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Emotional Modulation of Gaze Cueing Does Not Depend on a Global Perceptual Processing Strategy

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Research on emotional modulation of attention in gaze cueing has resulted in contradictory findings. Some studies found larger gaze cueing effects (GCEs) in response to a fearful gaze cue, whereas others did not. A recent study explained this discrepancy within a cognitive resource account, in which perceptual demands of the task promote a bias toward either a local (discrimination task) or global (localization task) processing strategy. During local processing, the integration of emotional expression with gaze direction is assumed to be impaired, whereas during global processing integration is assumed to be facilitated. In the current study, we investigated the cognitive resource account in three experiments. In Experiment 1, we manipulated task demands by adopting a detection or a localization task whilst both should allow global processing. In Experiments 2 and 3, we induced either a local or global perceptual processing strategy by presenting local or global targets (Experiment 2) or by priming local or global perception prior to the gaze cueing task (Experiment 3). Results showed faster orienting in response to a fearful face cue independent of task demands in Experiment 1. Inducing local and global processing strategies in Experiments 2 and 3 did not affect emotional modulation of the GCE. In contrast, Bayesian analyses provided evidence of absence of such an effect, demonstrating that local or global processing strategies cannot explain the mixed findings obtained in emotional modulation of gaze cueing.

Keywords: emotional gaze cueing, fearful expression, attention, local and global processing

Shifting eye gaze is an efficient way to signal an important event in nonverbal communication. From infancy on, human observers are automatically drawn to the eyes of other people and tend to automatically follow their gaze (Farroni et al., 2002). It is believed that we follow other people's gaze shifts because these may signal an important event (Frischen et al., 2007). In the lab, so-called gaze cues are used to investigate this phenomenon. In a typical gaze cueing paradigm (e.g., Driver et al., 1999; Friesen & Kingstone, 1998), gaze cues consisting of schematic or photographed faces are presented at fixation. The gaze of the face can be directed toward the observer or averted to the left or the right. Previous research consistently found that people respond faster to a target that is presented at the gazed-at location (validly cued location) than to targets at the opposite location (invalidly cued location) (McKay et al., 2021). The difference in reaction time (RT) is referred to as the GCE (Driver et al., 1999; Friesen et al., 2004, 2005; Friesen & Kingstone, 1998).

The shift of attention when observing averted eye gaze is believed to occur automatically (Driver et al., 1999; Friesen & Kingstone, 1998; Langton & Bruce, 1999; but see Tipples, 2002), presumably because a gaze shift may signal an important event (Frischen et al., 2007). Within an evolutionary account, this nonverbal way of communication may have evolved because it was beneficial for survival (Emery, 2000). In this context, it is reasonable to assume that an averted gaze with a fearful expression might exacerbate the observer's tendency to follow the gaze in order to rapidly detect a potential threat. Consequently, the GCE should especially be larger with a fearful relative to a neutral gaze cue. A recent meta-analysis showed that indeed there is consistent evidence for a stronger GCE when the gaze has a fearful relative to a neutral or happy expression (McKay et al., 2021). However, individual studies that examined emotional modulation of the GCE yielded inconsistent results (see for review, Dalmaso et al., 2020). Multiple gaze cueing studies with a fearful gaze cue and a neutral target showed no modulation of the GCE (e.g., Coy et al, 2019; Galfano et al., 2011; Graham et al., 2010, Experiments 1–3; Hietanen & Leppänen, 2003; Holmes et al., 2010), whereas other studies did (e.g., Carlson, 2016; Graham et al., 2010, Experiment 5; Lassalle & Itier, 2013, 2015; Matsunaka & Hiraki, 2019, with eye movements; McCrackin & Itier, 2018, 2019; Neath et al., 2013; Putman et al., 2006; Tipples, 2006). In addition, several studies showed that the effect was mediated by other factors. For example, a larger GCE for a fearful gaze cue was found only when the emotional valence of the target was congruent with the fearful expression (Bayliss et al., 2010; Friesen et al., 2011; Kuhn & Tipples, 2011; Pecchinenda et al., 2008), indicating the relevance of emotional context in emotional gaze cueing. Other studies found that only highly anxious individuals showed a larger GCE in response to a fearful gaze cue (Fox et al., 2007; Mathews et al., 2003; Putman et al., 2006; Tipples, 2006; but see McCrackin & Itier, 2019). Although

All (raw and processed) data have been made publicly available at the OSF Repository and can be accessed at https://osf.io/wqfc6/?view_only=ddd26573be2945a9a18e0cfccbc32ce9 (Mulckhuyse, 2022).

Manon Mulckhuyse served as lead for conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, validation, visualization, writing—original draft, writing—review and editing.

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context and emotional state might play an important role in emotional modulation of attention, they are not the only factors that can explain the inconsistencies found in emotional gaze cueing so far.

Several studies have tried to provide clarity by tweaking different task parameters, such as the gaze cue-target Stimulus Onset Asynchrony (SOA) allowing more time to integrate facial expression and gaze (e.g., Graham et al., 2010), or the ecological validity of the gaze stimulus, such as pictures of faces versus schematic faces (Hietanen, & Leppänen, 2003) and static versus dynamic gaze (Lassalle & Itier, 2015). However, none of these parameters has been proven to be decisive. For instance, whilst Graham et al. (2010) found emotional modulation of the GCE only with an SOA of more than 475 ms, McCrackin and Itier (2018) found a stable larger GCE for fearful relative to neutral gaze cueing with SOAs ranging from 300 to 700 ms.

Recently, a possible explanation for the inconsistent findings has been put forward by Chen et al. (2021). They argued that task demands may influence whether an emotional expression modulates the cueing effect. In their study, they compared a more cognitive demanding task to a less cognitive demanding task. That is a discrimination versus a localization task. Indeed, most studies that found an effect of fearful expressions on gaze cueing used a localization task (Carlson, 2016; Lassalle & Itier, 2013, 2015; McCrackin & Itier, 2018, 2019; Matsunaka & Hiraki, 2019; Neath et al., 2013), whereas most studies that used a discrimination task did not (Coy et al., 2019; Holmes et al., 2010; Pecchinenda et al., 2008, Experiment 2). By comparing the two different tasks directly, Chen et al. (2021) showed that fear modulated the GCE only when a localization response was required. They explained their findings by proposing that participants may adopt a local processing strategy for a discrimination task and a global processing strategy for a localization task. That is, in the discrimination task increased cognitive resources are needed for the more perceptual demanding task of discriminating the target, whereas less cognitive recourses are needed for localizing. Consequently, in the discrimination task, local processing precludes the integration of emotional expression and gaze direction and therefore does not affect attentional orienting, whereas in the localization task, global processing allows for integration of expression and gaze direction and hence affects spatial orienting. The integration of emotional expression and gaze direction is crucial in order to correctly interpret the meaning of this signal. For example, an averted fearful gaze signals a possible threat in the environment demanding a rapid action response, whereas a direct fearful gaze conveys a more ambiguous signal and may require a different response (Adams et al., 2012).

If integration is impaired due to the high task demands in a discrimination task, a detection task, which imposes comparable low cognitive demands as a localization task, should yield similar results as a localization task. However, previous studies using a detection task did not find an effect of emotional gaze cues either (Graham et al., 2010, Experiments 1 and 2; Hietanen & Leppänen, 2003).

In the current study, we tested the cognitive resources account in three different experiments. In the first experiment, we adopted a localization and detection task as a within-subjects' manipulation to directly compare the effects of a fearful gaze cue on attention in two cognitively low-demanding tasks. In the second experiment, we adopted a discrimination task in which local or global targets had to be discriminated thereby inducing either a local or global processing strategy. In the third experiment, we primed local or global perception prior to the gaze cueing task.

As described above, in the localization as well as the detection task, task demands are low and therefore, we expect to find a stronger GCE in the localization as well as the detection task for the fearful relative to the neutral gaze cue.

Transparency and Openness

For all experiments, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow JARS (Kazak, 2018). All data, analysis code, and research materials are available at Open Science Framework (OSF) Repository (https://osf.io/wqfc6/?view_only=ddd26573be2945a9a18e0cfccbc32ce9). Data were analyzed using JASP Version 0.16.4 (JASP Team, 2022). This study's design and its analysis were not preregistered.

Experiment 1

Method

Participants

We used G*Power 3 software to calculate the sample size (Faul et al., 2007). Given a medium effect size of $\eta^2 = 0.06$ and adequate power of $1 - \beta > 0.95$, at least 35 participants were required. Seventy-six undergraduate students signed up for the online study to fulfill course credits. However, data of 10 participants were excluded because of technical errors or because no response was recorded in 50% or more of the trials. In addition, a two-tailed binomial test for each participant revealed that 25 of the remaining 66 participants scored not significantly above chance level ($p > .01$) on the catch trials ≥25% incorrect responses in the detection task. These participants were excluded from analyses, resulting in datasets of 41 participants (4 males, 37 females, ages between 19 and 22) that were included in the analyses. All participants provided informed consent before participation and were free to terminate the experiment at any time. Participants had normal or corrected-to-normal vision. The study was approved by the local ethics committee (Leiden University, Institute of Psychological Research; CEP19-1211/579).

Apparatus and Stimuli

The experiment was programmed in OpenSesame 3.3.5 (Mathôt et al., 2012) and run via OSWeb with a resolution of 1,024 × 768 px on the JATOS server of Leiden University. The gaze cues consisted of black and white pictures of four individuals (two female) expressing fearful or neutral expressions, taken from the MacBrain Face Stimulus Set (Tottenham et al., 2009: models #02, 03, 24, and 27). Averted gaze was manipulated for each picture to produce leftward and rightward gaze (with an eye displacement of 20 pixels). An elliptical mask was applied to each picture so hair, ear, and shoulders were not visible. The faces (224 × 160 px) were presented at the center of the screen on a white background. In the localization task as well as the detection task, the target consisted of a black asterisk (16 × 16 px). Both targets were presented 300 px left or right of fixation.

Design and Procedure

The experiment consisted of eight blocks of 32 experimental trials each. In the detection task, in each block six catch trials were added in which no target was presented. In total, there were 24 catch trials. Participants either started with the localization or with the detection task for four blocks in a row. The task was counterbalanced between subjects. Emotional expression and cue validity were counterbalanced but presented randomly within a block of trials. The target could appear with equal probability on the left (50%) or the right (50%) of fixation. The gaze was 50% valid.

Participants were asked to sign informed consent by pressing "Y" on the keyboard in order to continue with the experiment. Clear instructions about the task were presented on the screen. Participants were asked to keep their eyes fixated on the center of the screen and to respond as accurately and fast as possible. Each task started with a practice block of 16 trials in which only neutral gaze cues were presented. After each block, participants received feedback about their performance.

Each trial started with a fixation dot presented for 600 ms at the center of the screen (see Figure 1). A neutral gaze cue with the eyes directed at the observer was presented for 500 ms with an additional jitter of 0–100 ms. Subsequently, the gaze changed to averted for 200 ms after which the emotional expression changed from neutral to fearful or stayed neutral for 300 ms. Simultaneously with the offset of the face, the target was presented either to the left or to the right side of the gaze cue.

In the localization task, participants had to respond by pressing the "z" key on the keyboard with their left index finger if the target was presented on the left, and the "m" key with their right index finger if the target was presented on the right. In the detection task, participants had to respond with their dominant index finger by pressing the spacebar if the target was presented and to withhold their response if no target was presented. The target remained on the screen until the participant's response or for a maximum of 2,500 ms before the next trial began. The fixation dot turned red for 600 ms after an incorrect response.

Results

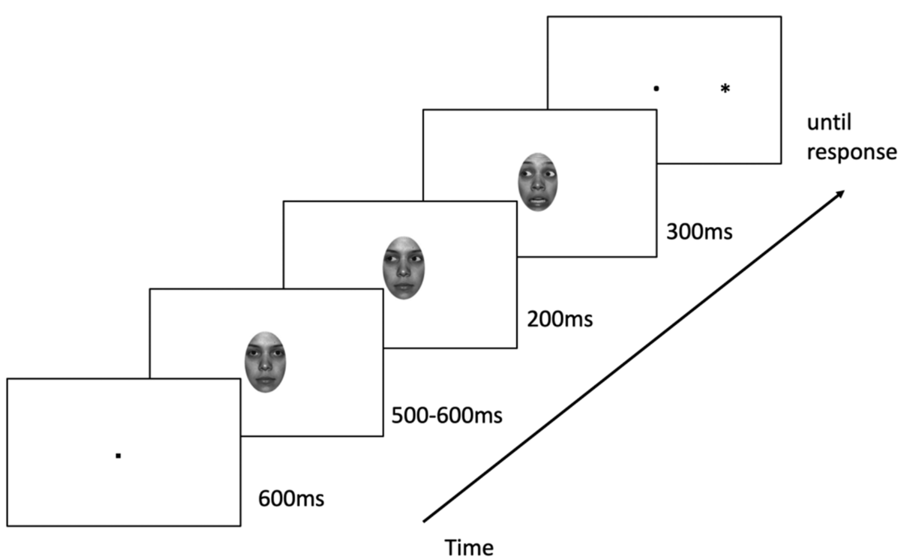
Data Analyses

Responses below 100 ms were considered anticipatory responses and excluded from analysis (<1%). In addition, response times on correct trials lower or above 2.5 *SD* of the mean for each task separately (localization task: 4%; detection task: 2%) were excluded from analyses. The mean error rate on the catch trials was 11.1%, $SD = 6.3$. Mean RT and accuracy were analyzed separately with a repeated measures analysis of variance (ANOVA) with the within-subject factors task (detection and localization), emotion (fearful and neutral), and cue validity (valid and invalid). The significant interaction in RT between emotion and cue validity was followed up by *t*-tests between fearful and neutral in the valid and invalid trials averaged across tasks.

Reaction Time

The mean RTs and the GCE are reported in Table 1. A repeated measures ANOVA on RT with task (detection and localization), emotional expression (neutral and fearful), and cue validity (valid and invalid) showed a main effect of task, $F(1, 40) = 15.847$, $p < .01$, $\eta^2 = 0.28$, due to faster responses in the localization ($M = 354.79$ ms, $SE = 5.82$ ms) than the detection task ($M = 375.06$ ms, $SE = 6.46$ ms), and a main effect of cue validity, $F(1, 40) = 113.119$, $p < .01$, $\eta^2 = 0.74$, due to faster responses on the valid trials ($M = 355.39$, $SE = 5.43$) than the invalid trials ($M = 374.46$, $SE = 5.9$). In addition, there was a significant interaction between cue

Figure 1
From Bottom to Top, Succession of Events in a Trial With a Fearful Invalid Gaze Cue



Note. The face picture is taken from the NimStim database (Tottenham et al., 2009) with permission for publication.

Table 1
Mean Reaction Times, Standard Errors, and the Gaze Cueing Effect (GCE) in Milliseconds of Experiments 1, 2, and 3

Experiment 1	Localization task		Detection task	
	Neutral	Fear	Neutral	Fear
Valid	348.06 (5.77)	340.50 (5.43)	370.98 (6.44)	362.03 (7.34)
Invalid	364.09 (6.59)	366.51 (6.57)	384.15 (6.21)	383.09 (7)
GCE	16.03 (2.87)	26.02 (3.09)	13.17 (3.12)	21.06 (2.3)
Experiment 2	Global target		Local target	
	Neutral	Fear	Neutral	Fear
Valid	512.43 (8.78)	510.89 (8.09)	588.4 (9.07)	586.99 (9.4)
Invalid	527.18 (8.91)	528.573 (8.73)	614.72 (8.96)	618.26 (9.47)
GCE	14.75 (3.11)	17.68 (3.45)	26.32 (4.9)	31.26 (4.65)
Experiment 3	Global prime Fear	Local prime Fear		
Valid	445.35 (11.81)	427.37 (10.59)		
Invalid	477.01 (11.2)	463.99 (10.47)		
GCE	31.66 (4.29)	36.62 (3.51)		

Note. GCE =gaze cueing effect.

validity and emotion, $F(1, 40) = 11.851$, $p < .01$, $\eta^2 = 0.23$. The other effects were not significant (all $ps > .06$; Figure 2).

To follow up on the interaction between cue validity and emotional expression, we collapsed the data across tasks (see Figure 3) and performed planned comparisons between the fearful valid cue ($M = 351.26$, $SE = 5.9$) and the neutral valid cue ($M = 359.52$, $SE = 5.3$), which was significant $t(40) = 3.119$, $p < .01$, $d = .49$, whereas there was no difference in RTs between the invalid fearful cue ($M = 374.8$, $SE = 6.2$) and the invalid neutral cue ($M = 374.12$, $SE = 5.8$).

Accuracy

Accuracy was at ceiling for the detection ($M = 99\%$, $SE = 0.01$) and the localization task ($M = 100\%$, $SE = 0.01$). A repeated measures ANOVA on accuracy with task (detection and localization), emotional expression (neutral and fearful), and cue validity (valid and invalid) showed no main effects nor interaction effects (all $ps > .09$).

Discussion

Across tasks, RTs were shorter at the validly cued location in response to the fearful relative to the neutral gaze cue. At the invalidly cued location, there were no differences. This is consistent with previous research that mainly showed an effect of a fearful expression at the valid rather than the invalid location for manual responses (Carlson, 2016; Lassalle & Itier, 2013, 2015; McCrackin & Itier, 2018, 2019; Neath et al., 2013) as well as for eye movements (Matsunaka & Hiraki, 2019). Within an evolutionary account, it makes sense that emotional expressions and averted gaze mostly affect orienting, since rapid detection of a potential threat is crucial in survival. Sustaining spatial attention to a possible threatening location may be of less importance after the location has been inspected.

More importantly, there was no three-way interaction with task even though RTs were higher in the detection than in the localization task. Higher RTs could indicate that the detection task required more cognitive load, most probably due to the addition of catch trials in which participants had to withhold a response. Indeed, it has been shown with neutral gaze cues that the GCE is typically larger for a localization task than a detection task (McKay et al., 2021). However, the higher cognitive load of the detection task did not diminish orienting in response to a fearful gaze cue. Therefore, our results are consistent with the theory that due to low perceptual demands of the task, independent of response mode, enough resources are available for the integration of emotional expression with gaze direction (Chen et al., 2021). However, whether this is due to global perceptual processing is unclear. Therefore, in Experiment 2, we included targets that had to be perceived either at the global or the local level (Navon, 1977).

Discrimination of local targets requires higher perceptual demands but in addition, induces a local processing strategy. In contrast, discrimination of global targets requires less perceptual demands and induces a global processing strategy (Navon, 2003). Therefore, we expected to find a larger cueing effect in response to the fearful relative to the neutral gaze cue when the global target had to be discriminated and no emotional modulation of the GCE when the local target had to be discriminated.

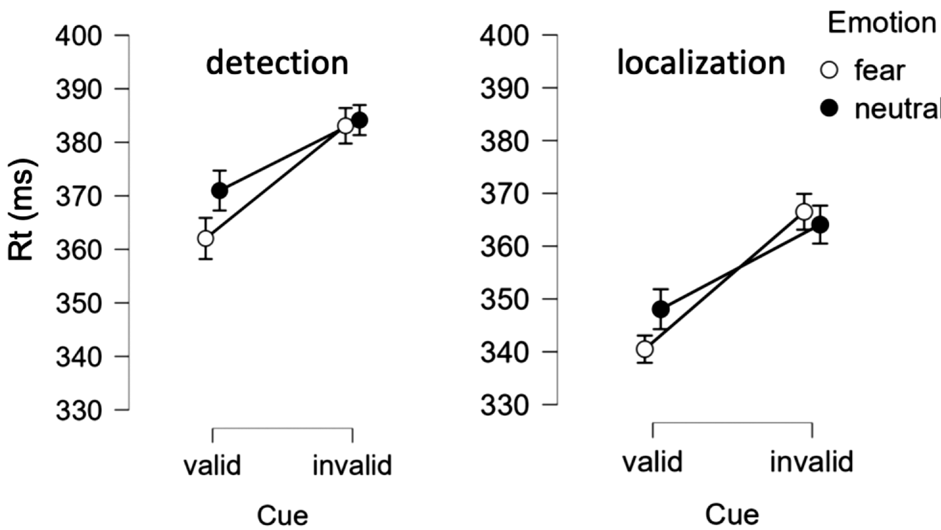
Experiment 2

Method

Participants

We used G*Power 3 software to calculate the sample size (Faul et al., 2007). Given a small to medium effect size of $\eta^2 = 0.025$ and adequate power of $1 - \beta > .95$, at least 55 participants were required. Sixty-three undergraduate students signed up for the online study to fulfill course credits. However, seven participants were excluded because they did not finish the experiment. This resulted in datasets of 56 participants (7 male, 49 female, aged between 20 and 28) that were included in the analyses. All participants provided

Figure 2
Mean Reaction Times in the Detection and Localization Task for Valid and Invalid Trials



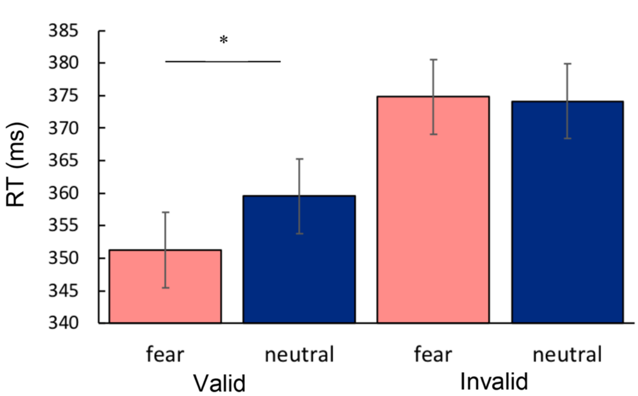
Note. Open circle is fearful, and filled circle is a neutral expression.

informed consent before participation and were free to terminate the experiment at any time. Participants had normal or corrected-to-normal vision. The study was approved by the local ethics committee (Leiden University, Institute of Psychological Research; V2-3396).

Apparatus and Stimuli

The experiment was programmed in OpenSesame 3.3.5 (Mathôt et al., 2012) and run via OSWeb with a resolution of 1,024 × 768 px on the JATOS server of Leiden University. The gaze cues were similar to Experiment 1. The targets were either the digit 6 or 9 made up out of the digit 8 (Srinivasan & Hanif, 2010). The global target (160 px × 150 px) was made up out of local 8s. The local target (16 px × 18 px) consisted of a global 8 made up of local 6s or local 9s (see Figure 4) and was presented with the center 300 px left or right of fixation.

Figure 3
Mean Reaction Times for Valid and Invalid Trials Averaged Across Tasks



Note. Orange (Light colored) bar is fearful, blue (dark colored) bar is a neutral expression. See the online article for the color version of this figure.

Design and Procedure

The experiment consisted of eight blocks of 32 experimental trials each. Participants either started with the global target or with the local target task for four blocks in a row. The task was counterbalanced between subjects. Emotional expression and cue validity were counterbalanced but presented randomly within a block of trials. The target could appear with equal probability on the left (50%) or the right (50%) of fixation. The gaze was 50% valid.

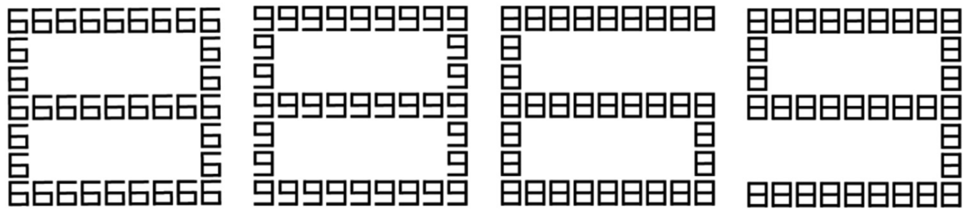
Participants were asked to sign informed consent by pressing “Y” on the keyboard in order to continue with the experiment. Clear instructions about the task were presented on the screen. Participants were asked to keep their eyes fixated on the center of the screen and to respond as accurately and fast as possible. Each task started with a practice block of 32 trials in which only neutral gaze cues were presented. After each block, participants received feedback about their performance.

Each trial started with a fixation dot presented for 800 ms with a variable delay of 100 ms at the center of the screen. A neutral gaze cue with the eyes directed at the observer was presented for 500 ms. Subsequently, the gaze changed to averted for 200 ms after which the emotional expression changed from neutral to fearful or stayed neutral for 300 ms. Simultaneously with the offset of the face, the target was presented either to the left or to the right side of the gaze cue.

In both tasks, participants had to respond by pressing the “m” key on the keyboard with their right index finger if the target was a 6, and the “z” key with their left index finger if the target was an 8. The target remained on the screen until the participant’s response or for a maximum of 2,500 ms before the next trial

Figure 4

Local and Global Digits Used as Targets in Experiment 2 and as Primes in Experiment 3



Note. On the left local 6 and 9 and on the right global 6 and 9.

began. The fixation dot turned red for 600 ms after an incorrect response.

Data Analyses

Responses below 100 ms were excluded from analysis (<1%). In addition, response times on correct trials lower or above 2.5 *SD* of the mean for each task separately (global condition: <3.6%; local condition: 3.5%) were excluded from analyses. Mean RT and accuracy were analyzed separately with a repeated measures ANOVA with the within-subject factors target (local and global), emotion (fearful and neutral), and cue validity (valid and invalid). The significant interaction in RT between target and cue validity was followed up by *t*-tests between the cue validity effect of the local and global targets averaged across emotions. To test for evidence of absence, besides a frequentist analysis, the Bayes factor (Bf_{01}) was calculated for a repeated ANOVA on the GCE (RT Invalid–RT Valid) with the factors target (local and global) and emotion (fear and neutral). The Bayes factor was interpreted based on van Doorn et al. (2021).

Results

Reaction Time

The mean RTs are reported in Table 1. A repeated measures ANOVA on RT with target (local and global), cue validity (valid and invalid), and emotion (fear and neutral) showed a main effect of cue, $F(1, 55) = 88.373$, $p < .01$, $\eta^2 = 0.62$, due to shorter RT at the validly cued ($M = 549.68$ ms, $SE = 8.11$ ms) than the invalidly cued location ($M = 572.18$ ms, $SE = 8.24$ ms). There was a main effect of the target, $F(1, 55) = 242.55$, $p < .01$, $\eta^2 = 0.82$, due to shorter RTs to global ($M = 519.77$, $SE = 8.36$) than local targets ($M = 602.09$, $SE = 8.78$) and an interaction between cue validity and target, $F(1, 55) = 7.99$, $p < .01$, $\eta^2 = 0.13$. As can be seen in Figure 5, averaged across emotional expressions the cueing effect was stronger with local ($M = 28.79$, $SE = 3.94$) than global targets, $M = 16.22$, $SE = 2.42$; $t(55) = 2.827$, $p < .01$, $d = .38$. However, none of the other effects were significant (all *p*s > .26).

To test whether there was evidence of absence of an effect of local and global processing on emotional modulation of the GCE, we performed a frequentist and Bayesian repeated ANOVA on the GCE (RT Invalid–RT Valid) with the factors target (local and global) and emotion (fear and neutral). The results provided moderate evidence against emotional modulation of the GCE due to local or global processing, $F(1, 55) = 0.80$, $p = .78$, $Bf_{01} = 6.213$; Figure 6.

Accuracy

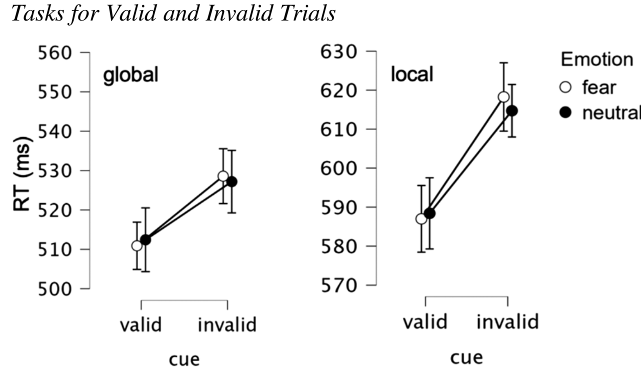
A repeated measures ANOVA on accuracy with target (local and global), cue validity (valid and invalid), and emotion (fear and neutral) showed the main effects of the target, $F(1, 55) = 5.175$, $p = .03$, $\eta^2 = 0.09$, due to higher accuracy for the global ($M = 94\%$, $SE = 0.6\%$) than the local target ($M = 92\%$, $SE = 0.7$ ms) and emotion, $F(1, 55) = 7.62$, $p < .01$, $\eta^2 = 0.12$, due to higher accuracy for the neutral ($M = 94\%$, $SE = 0.6$) than the fearful gaze cue ($M = 92\%$, $SE = 0.6$). The main effect of the cue did not reach significance ($p = .09$), and neither did any of the interactions (all *p*s > .19).

Discussion

For the local as well as the global targets, RTs were shorter at the validly cued than the invalidly cued locations, indicating the typical GCE (Mckay et al., 2021). However, the fearful gaze cue in the global condition did not modulate the GCE despite the clear difference in task difficulty between the two target conditions: RTs were shorter and accuracy was higher in the global than the local target condition. Furthermore, the GCE was weaker when global targets had to be discriminated indicating that in the global condition attention remained more distributed over the display (Huntsinger,

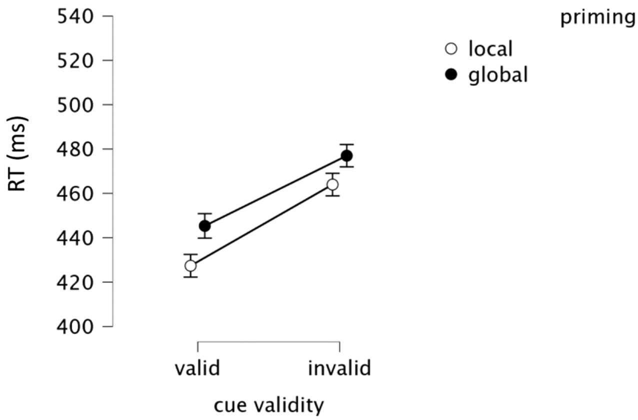
Figure 5

Mean Reaction Times in the Global and Local Discrimination Tasks for Valid and Invalid Trials



Note. Open circle is fearful, filled circle is a neutral expression.

Figure 6
Mean Reaction Times for Valid and Invalid Trials



Note. Open circle is local, and the filled circle is global priming.

2012) and was less focused on the gazed-at location (Chong & Treisman, 2005). Together these findings demonstrate evidence of a global processing strategy, but they do not show stronger orienting in response to the fearful gaze cue. In contrast, the Bayes factor even indicated evidence for this null finding. Possibly, the absence of an effect was due to the task participants had to perform. As shown by Chen et al. (2021), a discrimination task diminished the modulation of the GCE in response to a fearful gaze cue substantially. Therefore, adopting a discrimination task, even though a global perceptual processing style is induced, may have been too cognitively demanding in order to leave enough resources available to integrate the emotional expression with the gaze direction. Therefore, in Experiment 3, the localization task was reintroduced but each trial was preceded by a global or local digit identification task in order to prime global or local perception. Previous research (Srinivasan & Hanif, 2010) showed that priming with global and local digits affected subsequent global and local perceptual processing strategies. In addition, in Experiment 3, the neutral gaze cue always changed to fearful. We expected to find a larger cueing effect in the global priming than in the local priming condition.

Experiment 3

Method

Participants

We used G*Power 3 software to calculate the sample size (Faul et al., 2007). Given a medium to small effect size of $\eta^2 = 0.025$ and adequate power of $1 - \beta > .95$, at least 86 participants were required. Hundred and thirty undergraduate students signed up for the online study to fulfill course credits. However, 23 participants were excluded because they did not finish the experiment. In addition, six participants were excluded because of more than 55% error in the digit identification or the gaze cueing task. This resulted in datasets of 101 participants (11 male, 89 female, 1 unknown, aged between 17 and 40) that were included in the analyses. All participants provided informed consent before participation and were free to terminate the experiment at any time. Participants had normal or corrected-to-normal vision. The study was approved by the local ethics committee (Leiden University, Institute of Psychological Research; V2-3396).

Apparatus and Stimuli

The experiment was programmed in OpenSesame 3.3.5 (Mathôt et al., 2012) and run via OSWeb with a resolution of 1024 × 768 px on the JATOS server of Leiden University. The gaze cues and target were similar to Experiment 1, but the neutral expression always changed to fearful. The global and local prime targets were similar to the local and global targets used in Experiment 2 and were presented at fixation.

Design and Procedure

The experiment consisted of four blocks of 32 experimental trials each. Participants either started with the global digit priming task or the local digit priming task for two blocks in a row. Local and global priming was counterbalanced between subjects. Cue validity was counterbalanced but presented randomly within a block of trials. The target could appear with equal probability on the left (50%) or the right (50%) of fixation. The gaze was 50% valid.

Participants were asked to sign informed consent by pressing “Y” on the keyboard in order to continue with the experiment. Clear instructions about the task were presented on the screen. Participants were asked to keep their eyes fixated on the center of the screen and to make a speeded response to the location of the asterisk and then a response regarding the digit. Each task started with a practice block of 32 trials. After each block, participants received feedback about their performance.

Each trial started with a fixation dot presented for 1,450 ms after which the digit prime was presented at fixation for 200 ms. This was followed by the fixation dot for 100 ms after which a neutral gaze cue with the eyes directed at the observer was presented for 300 ms with a variable delay of 100 ms. Subsequently, the gaze changed to averted for 100 ms after which the emotional expression changed from neutral to fearful for 200 ms. Simultaneously with the offset of the face, the target was presented either to the left or to the right side of the gaze cue.

Participants had to respond by pressing the “z” key on the keyboard with their left index finger if the target was presented on the left, and the “m” key with their right index finger if the target was presented on the right. The target remained on the screen until the participant’s response. The fixation dot turned red for 600 ms after an incorrect response. After a delay of 750 ms in which the black fixation dot was presented, participants were prompted to indicate whether the digit prime was a 6 or a 9. Response keys were “s” for a six and “n” for a nine. The fixation dot turned red for 600 ms after an incorrect response.

Results

Data Analyses

To assess the priming task, a *t*-test between mean accuracy on the local and global targets was performed. Subsequently, mean RT and accuracy were analyzed separately with a repeated measures ANOVA with the within-subject factors priming (local and global) and cue validity (valid and invalid). To test for evidence of absence, besides a frequentist analysis, the Bayes factor (Bf_{01}) was calculated for a *t*-test on the GCE (RT Invalid–RT Valid) between local and global priming. The Bayes factor was interpreted based on van Doorn et al. (2021).

Priming Task

The mean percentage correct of the identification of the global target was 94% (min = 55%, max = 100%, *SE* = 0.7) and of the local target 95% (min = 73%, max = 100%, *SE* = 0.6). A paired sampled *t*-test showed no significant difference ($p = .07$).

Reaction Time

The mean RTs are reported in Table 1. A repeated measures ANOVA on RT with priming (local and global) and cue (valid and invalid) showed a main effect of cue, $F(1, 100) = 122.619$, $p < .01$, $\eta^2 = 0.55$, due to shorter RT at the validly cued ($M = 436.36$ ms, $SE = 10.34$ ms) than the invalidly cued location ($M = 470.5$ ms, $SE = 10.04$ ms). The main effect of priming did not reach significance ($p = .06$) and there was no interaction ($p = .31$).

To test whether there was evidence of absence of an effect of local and global priming on the GCE, we performed a frequentist and Bayesian *t*-test on the GCE (RT Invalid–RT Valid) between local and global priming. The results provided moderate evidence against a modulation of the GCE due to perceptual processing strategies, $t(100) = 1.024$, $p = 0.31$, $Bf_{01} = 5.462$.

Accuracy

Accuracy was at ceiling, however, a repeated measures ANOVA on accuracy with priming (local and global) and cue (valid and invalid) showed a main effect of cue, $F(1, 100) = 33.909$, $p < .01$, $\eta^2 = 0.25$), due to higher accuracy at the validly cued ($M = 99\%$, $SE = 0.1\%$) than the invalidly cued location ($M = 98\%$, $SE = 0.3\%$). In addition, it showed the main effect of priming, $F(1, 100) = 4.743$, $p = .03$, $\eta^2 = 0.05$, due to higher accuracy in the global ($M = 99\%$, $SE = 0.2\%$) than the local condition ($M = 98\%$, $SE = 0.2\%$), but no interaction ($p = .13$).

Discussion

For local as well as global priming, performance was better at the validly cued than the invalidly cued locations, indicating the typical GCE (McKay et al., 2021). However, even though we adopted a localization task there was no modulation of the GCE after global priming. In contrast, the Bayesian analysis showed evidence of absence of such an effect.

General Discussion

The current study investigated whether the cognitive resources account (Chen et al., 2021) can explain the inconsistent findings of gaze cueing studies with fearful expressions. In Experiment 1, we tested whether changing the task to a detection task would yield similar results to the commonly used localization task. Indeed, we found a stronger GCE for the fearful relative to the neutral expression in both tasks. In addition, the interaction was driven by faster responses to the validly cued location, which is consistent with previous findings and can be explained within the cognitive resource account proposed by Chen et al. (2021). However, whether a bias toward global perceptual processing is the determining factor in emotional modulation of gaze cueing, was tested by presenting local and global targets in Experiment 2, and by priming local or global perception prior to the gaze cueing task in Experiment 3. In both experiments we found the typical GCE, however, a global or local perceptual processing strategy did not modulate the GCE for the fearful expression. The findings of Experiment 2 indicated that a global perceptual processing strategy even reduced the GCE. This suggests that when a global perceptual strategy is adopted, spatially shifting of attention in response to the gaze cue is weaker and hence attention is less focused on the gazed-at location. Findings of Experiment 3, in which RTs were longer after global priming relative to local priming seems to corroborate this explanation. When a global perceptual strategy is adopted, attention remains more distributed over the display slowing down response times to the target. Altogether, our findings do not support the hypothesis that a global processing strategy due to lower perceptual task demands allows for the integration of the emotional expression with the gaze direction. Moreover, studies that investigated the effects of local and global priming in an emotion recognition task showed that emotional recognition may be facilitated when local rather than global processing is induced (Martin et al., 2012). In addition, priming local perception was associated with improved recognition of negative emotional expressions, whereas global perception was associated with positive emotions (Srinivasan & Gupta, 2011; Srinivasan & Hanif, 2010). Therefore, it seems unlikely that a negative expression, such as a fearful expression is not integrated with the gaze direction in emotional gaze cueing due to local processing.

Given that emotional modulation of the gaze cueing task is less often found with a discrimination than a localization task, other processes induced by task demands may account for the lack of an effect. For instance, with neutral gaze cues, it has been shown that a localization task induces stronger cueing effects than a discrimination task (McKay et al., 2021). One of the explanations that has been put forward is the so-called cue-relevance account, in which the directional gaze cues are more relevant for a location-based decision than for a category-based decision. An alternative explanation is the spatial congruency account in which the response hand that maps onto the direction of the gaze cue (left gaze—left-hand response and right gaze—right-hand response) is initiated faster than a spatially incongruent response (McKay et al., 2021). Possibly, a fearful expression exerts its influence more pronounced on action-related processes than on spatial attention-related processes. Indeed, research has shown that emotional stimuli affect motor excitability (Van Loon et al., 2010). For example, a transcranial magnetic stimulation study showed that a single pulse to the primary motor cortex during the presentation of neutral or emotional facial expressions increased the motor-evoked potential for fearful relative to other expressions (Schutter et al., 2008). These studies demonstrate the strong link between emotion and action preparation. Therefore, a fearful gaze cue might not only affect attention processes, but additionally motor processes. However, previous studies have shown that when the response is no longer spatially congruent, a stronger GCE for emotional faces has been found in a localization relative to a discrimination task (Chen et al., 2021).

Besides the difference in perceptual load, the discrimination and localization/detection tasks differ in cognitive load. Several studies have investigated whether cognitive load affects gaze cueing with neutral gaze cues. These studies used concurrent tasks but showed inconsistent findings. Some studies showed that cognitive load did not disrupt the GCE indicating the automatic nature of orienting (Hayward & Ristic, 2013; Law et al., 2010), whereas other studies showed interference of attention orienting pending on the extent of the load, indicating that orienting in response to eye gaze is under top-down control (Bobak & Langton, 2015). With respect to emotional gaze cueing, Pecchinenda and Petrucci (2016) found that the gaze cueing with angry face cues was even enhanced under high cognitive load, although the GCE for neutral cues was reduced, irrespective of load. Their finding with angry cues suggests that limited cognitive resources due to task demands are not the crucial factor in determining whether an emotional expression modulates the GCE. However, future research is necessary to determine whether the nature of the cognitive load task, tapping into executive functions, such as verbal working memory (Bobak & Langton, 2015; Pecchinenda & Petrucci, 2016), or into visual–spatial demands, such as target discrimination (Chen et al., 2021; Pecchinenda & Petrucci, 2016), are crucial in reducing the modulating effect of emotional expression on gaze cueing.

In Experiment 2, we found decreased accuracy after a fearful relative to a neutral gaze cue. However, this effect was not modulated by the local and global targets. Unfortunately, most studies on emotional gaze cueing do not report analyses on accuracy, possibly because of ceiling effects due to the overused localization task. Studies that did analyze accuracy report no effect of emotional expression (Carlson, 2016; Chen et al., 2021; Galfano et al., 2011; Graham et al., 2010). In order to refine the mechanisms underlying emotional modulation of gaze cueing, future research should not only focus on RT but also on visual processing (Smith & Ratcliff, 2009). If an emotional gaze cue enhances attentional processes, this should be evident in RT as well as improved accuracy and improved signal detection. For example, in spatial cueing studies it has been shown that spatial attention enhances sensory processing at that location (e.g., Carrasco et al., 2000; Luck et al., 1994). To my knowledge, no emotional gaze cueing study measured sensitivity in relation to valid and invalid emotional gaze cues.

Besides investigating the influence of task parameters on emotional gaze cueing, social factors, such as the sex or age of observers may also play a role (Dalmaso et al., 2020). For instance, it has been shown that GCE is stronger in females than males (Bayliss et al., 2005; McCrackin & Itier, 2019). A limitation of our study is that we did not balance the sex of the participants in our study.

In conclusion, our findings show that a fearful face cue induces a stronger GCE than a neutral gaze cue in tasks that require low cognitive and perceptual demands, such as a detection and localization task. However, inducing a global or local perceptual processing strategy does not affect emotional modulation of the GCE. Moreover, adopting a global perceptual processing strategy may even reduce the GCE, irrespective of emotional expression. Future research is necessary to determine what mechanisms are responsible for the mixed findings reported so far in the literature on emotional gaze cueing (McKay et al., 2021).

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