of SOA with the aim of improving the effect sizes. A target circle then appeared immediately after the offset of the cueing stimuli, positioned on the left or right of the screen at approximately 13° eccentricity from the fixation point. Participants were instructed to look at the target circle as quickly as possible and maintain fixation until the target circle disappeared. The target was presented until the participant responded (by looking at the target circle for at least 100ms). After the participant looked at the target, the target circle disappeared and a fixation point was contingently presented in the center of the screen.

Data Analysis

Gaze RTs less than 100ms and RTs above and below 2.5 SDs from the individual mean for each condition were excluded, which was 4.3% of all trials.

For the analysis of gaze RTs, we used the individual mean time to first fixations to the target circle for each condition, affective priming (threatening, neutral), type of cueing sequence (arrow, closed eyes, direct gaze) and validity (valid, invalid) as independent variables. The distributions of RTs for each condition mostly showed the skewness and kurtosis within the range characteristic of a normal distribution (skewness range: -.01 ~ 1.59; kurtosis range: -1.13 ~ 2.03).

Results

Figure 3 shows the mean gaze RTs in each condition. An ANOVA revealed a significant three-way interaction between affective priming, cueing sequence, and validity ($F(2, 58) = 3.817$, $p = .034$, $\eta_p^2 = .214$). The interaction between priming and cue validity was also significant ($F(2, 58) = 4.697$, $p = .039$, $\eta_p^2 = .139$). No other interactions reached significance (validity × cueing sequence: $F(2, 58) = 2.938$, $p = .069$, $\eta_p^2 = .173$; priming × cueing sequence: $F(2, 58) = 0.166$, $p = .848$, $\eta_p^2 = .012$). There was a significant main effect of validity ($F(1, 29) = 23.795$, $p < .001$, $\eta_p^2 = .477$; Valid mean RT = 247.96 ms vs. Invalid mean RT = 269.73 ms) and cueing sequence ($F(2, 58) = 4.248$, $p < .024$, $\eta_p^2 = .233$; Direct gaze mean RT = 252.24 ms, Closed eyes mean RT = 259.69 ms, Arrow mean RT = 264.59 ms), but no significant main effect of priming was observed ($F(1, 29) = 0.046$, $p = .831$, $\eta_p^2 = .002$; Neutral mean RT = 259.11ms vs. Threatening mean RT = 258.58 ms).

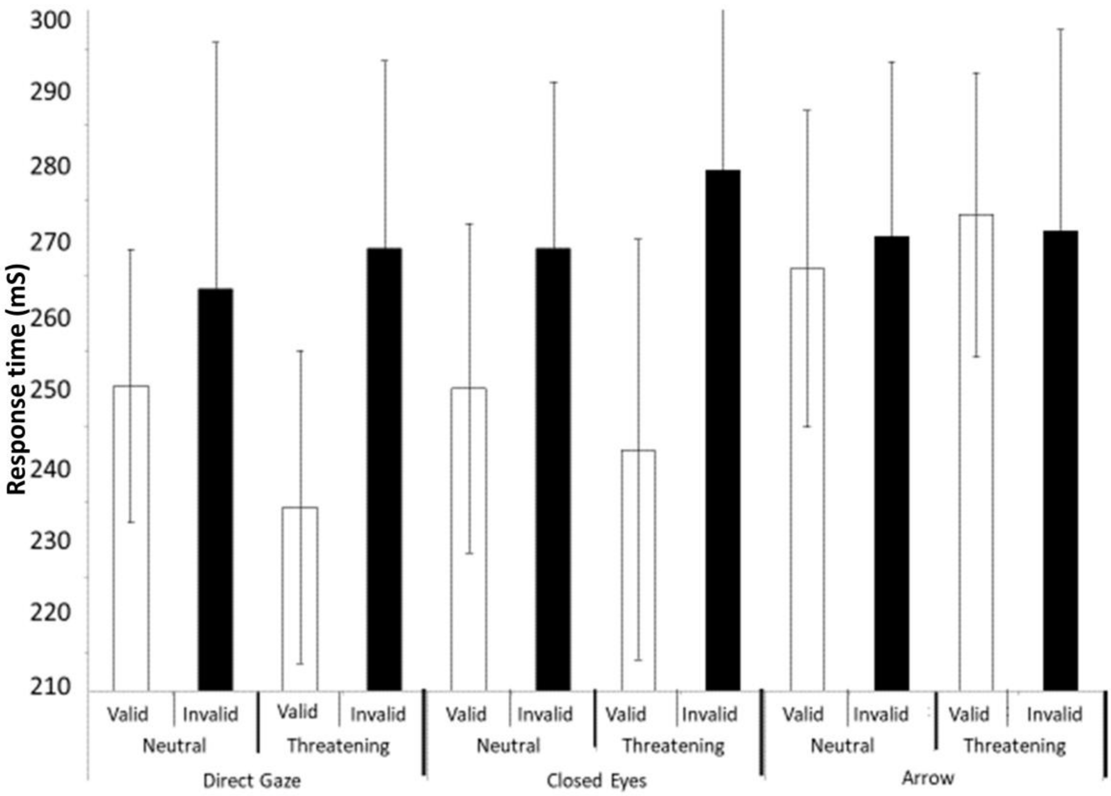

Figure 3. Mean gaze RTs as a function of cueing sequence (direct gaze, closed eyes, and arrow), affective priming (neutral, threatening), and cue validity (valid, invalid). Error bars show standard deviations.

Firstly, to examine how affective priming influences attentional orienting, we compared each priming condition across the conditions in the cueing sequence and validity factors with Bonferroni-corrected post-hoc analyses. For valid cue trials, threatening affective priming resulted in faster response times than neutral priming stimuli, which was significant only in the direct gaze condition ($p = .032$, $\eta_p^2 = .149$), but not in the closed eyes (p = .202, η_p^2 = .055) or arrow (p = .246, η_p^2 = .046) conditions. In the invalid condition, threatening affective priming resulted in slower response times than neutral priming stimuli, which was only significant in the closed eyes condition (p = .037, η_p^2 = .141) but not in the direct gaze (p = .609, η_p^2 = .009) or arrow (p = .696, η_p^2 = .005) conditions. To summarize, affective priming enhanced gaze cueing effects both in the closed eyes and direct gaze conditions. There was no influence of affective priming on arrow cueing effects.

Secondly, to clarify effects of cue validity, Bonferroni-corrected post-hoc analyses compared the effect of validity across conditions in the priming and cueing sequece factors. This revealed that threatening priming induced significant cueing effects (*i.e.* valid < invalid) in the closed eyes (p < .001, η_p^2 = .454) and direct gaze (p < .001, η_p^2 = .456) conditions, but not in the arrow condition (p = .241, η_p^2 = .046). For neutral priming, the cueing effect was significant in the closed eyes condition (p = .004, η_p^2 = .257) and arrow (p = .013, η_p^2 = .194) conditions, but there was a marginal cueing effect in the direct gaze (p = .0974, η_p^2 = .092).

Finally, we compared each cueing sequence condition across conditions of the affective priming and validity factors. A significant difference in gaze RTs was only found between the direct gaze and arrow conditions for threatening priming and valid cue trials (p

= .004).

Comparing cueing effects

To probe the effects of affective priming on cueing effects, we calculated the mean cueing effect (mean invalid RT minus mean valid RT) for each priming and cueing sequence, and conducted an ANOVA with affective priming and type of cueing sequence. There was a significant main effect of affective priming ($F(1, 29) = 8.185$, $p = .008$, $\eta_p^2 = .220$; Neutral mean cueing effect = 14.414 ms vs. Threatening mean cueing effect = 26.911 ms). No main effect of cue approached significance ($F(1, 29) = 3.183$, $p = .052$, $\eta_p^2 = .099$). A significant interaction between affective priming and type of cueing was found ($F(2, 58) = 5.230$, $p = .008$, $\eta_p^2 = .153$).

Series of Bonferroni-corrected post-hoc analyses showed that threatening priming enhanced cueing effects than neutral priming in the closed eyes ($p = .009$, $\eta_p^2 = .210$; Neutral mean cueing effect = 18.704 ms vs. Threatening mean cueing effect = 37.234 ms) and the direct gaze ($p = .009$, $\eta_p^2 = .211$; Neutral mean cueing effect = 11.758 ms vs. Threatening mean cueing effect = 36.057 ms) conditions, but not in the arrow condition ($p = .347$, $\eta_p^2 = .031$; Neutral mean cueing effect = 12.779 ms vs. Threatening mean cueing effect = 7.441 ms). Thus, affective priming with threatening stimuli increased cueing effects only in the direct gaze and closed eyes conditions.

After threatening priming, the gaze cueing effects were larger than the arrow cueing effect (Closed eyes = 37.234 vs. Arrow =7.411; p = .008, η_p^2 = 208.: Direct gaze = 36.057 vs. Arrow; p = .006, η_p^2 = 228.).

Discussion

Study 2 was conducted to assess the effects of affective priming on the gaze cueing effect by measuring time to first fixate targets using gaze-contingent eye tracking. Consistent with the results of Study 1, affective priming enhanced the effects of eye gaze cueing but not arrow cueing. Thus, we replicated the effect of affective priming on orienting to eye gaze cues, as also found in Study 1. Against predictions, however, the direct gaze condition again did not show larger cueing effects than the other conditions. The replication of the key findings reported in Study 1 supports the robustness of the present results.

In Study 2, we found significant cueing effects following neutral priming in closed eyes condition and most crucially in arrow condition, as well as a marginal cueing effect in direct gaze condition. These cueing effects after neutral priming negate a possible claim that the arrow cues used in the current study cannot elicit cueing effect in any condition, and corroborate our argument that affective priming enhanced gaze cueing effects but not arrow cueing effects.

General discussion

In Studies 1 and 2, affective threatening priming consistently enhanced the gaze cueing effect, but did not influence the attentional orienting to the direction of arrow cues. These results thus support the hypothesis that affective priming preferentially facilitates social attention. However, gaze cueing preceded by direct gaze did not elicit a larger cueing effect than the other cueing sequence conditions, and our hypothesis that direct gaze would further facilitate the gaze cueing effect could therefore not be supported.

It has been shown that the levels of cueing effects are identical for arrows and gaze both in covert and overt orienting tasks (Tipples, 2002; Kuhn & Kingstone, 2009). Consistently, we did not find significant differences in cueing effects between arrow and gaze cues after neutral priming. The identical levels of cueing effects for gaze and arrow cues have also been suggested in event-related-potentials (ERP) studies. For example, effects of validity on the P1 and N1 amplitudes have been shown for targets preceded by gaze and arrow cues (Eimer, 1997; Schuller & Rossion, 2001). Hietanen et al. (2008) have compared the ERPs triggered by the targets preceded by gaze and arrow cues, and they showed similar patterns of P1 and N1 responses for the targets preceded by gaze and arrow cues although amplitudes were different between cue types. It was suggested that gaze and arrow cues have similar effects of attention orienting on the processing of incoming visual information. Also, fMRI studies have reported overlap in brain activation during automatic orienting to gaze and arrow cues (Hietanen, et al., 2006; Sato et al., 2009). It has been suggested that the superior temporal sulcus (STS) could be involved in automatic attentional orienting towards the cued direction, regardless of the type of attention-triggering stimulus (Sato et al., 2009). Generally, gaze and arrow cues have identical levels of cueing effects on automatic attentional orienting and overlapping brain regions processing attention-triggering stimuli.

However, for the affective priming effects observed in the current study, there are several possible mechanisms which can account for the relationship between affective priming and gaze cueing effects. Firstly, it is possible that gaze cues are processed as emotional stimuli, even though it only shows a 'neutral' facial expression (Lee et al., 2008). As a result, enhanced amygdala activity, which is known to occur following affective priming, might mediate enhanced processing of gaze cues as an emotional stimulus (Adolphs et al., 2001; Anderson & Phelps, 2001; Hamann, 2001). By contrast, affective priming may not affect arrow cueing since arrows do not represent emotional stimuli.

Secondly, an enhanced response to gaze cues in the threatening priming condition may be related to the detection of a threat since the gaze direction of another person can be an important source of threat perception (Mathews et al., 2003). It might reflect the proposed differences between the strength in social relevance, given proposals that eyes are 'biological' stimuli but arrows are not (Birmingham & Kingstone, 2009). Thus, induced fearful experience through affective priming could facilitate fight or flight responses, which subsequently facilitated sensitivity to gaze cues. By contrast, arrows do not constitute such ecologically valid signals for threat detection.

We highlight that these interpretations are not mutually exclusive, and actually share the common assumption that affective priming and gaze cueing share similar neural mechanisms or serve similar functions. This position is consistent with evidence from neuropsychological findings. For instance, studies of split-brain patients have revealed that the reflexive gaze cueing effect is lateralized to the cortical mechanisms involved in face/gaze processing (Kingstone et al., 2000; Friesen & Kingstone, 2003). In addition, a split-brain patient exhibited no lateralization of reflexive orienting to arrows (Ristic et al., 2002). The neural substrates for attentional orientation to cues are considered to be different for nonbiological cues and gaze cues. Altogether, the evidence points to a possibility that emotional processing and gaze cueing share overlapping neural substrates (Adolphs, 2002), which can subserve the proposed functional overlap and the observed relationship between affective priming and gaze cueing in the current study.

Also, we acknowledge that motor preparation, as well as attentional shift, could have contributed to the cueing effect observed in the current studies. It has been argued that the direction of cues induces motor preparation to respond to the target (Brown et al., 2011). An electrophysiological study of the Posner paradigm has shown that delayed offset of motor-readiness potentials such as the late positive complex (LPC) is associated with long RTs, suggesting a longer response selection stage in conditions in which the cue and the target were spatially incompatible (Perchet & Garcia-Larrea, 2000). Thus, it would be possible that enhanced cueing effects after affective priming could include enhanced motor preparation. As the current study cannot fully dissociate the effects of affective priming between attention orienting and motor preparation, further studies with stricter control and possibly the utilization of brain imaging techniques will be required to identify the mechanisms underlying the influence of affective priming on gaze cueing effects.

We hypothesized that cueing effects would be more enhanced when the gaze cue followed a period of direct gaze than closed eyes, but results did not fully support our hypothesis. Some studies have reported larger gaze cueing effects after direct gaze than non-direct gaze (Bristow et al., 2007; Xu et al., 2018). One possibility is that direct gaze drew attention to the eye area itself, and not to the peripheral areas, thereby weakening the gaze cueing effect. For example, Senju and Hasegawa (2005) showed that, compared to averted gaze or closed eyes, response time to a peripheral target was delayed after presenting direct gaze in the center of a screen. Similarly, Conty et al. (2010) showed that the cognitive processing for stimuli in non-facial areas can be disturbed when the facial stimuli showed direct gaze. Thus, direct gaze can draw attention to the eye region, at the cost of the efficiency to process the surrounding area, under some experimental contexts. This could contribute to the observed lack of stronger cueing effects for direct gaze cuing sequence than other conditions.

We also acknowledge that we did not observe significant cueing effects for arrow stimuli in threatening priming conditions. This could be specific to the condition in our experiment, in which arrow (and gaze) cues always followed affective priming, or the specific types of arrow cues used in our study. Further studies will need to establish the robustness and generalisability of affective priming effects on the arrow cueing.

Another remained question is the difference in the way priming enhanced gaze cueing effects for direct gaze and closed eyes conditions. Affective priming decreased RTs for valid gaze cueing in direct gaze condition, while increased RTs for invalid gaze cueing in closed eyes condition. Importantly, both effects eventually lead to the enhanced cueing effects (i.e. the difference RTs between valid and invalid cues) of the gaze cue. Previous studies on cueing effects have mainly focused on the differences in RTs between valid and invalid trials (see a review, Frischen et al., 2007), and are not particularly informative to interpret the current finding. It is still possible that there are different mechanisms of affective attention preceded by direct gaze and closed eyes. A possible direction for further exploration would be to compare RTs for each SOA, which unfortunately is not feasible in the current study. As discussed above, the current study used a comparatively small number of trials per condition to avoid possible habituation, which would make it difficult to compare the difference of SOA with sufficient power. In addition, due to the small number of trials per condition, we adopted first fixation time to the target for analysis in Study 2 rather than a more narrowly defined 'saccade' which would require a stricter definition of speed and amplitude. This measurement is used in wider participant populations such as infants and young children, which could compensate for smaller trial numbers and noisier gaze data (e.g., Van Rooijen, Junge, & Kemner, 2018). However, we also acknowledge that this measurement limits our interpretation of the oculomotor or attentional mechanisms underlying the current finding. Future studies using between-subject designs, which would allow for incorporating more trials per condition without risking habituation, will help to identify priming effects on gaze cueing and clarify attentional mechanisms.

To conclude, the results of the current studies suggest that the effects of affective priming on gaze cueing may not be based on general attention/arousal system but are related to social or emotional processing. The different cueing effects of gaze and arrow cues may reflect differences in the neural substrates of attentional orientation to biological and nonbiological cues. Future research would benefit from investigating the neural substrates that underlie social attention and emotional processing, which seem to show functional overlap.

Author's contributions

MI designed the study, conducted data collection, analysed data and wrote the initial draft of the manuscript. MI and JH programmed the experimental paradigm. All authors have contributed to interpretation, critically reviewed the manuscript, approved the final version of the manuscript, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data accessibility

The data sets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Conflict of interests

Authors have no conflicts of interest.

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