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Both Fearful and happy expressions interact with gaze direction by 200ms SOA to speed attention orienting

Sarah D. McCrackin* and Roxane J. Itier

Department of Psychology, University of Waterloo, Waterloo, Canada

*corresponding author

Department of Psychology,
University of Waterloo,
200 University Ave W,
Waterloo, ON, N2L 3G1
Sarah McCrackin's e-mail: sdmccrac@uwaterloo.ca
Roxane Itier's email: ritier@uwaterloo.ca

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ABSTRACT

Attention orienting towards a gazed-at location is fundamental to social attention. Whether gaze cues can interact with emotional expressions other than those signaling environmental threat to modulate this gaze cuing, and whether this integration changes over time, remains unclear. With four experiments we demonstrate that, when perceived motion inherent to dynamic displays is controlled for, gaze cuing is enhanced by both fearful and happy faces compared to neutral faces. This enhancement is seen with stimulus-onset-asynchronies ranging from 200-700ms. Thus, gaze cuing can be reliably modulated by positive expressions, albeit to a smaller degree than fearful ones, and this gaze-emotion integration impacts behaviour as early as 200ms post-cue onset.

KEYWORDS:

facial expressions of emotion, gaze cuing, attention orienting, stimulus-onset asynchrony, threat detection, apparent motion

INTRODUCTION

Inferring the mental states of others (also called mentalizing or theory of mind) is important for positive social interactions, and relies heavily on the ability to extract cues from an individual's face (Baron-Cohen, 1995). The direction of a person's gaze provides invaluable insight into what they are attending to (Baron-Cohen, 1995; Itier & Batty, 2009), while characteristic facial expressions provide information about an individual's affective state (Ekman and Friesen, 1971). The successful integration of these separate facial cues allows one to make inferences about people's emotional reaction to environmental objects. For example, the typical interpretation of someone looking to the left and then expressing fear is that the individual is afraid of what they just saw. In contrast, the inability to properly combine these cues is associated with poor social functioning (Hayward & Ristic, 2017) and autistic-like traits (Lassalle & Itier, 2015b; Bayliss & Tipper, 2005; Bayliss & Tipper, 2006), emphasizing the need to understand how this integration works in both neurotypical and clinical populations.

Gaze direction spontaneously orients an observer's attention to gazed-at locations (Friesen & Kingstone, 1998). This phenomenon is termed gaze cuing and has received a lot of attention in recent years. Gaze cuing is commonly studied in the lab using a modified Posner cuing task (Posner, 1980), in which a centrally-fixated face shifts its gaze towards (congruent) or away from (incongruent) a peripheral target (Driver et al., 1999; Friesen & Kingstone, 1998). Participants are faster to respond to congruent than to incongruent targets, even when they are told that gaze is not predictive of target location. This gaze cuing effect is indicative of attention orienting based on gaze cues and has been reliably found using a variety of tasks (for a review see Frischen et al., 2007).

The modulation of the gaze cuing effect by various facial expressions has been used to probe the integration of gaze cues with emotion cues during social attention. In neurotypical populations, many studies have now shown that, compared to happy or neutral expressions, gaze cuing is enhanced by expressions of fear, (Bayless, Glover, Taylor, & Itier, 2011; Graham, Friesen, Fichtenholtz, & LaBar, 2010; Lassalle & Itier, 2013; 2015a; 2015b; Neath, Nilsen, Gittsovich, & Itier, 2013; Putman, Hermans, & Van Honk, 2006; Tipples, 2006), anger (Holmes et al., 2006; Lassalle & Itier, 2013; 2015a) and surprise (Bayless et al., 2011; Lassalle & Itier, 2013; 2015a; Neath et al., 2013). In contrast, most studies have found similar gaze cuing effects for happy and neutral faces (Holmes et al., 2006; Lassalle & Itier, 2013; 2015a; Neath et al., 2013; Putman et al., 2006; Tipples, 2006). As fear denotes a threat in the environment, anger denotes a possible danger, and surprise denotes an unexpected and potentially dangerous event, these findings have been interpreted as reflecting a heightened sensitivity of the attentional orienting system to threat or uncertainty (e.g. Graham et al., 2010; Holmes et al, 2006; Tipples, 2006; Lassalle & Itier, 2013). These enhancements of gaze cuing by facial expressions appear driven most consistently by faster response times to emotion than neutral conditions in congruent trials, with less consistent or even no differences between expressions in incongruent trials (Bayless et al., 2011; Lassalle & Itier, 2013; 2015a; 2015b; Neath et al., 2013). As attention is first oriented toward the gazed-at location in both congruent and incongruent trials but presumably needs to be reoriented towards the correct target location in incongruent trials, some have suggested that this pattern of results reflects a true facilitation of gaze-oriented attention by the emotional content of the face (e.g. Lassalle & Itier, 2013).

However, not all studies have found that emotional expressions modulate gaze cuing, and several factors have been identified that impact the integration of gaze and emotion cues. One important factor is the dynamicity of the cue presentation. Studies that used static cues, that is, still images of emotional faces with averted gaze, have failed to report gaze cuing enhancement (Hietanen & Leppänen, 2003 [Exps.1–4]; Holmes et al., 2006 [Exp.3]; Hori et al., 2005). In contrast, emotional modulation can be more reliably elicited with dynamic displays. In such displays, different pictures of the same individual are rapidly presented one after another to elicit the perception of a face looking to the side and expressing an emotion. Specifically, sequences in which a neutral face with direct gaze first averts its gaze and then reacts emotionally while keeping its gaze averted, have most consistently yielded a gaze cuing enhancement with fear, anger and surprise (Graham et al., 2010 [Exp.5-6]; Lassalle & Itier, 2015a,b; Neath et al., 2013).

In this type of sequence, the change that occurs between the neutral averted and emotion averted frames creates a perceived movement on the face. This movement is absent in neutral trials, in which the last frame remains still (the same neutral averted gaze face). It is possible that the reported enhancement of gaze cuing by facial expressions may, in part, be driven by this apparent motion in emotional trials. Graham et al. (2010) investigated this possibility. They compared their emotional condition, in which the neutral averted gaze face was followed by a brief emotional averted gaze face with 55% emotional intensity and then 100% emotional intensity, to a control condition with movement in which the 55% emotional intensity face reverted back to neutral for the rest of the trial. As both of these conditions contained apparent motion, but differing amounts of affective information, the authors interpreted the larger cuing effect found with the full emotional faces as indicating that apparent motion on the face was not responsible for the emotional enhancement of gaze cuing. However, as it included an emotional face of 55% intensity, this control condition still contained affective information and so cannot be considered a neutral movement. Thus, from this experiment alone, it cannot be concluded that apparent motion is not at least partly driving the emotional enhancement of the cuing effect. To rule out this possibility, we created a movement condition devoid of emotion in the present study – a neutral face sticking its tongue out (hereafter neutral tongue condition) – to compare to our emotion conditions.

The second main modulator of this gaze and emotion integration is the cue to target time interval or stimulus onset asynchrony (SOA). Varying SOA length can help estimate the time needed for this integration to occur. Using the dynamic sequence that best elicits enhancement of gaze cuing with emotion, Graham et al. (2010) compared several short (175-275ms) and long (475-575ms) SOAs. They found that gaze cuing was enhanced by fearful expressions only in the long SOA condition, concluding that at least 300ms was required for gaze and emotion cues to be integrated. However, only that study has investigated this question, highlighting the need for replication. In particular, since different SOAs were averaged in their short SOA condition, it is possible that the lack of emotional modulation in this condition was driven by the shortest SOAs used, masking more subtle effects that would otherwise emerge after just 200ms of integration time, or shortly after. Accordingly, two previous studies have reported emotional modulation of gaze cuing at SOAs of 200ms (Bayless et al., 2011 and Putman et al., 2006). Although both involved other potentially confounding factors (Bayless et al. used videos as stimuli and gaze cuing was enhanced for fearful compared to happy, but not neutral faces, while the effect reported by Putman et al. correlated with anxiety), gaze and emotion cues might interact earlier than previously thought. This idea is supported by results from Event-Related Potential (ERP) studies that show that fearful and neutral expressions are reliably discriminated as early as 150ms post-face onset (see Calvo and Numenmaa, 2015, for a review), while gaze processing begins between 170 and 200ms (Itier & Batty, 2009 for a review), making it possible that the two start interacting around the 200ms range. While the interaction between gaze and expressions was reflected in ERPs starting around 270ms in one study (Klucharev & Sams, 2004), a more recent study reported integration of gaze, body and emotion cues within the premotor cortex by 200ms (Conty et al., 2012). In any case, both studies point at timings shorter than 300ms. One of the main goals of the present study was to re-evaluate the timing at which gaze and emotion interaction begins to modulate social attention behaviour.

The time it takes to integrate gaze and threat-related emotional expressions could thus be shorter than currently assumed. Moreover, it is possible that the integration time varies depending on the expression. As fast timing is less essential for non-threatening situations, it is possible that happy expressions modulate gaze cuing at longer SOAs than fearful expressions, resulting in those effects being missed in previous literature where SOAs do not typically exceed 500ms. Indeed, Graham et al. (2010) reported that happy expressions produced a similar gaze cuing enhancement as fearful faces only in their longer SOA condition (475-575ms). However, this was only found in one of their six experiments (Exp.5), and there was no cuing effect for neutral faces (see Table 5 of their paper p352), which is at odds with the rest of the literature reporting reliable gaze cuing effects for neutral faces with SOAs from 100-700ms (Frischen et al., 2007). The only other study which reported enhanced orienting by happy faces found this effect only for female face stimuli (Hori et al., 2005). Since these results are mixed, an effort should be made to see if this happy effect can be reliably reproduced.

The idea that happy and other non-threatening expressions could potentiate gaze cuing fits with the neuroimaging literature on social attention, which does not support a strict threat/non-threat dichotomy. The amygdala is a subcortical brain structure heavily involved in the processing of emotional expressions (Wang et al., 2014), gaze direction (Sauer, Mothes-Lasch, Miltner & Straube, 2014) and their interaction (N'Diaye et al., 2009). It has been suggested that the amygdala plays a role in the emotional modulation of gaze cuing, as it has been shown to interact with several core nodes of the complex gaze-oriented attention system (Hoffman et al., 2007; Kawashima et al., 1999; N'Diaye et al., 2009). Importantly, the amygdala is responsive to both positive and negative expressions (Wang et al., 2014), and may play a more general role in relevance detection as opposed to threat detection (Sander et al., 2003). This sensitivity to non-threatening expressions suggests that happy expressions may modulate social attention as well, though potentially to a lesser extent or with a different time-course than fearful expressions. The latter two possibilities were examined in the present study.

In summary, the present study investigated the interaction of gaze cues with fearful and happy facial expressions in social attention. We used the most ecological dynamic gaze cuing sequence, where the gaze shifted before the onset of the expression (Lassalle & Itier, 2015a). We controlled for apparent motion using an original neutral face with tongue protrusion as a neutral baseline, first validated in a separate study. Then, in a series of four experiments, we varied the SOA to evaluate when the emotional modulation of gaze cuing emerges for fearful and happy facial expressions. Based on the findings from Graham et al. (2010) indicating that emotion impacts gaze cuing after 300ms SOAs, we first investigated the possible rise and fall of the cuing enhancement by fear (Exp.1) and happiness (Exp.2) across long SOAs (300-700ms). In accordance with previous behavioral and neuroimaging research, supporting the idea that the social attention system should also be modulated by positive, non-threatening emotions, we expected to see enhanced gaze cuing for fearful compared to neutral tongue expressions (fear effect) but also for happy compared to neutral tongue expressions (happiness effect). In Exp.3 we directly compared the cuing effects elicited by fearful, happy and neutral tongue faces, predicting that the happiness effect would likely be smaller, and/or emerge at later SOAs than the fear effect, due to a possibly delayed integration of gaze cues with happy compared to fearful cues. However, based on the results of the first two experiments, we used shorter SOAs (200-350ms) to track the emergence of the fear and happiness effects. Experiment 4 sought to replicate the effects of Exp.3 and compared the neutral tongue condition to the classic neutral face condition used in the literature, to better relate our findings to previous studies. Finally, to follow-up on recent studies, and in an attempt to better elucidate the contribution of emotional content and apparent motion to social attention, we analyzed the gaze cuing effect but also conducted systematically separate analyses of facial expression for congruent and incongruent trials.

STIMULI VALIDATION STUDY – creating a neutral movement

The use of dynamic sequences in the gaze cuing paradigm, wherein several frames are rapidly presented back to back, renders the display a bit more realistic than the use of static stimuli. However, when facial expressions are employed, the perceived apparent motion of the face (as perceived when the averted gaze frame changes to a frame with an emotional expression) is lacking from the control condition with neutral expressions (in which the averted gaze frame is the final frame). To control for this apparent motion during emotion trials, we created a neutral gaze cuing condition by adding a tongue-protrusion movement to the neutral expression sequences. We first validated the sequence stimuli in a separate online study to ensure that the tongue protrusion was indeed perceived as a neutral movement.

Methods

Participants

Sixty-eight University of Waterloo (UW) undergraduate students received course credit for participating. The study was approved by the UW Research Ethics Board and participants gave informed consent upon opening the online study. Nine participants were excluded for failing to complete the study, resulting in a final sample of 59 (43 females, 16 males, mean age = 20.25 - *SD*=1.17) for data analysis.

A prescreening questionnaire administered at the beginning of each term was used to determine participants' eligibility. Individuals were ineligible if they reported a history of psychiatric or neurological illness, psychiatric or daily recreational drug use, or a past loss of consciousness for longer than 5 minutes. To ensure proficiency in English and uniform cultural exposure, only individuals reporting living in Canada or the United States for the past 5 years were selected. Participants rated their ability to recognize faces and facial expressions on Likert-type scales ranging from 0 (extremely poor) to 10 (extremely good). To ensure no face-related impairments, only those with self-reported abilities from 7-10 on both scales were eligible. All participants were right-handed with normal or corrected-to-normal vision and between the ages of 18-29.

Dynamic Sequence Stimuli

Four female and four male identities were selected from the NimStim database[1] (Tottenham et al., 2009), each expressing fearful, neutral and happy expressions (identities: 02, 03, 06, 09, 20, 22, 24, 27). Images were cropped to isolate the face and remove the ears, hair and clothing. For each facial expression, averted left and right gaze images were created by moving the pupils of direct gaze images to the right and left corners of the eyes. For the neutral movement condition, the mouth area of neutral gaze averted faces was edited to display a tongue protrusion in order to create the appearance that each person was sticking out their tongue (Fig.1).

In total, for each identity, there was one direct gaze image (direct neutral) and eight averted gaze images (4 expressions (fearful, happy, classic neutral, neutral tongue) x 2 gaze directions (left, right)). The "classic neutral" image consisted of the original neutral faces without tongue protrusion. Each of these images was flipped about the y-axis to create a mirrored image, doubling the number of images for each identity (e.g. the flipped averted left neutral was also used as a second averted right neutral image). This ensured that any facial asymmetry which

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[1] Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set.

could potentially impact the allocation of attention was balanced on the left and right sides of the screen. All photo-editing was completed using the GNU Image Manipulation Program (GIMP, version 2.8.0). Images were converted to greyscale and equalized for Root Mean Square (RMS) contrast and normalized pixel intensity (RMS contrast: *M* = 0.3902, *SD* = .00236, pixel intensity: *M* = 0.8024, *SD* = .00065) using the SHINE toolbox (Willenbockel et al., 2010).

Experimental Design and Procedure

The study was programmed using Qualtrics Survey Software. Forty-eight sequences were presented in random order (one for each of the six conditions -fear left gaze, fear right gaze, happy left gaze, happy right gaze, neutral tongue left gaze, neutral tongue right gaze- x 8 identities). Each sequence began with a fixation cross presented for 650 ms, followed by a classic neutral face with direct gaze presented for 300 ms, then the same identity with a neutral face and averted gaze for 100 ms, and then either a happy, fearful or neutral tongue face with averted gaze for 400 ms (see Fig.1). The only differences between these sequences and those used in the following in-lab experiments were the fixed timing of the initial fixation cross, the disappearance of the fixation cross with the appearance of the face, and the absence of a target following the last frame. The time between the gaze shift onset and the end of each sequence was 500ms, selected because it was the average SOA used in Experiments 1 and 2 (see Exp.1 method below). Participants viewed each sequence only once. They were instructed before each sequence to keep their eyes on the fixation cross and after the sequence, to use a nine-point Likert-type scale to rate the facial expressions' valence scale (ranging from 1/very negative to 9/very positive) and arousal level (ranging from 1/very un-intense to 9/very intense).

Stimuli validation Results

As expected, neutral tongue stimuli were given a valence rating very close to a completely neutral rating on our 9-point scale (Table 1; *M* = 4.73, *MSE* = .12; a truly neutral rating would be 5). Critically, paired t-tests (significance reached for $p<.016$ to correct for multiple comparisons) indicated that these stimuli were rated as significantly more positive than fearful stimuli ($t(58)= 11.37$, $p<.001$) and less positive than happy stimuli ($t(58)= -16.57$, $p<.001$). They were also perceived as significantly less arousing than both the fearful and happy stimuli (fear-neutral tongue comparison, $t(58)= -14.92$, $p<.001$; happy-neutral tongue comparison, $t(58)= -11.61$, $p<.001$). These findings suggest that the addition of tongues to the neutral stimuli did not affect participants' perception of the stimuli as neutral. As expected, happy stimuli were given significantly more positive valence ratings than fearful stimuli (*t*(58)= -24.60, *p* <.001), though the two did not differ on arousal ratings (*t*(58)= 1.21, *p* =.23).

Having succeeded in creating a neutral movement for our dynamic gaze cuing sequences, we then employed these stimuli in a series of four experiments evaluating the emotional modulation of gaze cuing across various cue to target intervals.

EXPERIMENT 1 – fearful and neutral tongue faces

Experiment 1 had two aims. The first was to confirm that fearful expressions still significantly enhance gaze cuing in a dynamic cuing paradigm when compared to a neutral condition that controls for apparent motion (neutral tongue protrusion). This replication would support the idea of a true threat-related increase in attention orienting rather than the mere product of using an inadequate neutral baseline. The second, most important, aim was to investigate the fear effect across a larger range of stimulus onset asynchronies (SOAs) than previously used. In particular, if emotion starts impacting gaze cuing at SOAs of 300ms (Graham et al. 2010), does the gaze cuing enhancement for fearful faces peak at later SOAs or does it plateau and then decrease at a certain SOA? To answer these questions, we used SOAs ranging from 300ms to 700ms, which we believed would capture the possible rise and fall of the fear effect. In addition, as the emotional modulation of the cuing effect is quite small (only 5-15ms larger than the cuing effect seen for neutral faces, depending on studies), we decided to increase the number of trials per conditions to maximize the likelihood of finding differences in cuing effect across SOAs. We used 128 trials per condition. As a comparison, our group previously used 32 trials/condition (Neath et al., 2013), 80 trials/condition (Lassalle & Itier, 2015a,b) and 88 trials/condition (Lassalle & Itier, 2013), while Graham et al. (2010) used 96 trials per condition in their Exp.5-6 comparing SOAs within-subject. Based on Graham et al.'s suggested SOA threshold, we expected to see larger fear cuing effects at 400-500ms SOA compared to 300ms SOA. Alternatively, if the integration of fearful expressions and gaze cues is faster than 300ms, as suggested by recent neuroimaging studies (e.g. Conty et al., 2012), then the fear effect should already be clearly observed at 300ms SOAs. It was unclear whether the cuing enhancement by fear would plateau or decrease at longer SOAs.

Methods

Participants

Thirty-four undergraduate students from UW participated in this study. One was removed for failing to complete the experiment, leaving a final sample of 33 for data analyses (20 females, 13 males, mean age = 20.82 years –*SD*=1.13; 27 right handed). Participants received course credit or were paid $20. The study was approved by the UW Research Ethics Board and participants gave written informed consent upon arrival. Participant eligibility was determined using the same prescreening procedure detailed in the Stimuli Validation Study.

Experimental Design and Procedure

The experiment was programmed using Experiment Builder (SR Research, http://sr-research.com). Faces were presented centrally on a white monitor background, 55.5cm away from the participant. A chinrest restricted head movement and maintained a constant distance from the screen. Each trial began with a fixation cross (0.723˚ by 0.723˚ of visual angle) presented at random for 500, 600, 700, or 800ms (Fig.1).

The fixation cross remained for the entire experiment, positioned between the nasion and nose of the face stimuli (11.90˚ down from the screen top, and centered horizontally). The immediately following face sequence (10.41˚ wide and 16.17˚ tall) began with a neutral direct-gaze face presented for 300ms, followed by the same neutral face with an averted gaze for 100ms, and finally ended with the same averted-gaze face expressing a fearful expression or a neutral tongue protrusion for 200, 300, 400, 500 or 600ms (Fig.1). Thus, from the start of gaze shift until target presentation, the SOA was 300, 400, 500, 600 or 700ms. This sequence gave the appearance of a person dynamically looking to one side and then reacting with a fearful expression or a neutral movement. Immediately upon the offset of the last face frame, a target asterisk (0.92˚ by 0.92˚) was presented on one side of the screen (14.15˚ from the center, centered vertically) until the participant responded or for a maximum of 500ms. Congruent trials occurred when the target was on the gazed-at side, while incongruent trials occurred when the target was on the opposite side. Half of all trials were congruent and the other half were incongruent, with the same number of right and left targets in each condition. Trial presentation was randomized within each block. In total, 16 blocks were run, with 160 trials per block. Across blocks there were a total of 128 trials for each of the 20 conditions (5 SOAs x 2 expressions x 2 congruency conditions).

Upon entering the lab, participants filled out a brief demographic questionnaire and were instructed to press the right or left arrow keys with the index and ring fingers on their dominant hand, corresponding to whichever side the target appeared on (target localization task). They were asked to answer as quickly as possible, but not at the cost of accuracy, and were informed that the gaze direction was not predictive of the target location. The importance of maintaining fixation on the fixation cross for the whole duration of each trial was emphasized, and participants completed 8 practice trials to ensure that they were correctly performing the task. The computer task took approximately 1.5 hours to complete.

Statistical Analysis

Responses were considered correct if the key response matched the side of the screen that the target was on, and if the response time was less than 2.5 standard deviations away from the mean for each condition (Selst & Jolicoeur, 1994). Responses were considered a miss if participants answered after the 500ms response time limit. Average reaction times were calculated for each experimental condition using the correct responses.

All statistical analyses were performed with SPSS Statistics 22. An omnibus ANOVA was run on the mean reaction times (RTs) with Expression (2: neutral tongue, fear), Congruency (2: incongruent, congruent), and SOA (5: 300, 400, 500, 600 and 700ms) as within-subjects factors. When Mauchly's Test of sphericity was significant, Greenhouse-Geisser corrected degrees of freedom are reported.

Results

Overall accuracy was very high, with an average of 95.48% correct responses (*SD* = 3.26%), and only 4.52% of trials lost due to incorrect responses, misses or timeouts.

A main effect of Congruency (*F*(1, 32) = 96.5, *MSE*=544.03, *p*<.0001, η_p^2=.75) was due to shorter RTs for congruent than incongruent targets, confirming the typical gaze cuing effect (Fig.2a,c). A main effect of SOA (*F*(1.60, 51.07) = 189.49, *MSE*=587.72, *p*<.0001, η_p^2=.86) was due to faster RTs at longer SOAs, reflecting a standard fore-period effect (Fig.2a). There was also a main effect of Expression (*F*(1, 32) = 8.99, *MSE*=155.38, *p*=.005, η_p^2=.22) with overall faster RTs for fear than neutral tongue trials, which was most pronounced at longer SOAs (Expression by SOA interaction, *F*(4, 128) = 2.97, *MSE*=66.84, *p*=.022, η_p^2=.085, Fig.2a).

Most importantly, there was an Expression by Congruency interaction (*F*(1, 32) = 34.6, *MSE*=104.37, *p*<.0001, η_p^2=.52), reflecting a larger gaze cuing effect for fear than neutral tongue trials (Fig.2b,d), which was stable across SOA (no Expression by SOA by Congruency interaction, F=.94, p=.43). Separate ANOVAs run on the congruent and incongruent trials indicated shorter RTs for fearful than neutral tongue trials in the congruent condition (main effect of Expression for congruent trials, F(1, 32) = 35.13, MSE=135.19, p<.0001, η_p^2=.52, Fig.2c), while no expression effect was seen for the incongruent trials (F(1, 32) = 2.064, MSE=124.57, p=.16, η_p^2=.06).

In our experiment, target presentation side was always assigned to a specific response: left target always corresponded to left finger response of the dominant hand and right target to right finger response of the dominant hand. As the majority of participants used their right (dominant) hand to respond, we checked whether possible Simon effects (Simon, 1990) could be influencing our results due to compatibility effects between response hand and target location when targets were presented on the right side. We thus re-analyzed the data using target side as another within-subjects factor. There was no main effect of target side (F=1.17, p= .29), and no significant interactions between target side and SOA (F=1.87, p=.12), target side, congruency and SOA (F= 1.81, p = .13), target side and emotion (F= .48, p=.49), target side, emotion and congruency (F= 3.72, p = .063), or target side, emotion and SOA (F= 1.04, p = .39). However, there was a target side by congruency interaction (F(1,32) = 5.047, p=.032, MSE = 203.044, η_p^2 = .136) and a four-way target side by emotion by congruency by SOA interaction (F(4,128) = 3.35, p=.012, MSE = 152.163, η_p^2 = .095). We thus re-analyzed the data separately for each SOA condition. There was a target side by emotion by congruency interaction only for the first two SOAs (300ms: F(1,32) = 5.289, p=.028, MSE = 162.871, η_p^2 = .142 and 400ms: F(1,32) = 12.767, p<.001, MSE=124.175, η_p^2 =.285). When we further divided these SOAs into left and right targets, we found no emotion by congruency interaction for right targets (300ms: F= .072, p=.790; 400ms: F= .001, p=.975), but a significant interaction for the left targets (300ms: F(1,32) = 13.151, p<.001, MSE= 112.336, η_p^2=*.291;* 400ms: F(1,32) = 18.917, p<.001, MSE= 170.94, η_p^2=.372), which was due to smaller gaze cuing for neutral tongue than fearful faces. Thus, at 300ms and 400ms SOA, the emotion difference in gaze cuing appeared to be found only for left targets.

Discussion

Using an apparent motion control for the neutral condition of our dynamic gaze cuing paradigm (neutral tongue protrusion), we investigated the time-course of the enhancement of gaze cuing by fearful expressions across 5 SOAs ranging from 300ms to 700ms. We showed that fearful faces produced stronger gaze cuing than neutral faces, confirming the idea that affective content, rather than apparent motion, is the driving force behind this effect. Furthermore, as reported previously (Lassalle & Itier, 2013; 2015a; Neath et al., 2013), this enhanced cuing effect was driven by faster responses for fearful than neutral faces in congruent trials while no expression difference was seen for incongruent trials (Fig.2c). This finding confirms a faster orienting of attention toward the location indicated by gaze when the face expresses fear compared to when it is neutral. Finally, we found that the gaze cuing enhancement by fear is already established by 300ms SOA and stable until 700ms SOA, as the cuing effect did not interact with SOA (Fig.2b).

It is interesting to note that at shorter SOAs (300 and 400ms), the larger gaze cuing for fearful than neutral tongue faces was only seen for left targets, due to a smaller cuing effect for neutral faces when targets were presented on the left compared to when they were presented on the right. However, this effect was due to both longer reaction times to left than right congruent targets and shorter reaction times to left than right incongruent targets, making the incongruent-congruent difference smaller for left targets. In the traditional Simon effect, responses are faster to targets which are compatible with (on the same side as) the response hand (Simon, 1990). The present effect does not reflect that: there was no systematically shorter reaction times for right targets as a true compatibility effect between the effector (right hand for most participants) and target side (right targets) would predict. Furthermore, this left/right target difference in gaze cuing was seen only for neutral faces and was not present at the other three SOAs. As no previous studies have investigated left/right target differences in gaze cuing paradigms with emotional expressions, it is at present unclear what these particular effects reflect.

Overall, the present results suggest that fearful cues and gaze cues likely need less time than the 300ms SOA threshold proposed by Graham et al., (2010) to produce a reaction time benefit, a possibility we explore later in Experiments 3 and 4. First, we tested the idea that happy faces could also orient attention faster than neutral faces.

EXPERIMENT 2 – happy and neutral tongue faces

In Experiment 1, we confirmed that fearful faces enhance gaze cuing using a neutral tongue condition which controlled for apparent motion. Experiment 2 investigated whether or not happy expressions can also enhance gaze cuing when compared to a neutral movement baseline and when a greater trial number is used. Finding no gaze cuing advantage for happy expressions would replicate previous research (Bayless et al., 2011; Hietanen & Leppänen, 2003; Holmes et al., 2006; Lassalle & Itier, 2013; 2015a; Neath et al., 2013; Putman et al., 2006; Tipples, 2006) and support the idea that gaze cuing is reliably enhanced only by emotional expressions that signal environmental threat or uncertainty. However, based on the neuroimaging literature suggesting a more flexible orienting system than a strictly threat modulated system, we predicted that happy faces would also enhance gaze cuing compared to our neutral tongue condition. This intuition was also based on recent results from our own group suggestive of a possible happy effect with this same dynamic sequence (e.g. Neath et al., 2013, Fig.3B; Lassalle & Itier, 2015a, Fig.3) that might not have emerged statistically due to low number of trials per condition or to inappropriate SOAs. Indeed, 500ms SOAs were used in both previous studies. However, the integration of happy and gaze cues might occur later than the integration of fearful and gaze cues, threat needing to be processed faster than other expressions for appropriate survival-related responses (Méndez-Bértolo et al., 2016). We hoped that using an appropriate control for apparent motion, a large number of trials per condition, and five SOAs, would allow us to track the emergence of a reliable happy effect.

Methods

Participants

Experiment 2 used the same pre-screening procedures and compensation as Experiment 1. Thirty-two undergraduates were tested, with one excluded for failing to complete the study, and another for poor accuracy[2], leaving a final sample of 30 participants (18 females, 12 males, mean age = 20.2 years –*SD*=1.32; 29 right handed).

Experimental Design and Procedure

Experiment 2 used the same design as Experiment 1, except happy expressions replaced the fearful expressions in the last sequence frame (Fig.1). The same localization task, SOAs, sequence timing and neutral tongue faces were used.

Statistical Analysis

The same data cleaning and averaging procedures as described in Experiment 1 were performed. A repeated measures ANOVA was run on the mean reaction times with within-subject

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[2] In all experiments, participants with accuracies less than 80% on this easy task were rejected as this reflected non compliance with task instructions or poor attention to the task.

factors of Expression (2: neutral tongue, happiness), Congruency (2: incongruent, congruent), and SOA (5: 300, 400, 500, 600 and 700ms).

Results

Accuracy was very high (*M* = 96.06%, *SD* = 4.03%), with only 3.94% of trials lost due to incorrect responses, misses or timeouts.

The typical gaze cuing effect was present, indicated by a main effect of Congruency (*F*(1, 29) = 143.21, *MSE*=314.57, *p*<.0001, η_p^2=.83) and faster response times for congruent than incongruent trials (Fig.3a,c). A main effect of SOA (*F*(1.74, 50.33) = 169.98, *MSE*=430.53, *p*<.0001, η_p^2=.85) was due to faster reaction times at later SOAs (classic fore-period effect, Fig.3a). There was also a main effect of Expression (*F*(1, 29) = 13.05, *MSE*=139.92, *p*=.001, η_p^2=.31) with overall faster RTs for happy than neutral tongue trials (Fig.3a,c).

Most importantly, there was an effect of the happy expressions on gaze cuing. Similar to Experiment 1, there was an Expression by Congruency interaction (*F*(1, 29) = 8.23, MSE=70.67, *p*=.008, η_p^2=.22), due to a larger gaze cuing effect for happy than for neutral tongue faces (Fig.3c,d). Separate ANOVAs revealed that this interaction was driven by slightly shorter reaction times for the happy congruent trials than neutral tongue congruent trials (main effect of Expression for congruent trials, *F*(1, 29) = 21.324, *MSE*=104.818, *p*<.001, η_p^2=.42, Fig.3c) while no expression effect was seen for incongruent trials (*F*= 1.6, *p*=.21). Furthermore, this larger gaze cuing effect for happy trials was consistent across SOAs (no Expression by SOA by Congruency interaction, *F* =.435, *p*=.718, Fig.3b).

Again, as the majority of the participants were right handed, we re-analyzed the data separating right and left targets to investigate possible response compatibility (Simon, 1990) effects. We found no main effect of target side (*F*= .88, *p*= .36), and no significant interactions between target side and SOA (*F*= 1.28, *p*=.28), target side, congruency and SOA (*F*= .92, *p* = .45), target side and emotion (*F*= 1.51, *p*=.22), target side, emotion and SOA (*F*= .31, *p* = .71), target side and congruency (*F*= 2.23, *p*=.14) or target side, emotion, congruency and SOA (*F*= 1.76, *p*=.14). However, there was an interaction between target side, emotion and congruency (*F*(1,29) = 4.25, *MSE* = 201.153, *p* = .048, η_p^2=.128) so left and right targets were analyzed separately. The interaction between emotion and congruency was not significant for right targets (*F* =.289, *p* =.595), but was significant for left targets (*F*(1,29) = 9.431, *MSE* = 237.095, *p* = .005, η_p^2=.245), with larger gaze cuing for happy than neutral tongue faces.

Discussion

Experiment 2 tested the prediction that happy expressions can also reliably produce a gaze cuing enhancement when compared to a neutral baseline which controls for apparent facial motion, and when a large number of trials and SOAs are used. Indeed, we found that happy expressions facilitated responding to targets relative to our neutral tongue condition in congruent trials (Fig.3c), indicating a faster orienting of attention towards the gazed-at location. In contrast, there was no RT difference between incongruent happy and incongruent neutral tongue trials. This pattern is similar to what was seen in Exp.1 with fearful faces, as is the finding that this happy effect did not vary as a function of SOA (Fig.3b). The latter result suggests that, as for fearful expressions, the happy expressions were already successfully integrated with the gaze cues at our shortest SOA of 300ms. This effect remained stable until 700ms SOA. Thus, contrary to our hypothesis, happy expressions do not appear to be integrated with gaze cues later than fearful expressions, at least when using 300-700ms SOAs. Interestingly, the analysis of target side indicated that the larger gaze cuing effect for happy faces was driven by left target trials. However, again, this pattern does not fit with traditional response compatibility effects (Simon, 1990).

In Experiment 3, we directly compared fearful, happy and neutral tongue faces at shorter SOAs to better track the emergence of these fearful and happy effects.

EXPERIMENT 3 – fearful, happy and neutral tongue faces

The findings from Experiment 2 suggest that previous studies may have failed to report reliable increases in gaze cuing for happy expressions because they lacked an adequate neutral baseline or the number of trials per condition necessary to detect this small effect. Indeed, our results suggest that the gaze cuing enhancement by happy expressions is smaller than that seen with fearful expressions. Across SOAs, the average increase in gaze cuing relative to the neutral tongue condition was 10ms for fearful expressions (Fig.2d) but only 5ms for happy expressions (Fig.3d). However, Experiments 1 and 2 were carried in different samples, making a direct comparison of these effects unreliable. In contrast, the fact that we found a happy effect from 300-700ms SOA in Exp.2 suggests that previous lack of significant happy effects were unlikely due to the use of SOAs that were too long. In fact, the results from Exp.1 and 2 support the idea that both fearful and happy faces increase gaze cuing even before the 300ms SOA threshold proposed by Graham et al. (2010). Thus, in Experiment 3, fearful, happy and neutral tongue conditions were all included within the same design at shorter SOAs of 200, 250, 300 and 350ms to span the 300ms SOA mark. This allowed us to directly compare the magnitude of the fear and happy cuing enhancements, and to track the emergence of these effects across those shorter SOAs. We also ensured a balance of gender in this experiment. Indeed, Exp.1 and 2 both included a larger proportion of females than males. As some studies have reported larger gaze cuing effects in females compared to male participants (Bayliss et al., 2005), we wanted to ensure that our results with happy faces were not driven by the female participants. Based on the pattern seen in Exp.1-2 and on the overall gaze cuing literature, we expected larger cuing effects for fearful compared to both neutral tongue and happy faces. We also expected to replicate our enhanced cuing effect for happy compared to neutral tongue faces (Exp.2). If our hypothesis was correct and emotion enhances gaze cuing before 300ms SOA, then we expected these predicted patterns at 300 and 350ms but also possibly at 250ms and even 200ms. As initially predicted, happy and gaze cues might be integrated slightly later than fearful and gaze cues yet before the 300ms SOA mark, a pattern that this particular design might reveal.

Methods

Participants

The same pre-screening procedures and compensation as in Experiments 1 and 2 were used. Forty-four participants were tested; one was removed for not completing the study, and another one for poor accuracy, leaving a final sample of 42 (21 females, 21 males, mean age = 20.43 ± *SD*=1.48; 35 right handed).

Experimental Design and Procedure

The same procedure and general trial sequence was used in Experiment 3 as in Experiments 1 and 2, with the following major differences. First, fearful, happy and neutral tongue conditions were all included together. Second, the last frame of the face sequence was presented for 100, 150, 200 or 250ms (Fig.1), resulting in 4 possible SOAs (200, 250, 300, 350ms). Third, 12 blocks were run, with 192 trials per block. There were 24 conditions (3 Expressions –fearful, happy, neutral tongue– X 2 Congruency conditions –congruent, incongruent– X 4 SOAs --200, 230, 300, 350ms), with a total of 96 trials per condition across blocks. Participants completed 12 practice trials before the study blocks.

Statistical Analysis

Data were cleaned, averaged and analyzed as in Experiments 1 and 2. A repeated measures ANOVA was performed on the mean reaction times with within-subjects factors of Expressions (3: fearful, happy, neutral tongue), Congruency (2: congruent, incongruent) and SOAs (200, 230, 300, 350ms).

<u>Results</u>

Target location accuracy was very high (*M* = 94.42%, *SD* = 4.18%); 5.58% of trials were excluded for incorrect, missed and timeout responses.

The classic gaze cuing effect was found (main effect of Congruency, *F*(1, 41) = 150.59, *MSE* = 532.13, $p < .001$, $\eta_p^2 = .79$) with shorter reaction times for congruent than incongruent trials (Fig.4a,c). A standard fore-period effect was observed with faster responses at longer than at shorter SOAs (main effect of SOA, *F*(1.81, 74.07) = 156.97, *MSE*=247.34, $p < .001$, $\eta_p^2 = .79$, Fig.4a).

A main effect of Expression was seen (*F*(1.674, 68.642) = 37.384, *MSE*=96.110, $p < .001$, $\eta_p^2 = .477$), qualified by an Expression by Congruency interaction (*F*(1.729, 70.88) = 31.94, *MSE* = 76.51, $p < .001$, $\eta_p^2 = .44$). Bonferroni corrected comparisons on the gaze cuing scores ($RT_{incongruent}$ - $RT_{congruent}$) showed that this interaction was due to a larger cuing effect for fearful than happy and neutral tongue trials (*ps*<.001, Mean fear – neutral tongue cuing effect difference = 9.7ms, 95% CI [6.5, 12.9]; Mean fear – happy cuing effect difference = 6.4ms, 95% CI [3.9, 8.9]). There was also a trending larger cuing effect for happy than neutral tongue trials (*p*=.083; Mean happy – neutral tongue cuing effect difference = 3.3ms, 95% CI [.3, -6.9]), though it should be noted that the happy versus neutral comparison only became significant with the less conservative Fischer's LSD correction (*p*=.028). This effect was confirmed with the congruent trials analysis below. Thus we found a gradient of emotion effects on gaze cuing, where fear produces the largest cuing effect, followed by the medium happy cuing effect, and then the smallest neutral tongue cuing effect (Fig.4d).

Follow-up ANOVAs were conducted on the congruent and incongruent trials separately. A main effect of Expression was found for both congruent (*F*(1.71, 69.96) = 49.01, *MSE* = 104.10, $p < .0001$, $\eta_p^2 = .55$) and incongruent trials (*F*(1.737, 71.216) = 13.278, *MSE* = 883.31, $p < .001$, $\eta_p^2 = .25$), albeit with a smaller effect size for the incongruent trials. Bonferroni-corrected paired comparisons confirmed faster RTs for congruent fear trials compared to congruent happy and congruent neutral tongue trials (p<.001 and p=.002 respectively; Mean fear – happy congruent RT difference = -2.9ms, 95% CI [-.9, -4.9]; Mean fear – neutral tongue congruent RT difference = -9.9ms, 95% CI [-7.2, -12.6]). Happy congruent trials were also faster than neutral tongue congruent trials (p<.001; Mean happy – neutral tongue congruent RT difference = -7ms, 95% CI [-4.1, -9.9]), as clearly seen on Fig.4c. For incongruent trials, happy faces elicited slightly shorter RTs than both neutral tongue and fearful faces (ps<.001, Fig.4c; Mean happy – neutral tongue incongruent RT difference = -3.7ms, 95% CI [-5.9, -1.5]; Mean happy – fear incongruent RT difference = -3.7ms, 95% CI [-5.307, -2.050]) while the latter two did not differ.

As in the two previous experiments, the three-way interaction between Expression, Congruency and SOA in the omnibus ANOVA was not significant (F= .946, p=.22). However, to ascertain that those effects were not driven by the longest SOAs, we re-ran the omnibus ANOVA with only the shortest two SOA conditions (200, 250ms) and still found the Expression by Congruency interaction significant (F(1.59, 65.52) = 10.49, MSE = 72.49, p<.001, η_p^2 =.204), confirming that emotion modulates the cuing effect even at SOAs of 200-250ms.

Finally, we separated right and left targets to looks for potential response compatibility effects, and found no main effect of target side (F= .78, p= .38), and no significant interactions between target side and SOA (F= 1.85, p=.14), target side and congruency (F= .07, p=.79), target side and emotion (F= 1.02, p=.35), target side, emotion and SOA (F= 2.24, p = .06), or target side, emotion, congruency and SOA (F= .83, p=.52). There was, however, an interaction between target side, emotion and congruency (F(2,82) = 5.45, p = .006, MSE = 179.57, η_p^2 = .12) as well as a target side, congruency and SOA interaction (F(2.81, 115.27) = 3.79, p = .014, MSE = 109.18, η_p^2 = .085). We thus ran separate ANOVAS on left target and right target trials and found significant emotion by congruency interactions for both right (F(1.58, 64.74) = 10.50, p < .001, MSE = 223.18, η_p^2 = .20) and left targets (F(2, 82) = 20.32, p < .001, MSE = 162.00, η_p^2 = .33). To compare the difference in gaze cuing between emotions on each side, we ran Bonferroni corrected paired comparisons on the gaze cuing effect directly (RT differences between incongruent and congruent trials). For the right targets, the gaze cuing effect was larger for fear than neutral tongue (p=.021) and happy faces (p<.001), while there was no difference between the neutral tongue and happy gaze cuing effects (p>.05). For the left targets, the gaze cuing effect was larger for fearful than neutral tongue (p<.001) and happy faces (p=.044), and also larger for happy than neutral tongue faces (p=.004). Thus, while the gaze cuing effect was largest for fear regardless of target side, the cuing effect for happy was larger than for neutral tongue faces for left targets only.

Discussion

Experiment 3 replicated the findings from Experiments 1 and 2, demonstrating that both fearful and happy expressions enhance gaze cuing relative to a neutral movement baseline. It also confirmed that fearful faces elicit a stronger cuing effect than happy faces as suggested by the indirect comparison of Exp.1 and 2. The magnitudes of these effects were remarkably similar to those found in Exp.1 and 2, with about 10ms more for fearful, and 5ms more for happy than for neutral tongue faces (Fig.4d, compared to Fig.2d and Fig.3d). As found in these two previous experiments, these small emotion benefits occurred mainly in congruent trials where a clear gradient emerged, with the fastest response times for fearful trials, followed by happy trials, and slowest responses for neutral tongue trials (Fig.4b,d). Interestingly, the happy incongruent trials also produced faster response times than both the neutral and fearful incongruent trials, a result we did not see in Exp.2. As the two experiments employed different SOAs, replication is necessary before we can interpret this result.

As in Experiments 1 and 2, we failed to find any effect of SOA on the emotional modulation of the gaze cuing effect (no three-way interaction of Expression, congruency and SOA) and still found a significant Expression by congruency interaction using only the two shortest SOAs. This finding goes against the claim that gaze cuing can be enhanced by emotional expressions only at SOAs longer than 300ms (Graham et al., 2010). In contrast, our results are in line with more recent neuroimaging findings suggesting an integration of facial expression and gaze cues around 200ms (Conty et al., 2012). Although lack of significant findings must always be treated with caution, the present results also do not support the idea that this integration occurs later for happy than fearful faces.

Finally, an analysis of left and right targets indicated that the emotion effects we report here cannot be explained by typical Simon (1990) effects between the target presentation side and the right hand used by most participants to respond. However, we did replicate the finding from Experiment 2, where happy-neutral tongue differences were present only for the left targets. We did not replicate the finding that fear-neutral differences were present only for left targets, as we found for the first two of the five SOAs used in Experiment 1.

How can we reconcile the present results with the previous literature reporting no emotion modulation of gaze cuing at SOAs shorter than 300ms for this type of dynamic paradigm, and no enhanced cuing effect for happy expression at any SOA? Gender imbalance can be ruled out given the balanced gender ratio in Exp.3. Trial number also does not seem to be the main reason. Despite being lower than in Exp.1-2, the number of trials used in Exp.3 was the same as used in Graham et al. (2010, Exp.5-6) and so this factor alone is unlikely the reason for our different results compared to that study. Small effect sizes are possible, as the magnitudes of the emotional enhancements of the gaze cuing effects are small. Most previous studies on gaze and emotion cue interaction did not report any measure of effect size but the few that did, reported partial eta square values for the congruency by emotion interactions that ranged from η_p^2=.05 (Neath et al., 2013) to η_p^2 =.21 and .22 (Lassalle & Itier, 2013), η_p^2 =.17 (Lassalle & Itier, 2015a) and η_p^2 =.31 (Lassalle & Itier, 2015b). Effect sizes were a bit larger in the present experiments (congruency x emotion η_p^2=.52 in Exp.1, .22 in Exp.2, .44 in Exp.3), which might be why we detected the happy effect. The magnitude of this happy effect is nonetheless very small and even in Exp.3, the difference between the happy and neutral tongue cuing effects was only trending with the Bonferroni correction, although it was significant with the less conservative Fischer's LSD correction. However, the faster cuing effect for happy expressions was seen in congruent trials even with Bonferroni correction, replicating the finding of Exp.2.

Two main differences exist between our study and Graham et al. (2010), the only study thus far to have attempted to control for apparent motion and to use various SOAs. The first difference is the use of multiple SOAs as separate conditions in our design while Graham et al. (2010) averaged several SOAs in their "short SOA" condition, including 175ms SOA which might have been too short for a full emotion and gaze cue integration. Thus, although they had a large number of trials in each condition, any possible effect on trials with SOAs greater than 200ms may have been cancelled by the shortest SOA trials they were averaged with. This possibility is supported by the magnitude of their cuing effect for fearful trials which was of 20ms at long SOAs (i.e. very similar to our 23ms for fear cuing in Exp.2 and 3) but only 13ms at their short SOA condition (see Exp.6, Table 6 p358 of their paper). The other main difference is the use of a neutral movement as a baseline condition to control for the apparent motion inherent to the use of facial expressions in dynamic displays. While the rest of the literature never controlled for facial motion, Graham et al. (2010) were the only ones to do so in their Exp.6. However, they added an emotional frame before presenting the neutral face so that their neutral condition with facial motion was not completely neutral. The results of Exp.2 and 3 suggest that the use of a neutral movement control might be necessary for studying the impact of emotional expressions on gaze cuing. However, despite our validation of the neutral tongue faces, it is still possible that these stimuli were perceived as different from the neutral condition classically used in the literature where no facial motion is present. Experiment 4 addressed this point.

EXPERIMENT 4 – fearful, happy, classic neutral, and neutral tongue faces

Results of Experiment 3 further supported our hypothesis that the emotional modulation of gaze cuing is not simply threat sensitive. We instead found an emotion gradient for gaze-congruent trials, with the largest cuing effect for fear (of about 23ms), a medium effect for happy (17ms), and the smallest effect for our neutral tongue baseline (13ms, see Fig.4d). In addition, this gradient was found using SOAs ranging from 200-350ms. While we presumed our results were mainly due to the use of a neutral condition wherein apparent motion was controlled for, and possibly to the use of multiple separate SOA conditions, we cannot rule out that other factors might be driving this effect. In particular, despite being rated significantly more neutral than the fearful and happy expressions in our validation study, the neutral tongue stimuli might still not be perceived in the same way as the classic neutral condition used in the literature. Perhaps the neutral tongue stimuli were perceived as displaying some affective information. Alternatively, as featural displacement is different between neutral tongue and emotional trials, it is possible that the tongue protrusion drew attention toward the lower part of the face and away from the cuing eyes, resulting in an altered cuing effect. To determine whether this was the case, in Experiment 4 we directly compared classic neutral faces, as previously used in the literature, to the neutral tongue, fearful and happy faces used in Exp. 1 to 3.

<u>Methods</u>

Participants

Participants were prescreened using the same selection criteria as in the other three experiments and received course credit for their time. Forty-seven participants were tested with 3 removed for poor accuracy, leaving a final sample of 44 participants (21 females, 23 males, mean age = 20.0 years ±*SD*=1.22; 38 right handed).

Experimental Design and Procedure

Experiment 4 used the same design as Experiment 3, with the addition of the “classic neutral” condition to the fearful, happy, and neutral tongue stimuli. The classic neutral condition consisted of neutral faces with no additional facial movement in the last sequence frame (see Fig.1), which is what previous gaze cuing studies have used. There were a total of 32 conditions

(4 expressions –fearful, happy, classic neutral, neutral tongue– X 2 congruency –congruent, incongruent– X 4 SOAs –200, 230, 300, 350ms), equally presented within each of the 12 blocks (256 trials/block, 96 trials per condition across blocks). Participants were given 16 practice trials before the first experimental block.

Statistical Analysis

The same data cleaning and averaging procedures used in the previous three experiments were applied here. A repeated measures ANOVA was performed on the mean reaction times with within-subjects factors of Expression (4: fear, happiness, classic neutral, neutral tongue), Congruency (2: incongruent, congruent), and SOA (4: 200, 250, 300, 350ms).

Results

Again, participants' accuracy was very high (*M* = 94.83%, *SD* = 4.13%) with few trials excluded as misses and time-outs (5.17%).

Participants responded faster to gaze-congruent than to gaze-incongruent targets, confirming a gaze cuing effect (main effect of Congruency: *F*(1, 43) = 100.84, *MSE* = 1064.99, *p* <.0001, η_p^2 =.701; Fig.5a,c). Participants also responded faster at the longer than at the shorter SOAs, resulting in a significant fore-period effect (main effect of SOA; *F*(2.08, 89.48) = 127.3, *MSE*=483.6, *p* <.001, η_p^2 = .748; Fig.5a). The cuing effect overall increased with longer SOAs (Congruency x SOA interaction, *F*(2.35, 101.06) = 4.59, *MSE*=248.7, *p* =.009, η_p^2 = .097).

A main effect of Expression was found (*F*(2.363, 101.630) = 16.6, *MSE*=324.9, *p* <.001, η_p^2 = .279; Fig.5a,c), which was further qualified by the significant Expression by Congruency interaction (*F*(2.348, 100.972) = 6.375, *MSE* = 234.6, *p* =.001, η_p^2 =.129). Follow-up comparisons on the gaze cuing effect scores ($RT_{incongruent}$ - $RT_{congruent}$) confirmed that the gaze cuing effect was larger for fear compared to the other three conditions (Bonferroni corrected, *ps*≤.013; Fig.5d; Mean fear – classic neutral cuing effect difference = 4.5ms, 95% CI [.7, 8.3]; Mean fear – neutral tongue cuing effect difference = 9ms, 95% CI [3.8, 14.3]; Mean fear – happy cuing effect difference = 6ms, 95% CI [1.7, 10.3]). In contrast, there was no difference in gaze cuing effect between the happy and the classic neutral trials or between the happy and the neutral tongue trials, despite overall smallest cuing effect for neutral tongue trials as clearly seen on Fig.5d. The cuing effect was also marginally larger for the classic neutral compared to the neutral tongue faces (*p*=.084 with Bonferroni correction, *p*=.014 with Fischer's LSD correction; Mean neutral tongue – classic neutral cuing effect difference = -4.6 ms, 95% CI [-9.5, .4]).

As before, separate follow-up ANOVAs were performed for the congruent and incongruent trials. A main effect of Expression was found for congruent trials (*F*(2.296, 98.721) = 9.27, *MSE* = 382.96, *p* <.001, η_p^2=.18). Bonferroni corrected comparisons indicated significantly faster response times for fearful congruent compared to both classic neutral and neutral tongue congruent trials (*ps*<.005; mean fear – classic neutral congruent RT difference = -7.3 ms, 95% CI [-1.7, -12.8]; mean fear – neutral tongue congruent RT difference = -7.4ms, 95% CI [-2.5, -12.3]), but not compared to happy congruent trials (*p*=1). Participants also responded to happy congruent trials significantly faster than to both neutral tongue congruent trials (*p*<.001; mean happy – neutral tongue congruent RT difference = -6.2ms, 95% CI [-2.6, -9.9]) and classic neutral congruent trials (*p*=.041; mean happy – classic neutral congruent RT difference = -6.1ms, 95% CI [-.2, -12.0]). Finally, RTs for the neutral tongue congruent and classic neutral congruent trials were not significantly different (*p*=1.0 with Bonferroni correction, *p*=.94 with Fischer's LSD test).

There was also a main effect of Expression for incongruent trials (*F*(2.375, 102.104) = 18.443, *MSE* = 185.232, *p* <.001, η_p^2=.30; Fig.5c). After Bonferroni correction, responses were slower to classic neutral than to all other expressions (*ps*≤.001; mean classic neutral - happy incongruent RT difference = 9.5 ms, 95% CI [13.0, 6.0]; mean classic neutral - fearful incongruent RT difference = 4.9 ms, 95% CI [8.3, 1.6]; mean classic neutral – neutral tongue incongruent RT difference = -5.8 ms, 95% CI [-9.3, -2.3]). Response times to happy incongruent trials were also faster than to fearful incongruent (*p*<.001; mean happy - fearful incongruent RT difference = -4.6ms, 95% CI [-2.1, -7.1]) and to neutral tongue incongruent trials as well, though the latter comparison was significant only using a less conservative Fischer's LSD test (*p*=.019; *p*=.11 with Bonferroni correction; mean happy – neutral tongue incongruent RT difference = -3.8 ms, 95% CI [.6, -8.0]). Response to fearful and neutral tongue incongruent trials did not differ (*p*=1.0 with Bonferroni, *p*=.56 with Fisher`s LSD).

Finally, as seen in Experiment 3, there was no congruency by emotion by SOA interaction (*F*(4.4, 189.5) = 1.21, *p*=.307, *MSE* = 386.4, η_p^2 = .027). Again, to ascertain that those effects were not driven by the longest SOAs, we re-ran the omnibus ANOVA with only the shortest two SOA conditions (200, 250ms), as done in Exp.3. We still found a significant Expression by Congruency interaction (*F*(2.48, 106.86) = 3.89, *MSE* = 154.18, *p* =.016, η_p^2 =.083), indicating that expression still modulates the cuing effect at SOAs of 200-250ms.

Again, we re-analyzed all the data using target side as another within-subjects factor. There was no main effect of target side (*F*= .140, *p*= .710), and no significant interaction between target side and emotion (*F* = 1.921, *p*=.129), target side and congruency (*F* = .025, *p*=.875), target side, congruency and SOA (*F* = 1.385, *p*=.250), target side, congruency and emotion (*F* = 2.144, *p*=.098), target side, emotion and SOA (*F* = .322, *p* = .929) or target side, emotion, congruency and SOA (*F* = .912, *p*=.488). Although there was an interaction between target side and SOA (*F*(3,129) = 3.414, *p*=.019, MSE = 230.134, η_p^2 = .074), the effect of target side was not significant at any SOA condition analyzed separately (200ms: *F*=.336, *p*=.565; 250ms: *F*=1.524, *p*=.224; 300ms: *F*=.135, *p*=.715; 350ms: *F*=.128, *p*=.723).

Discussion

The inclusion of both neutral tongue and classic neutral stimuli within the same study allowed us to bridge the gap between our first three experiments and the rest of the literature in which static neutral stimuli have been used. This difference in neutral condition baseline might be responsible for discrepancies with previous findings.

If we focus on the cuing effect itself (the difference between response times to incongruent and congruent faces), results of Exp.4 replicated the general findings of the literature: the cuing effect was larger for fearful than happy and classic neutral faces and the latter two did not differ. We also found that the cuing effect for fearful faces was larger than that to neutral tongue faces, replicating Exp.1 and 3 findings. However, concerning happy faces, we did not replicate the findings of Exp. 2 or 3 as the cuing effect for happy faces was statistically not different from that of neutral tongue faces. Importantly, the cuing effect for classic neutral faces was somewhat larger than that for neutral tongue faces, although statistical significance was found only with a less conservative Ficher's LSD correction. Overall, the pattern of data suggests that neutral tongue faces elicited the smallest cuing effect, fearful faces elicited the largest cuing effect, and happy and classic neutral faces elicited intermediate cuing effects (Fig.5d). The picture, however, becomes clearer if we take into account congruent and incongruent trials separately.

We observed significant differences between neutral and emotional faces during the congruent trials. Indeed, happy and fearful faces elicited similar response times that were both shorter than responses elicited by the classic neutral and neutral tongue faces. This effect replicates the findings of Exp.1, 2 and 3 when emotional faces were compared to neutral tongue faces in congruent trials. In other words, faster orienting of attention was seen for targets appearing in the gazed-at location when the face expressed an emotion (whether positive or negative), compared to neutral stimuli that contained apparent motion (neutral tongue) or not (classic neutral). The difference found between neutral and emotional trials can thus be attributed to the affective content of the facial expressions, rather than the apparent motion of the face. If apparent motion was the driving force behind emotional effects then neutral tongue faces should have elicited shorter responses than classic neutral faces in congruent trials.

Incongruent trials, on the other hand, seem to reflect a mixture of effects. Responses to fearful, happy but also neutral tongue faces were all significantly shorter than responses to the classic neutral faces. As classic neutral faces differed from the neutral tongue faces only on the apparent motion content, and as this apparent motion is common to neutral tongue and emotional faces, we conclude that apparent motion sped up responding to incongruent targets in general. In addition, a further effect of positive affect might be at play, as responses were even shorter for incongruent happy compared to both incongruent fearful and incongruent neutral tongue faces, which elicited similar responses (Fig.5c). The latter finding replicates what was found in Exp.3 for happy incongruent trials, although the reason why it was not found in Exp.2 is unclear. Thus, despite eliciting shorter responses in congruent trials, happy faces elicited overall an intermediate cuing effect in Exp.4 because of shorter responses in the incongruent condition, making the incongruent-congruent difference (the cuing effect) smaller.

The present pattern of results are unlikely due to attention to specific features. In particular, while the emotional faces involve featural changes in both the upper and lower parts of the face, the neutral tongue faces involve a change only to the lower part of the face. Tongue protrusion could thus have drawn attention away from the eye-region. If this was the case, then, during congruent trials, we would expect less orienting (and thus longer RTs) for neutral tongue trials than for emotional trials but also less orienting for neutral tongue trials than for classic neutral trials in which there was no movement. While we found longer RTs for congruent neutral tongue than emotional trials (Exp.3 and 4), neutral tongue and classic neutral trials elicited the same congruent responses in Exp.4. Thus, attention to the lower part of the face in the neutral tongue trials is not likely to account for the present results. Finally, the analysis of left and right target trials suggest that compatibility effects (right hand-right targets) were not at play and, contrary to what we found in Experiments 1-3, that these emotion differences were present for both left and right targets.

The present results support the idea that neutral tongue and classic neutral faces were both perceived as neutral. One could argue that the tongue protrusion might be perceived as reflecting some form of disgust. However, disgusted faces are rated as having a strong negative valence similar to that of fearful expressions (Russel & Bullock, 1985) while our validation study revealed that fearful faces were rated as negative but neutral tongue faces as neutral. Disgusted faces with a tongue protrusion also have other characteristic facial features (e.g. an upper lip raise and gape; Rozin, Lowery & Ebert, 1994) not present in our stimuli which were modified from neutral faces. Finally, previous reports have shown that disgusted and happy expressions produce equal gaze cuing effects (Bayliss, Frischen, Fenske, & Tipper, 2007) while we found larger cuing effect for happy than neutral tongue faces and, most importantly, similar responses for neutral and classic neutral faces in congruent trials (both longer than responses to emotional faces). For all these reasons, and given the pattern of results, we believe that our neutral tongue faces were perceived as neutral and that the differences elicited compared to classic neutral faces are attributable to the difference in perceived motion. However, we acknowledge that tongue protrusions might still elicit a unique perceived motion, different from the apparent movement perceived in the fearful and happy facial expressions. This represents a limitation of this present study. Future gaze cuing research could use a different neutral movement or find a way to quantify the apparent motion in each condition to help clarify this issue.

GENERAL DISCUSSION

Being able to appropriately integrate gaze cues with facial expressions is a necessary step in understanding people's mental states and reactions to their environment. In the present set of experiments we investigated this integration by monitoring the impact of fearful and happy expressions on gaze cuing. We used a dynamic gaze cuing paradigm where gaze shifts preceded emotional expressions, as if the person was reacting to an object in the environment. This type of cue sequence is more ecologically valid and has been shown to elicit the largest cuing response (Lassalle & Itier, 2015a). To control for the perceived motion of the face cue in the emotion trials, we created a neutral movement condition with a tongue protrusion that was perceived as neutral in a separate validation study. While this is a methodological point tied to this particular paradigm, it is an important one that enabled new findings regarding the integration of gaze and emotion cues that are important for informing theories of social attention.

Indeed, we found a larger cuing effect for fearful compared to happy and both neutral tongue and classic neutral faces (Experiments 1, 3 and 4), replicating previous reports in the literature using this particular dynamic sequence and a classic neutral condition without movement (Graham et al., 2010; Lassalle & Itier, 2015a, Neath et al., 2013). We also found a consistently larger cuing effect for happy than neutral tongue faces (Experiments 2, 3). However, this happiness effect was no longer present when the comparison was made to classic neutral faces (Exp.4), replicating the lack of difference between happy and classic neutral faces reported in the literature with this particular dynamic sequence (Graham et al., 2010; Lassalle & Itier, 2015a, Neath et al., 2013).

Past reports of gaze-orienting enhancement with fearful, (Bayless, Glover, Taylor, & Itier, 2011; Graham, Friesen, Fichtenholtz, & LaBar, 2010; Lassalle & Itier, 2013; 2015a; 2015b; Neath, Nilsen, Gittsovich, & Itier, 2013; Putman, Hermans, & Van Honk, 2006; Tipples, 2006), angry (Holmes et al., 2006; Lassalle & Itier, 2013; 2015a) and surprised (Bayless et al., 2011; Lassalle & Itier, 2013; 2015a; Neath et al., 2013), but not happy expressions (Holmes et al., 2006; Lassalle & Itier, 2013; 2015a; Neath et al., 2013; Putman et al., 2006; Tipples, 2006), have contributed to the generally accepted idea that the gaze-orienting attention network is only reliably modulated by facial expressions that signal nearby danger or uncertainty (i.e. possible danger). The present study demonstrates that, when perceived movement is controlled for, happy expressions also modulate gaze cuing. This finding is in line with the idea, supported by neuroimaging (eg. N'Diaye et al., 2009; Sander et al., 2003; Wang et al., 2014), that expressions which do not signal threat also likely impact this network. This methodological point thus has a significant theoretical impact and our results highlight the need to control for perceived motion in dynamic gaze cuing paradigms.

Our results also suggest that in addition to examining the cuing effect itself, studies would benefit from reporting congruent and incongruent trials separately, to start teasing apart the contribution of various factors to social attention. The present pattern of results suggests there are two factors at play which can impact attention. The first factor is the emotional content of the face which boosts attention orienting towards the gazed-at location. Indeed, congruent trials separated emotional (fearful, happy) from neutral expressions (neutral tongue or classic neutral), a pattern also reported in recent studies (Lassalle & Itier, 2013, 2015a, 2015b; Neath et al., 2013). The second factor is the perceived motion that occurs during emotion or neutral movement trials, which seems to impact the incongruent trials, although possibly at shorter SOAs only (effect found in Exp.3-4 but not Exp1-2). In incongruent trials, attention is first oriented toward the direction signaled by gaze, and has to orient back to the opposite target location. Facial motion appears to speed up this attention reorienting in short SOA trials.

We also analyzed our results for left and right targets separately to investigate if compatibility between the target side and response hand (right hand for the majority of the participants in every experiment) was responsible for our reported emotion effects. We found no consistent pattern of effects in line with a systematic Simon effect (1990) that could explain our fear or happy gaze cuing effects. We did find that the larger gaze cuing effect for happy trials was driven by responses to left targets in Experiment 2 and 3, though this did not replicate in Experiment 4. Our findings in Experiment 1 also suggested that our fear effect at the two shortest SOAs was driven by the left, but not right targets, though again, this did not replicate in Experiment 4. Overall, these results suggest that Simon effects are unlikely at play in these emotional modulations of the gaze cuing effect, but that target side may be an interesting factor to investigate further in future studies.

While our results cannot speak directly to the mechanism behind the increased orienting by fearful and happy cues, one possibility is that the mechanism is based on arousal rather than on valence. This idea will have to be tested by future studies, but our validation study results might offer some preliminary insight. Despite being opposite in valence, our happy and fearful faces were rated by participants as equally arousing, and more arousing than the neutral tongue stimuli. Those arousal ratings generally mapped onto the pattern of RTs seen for congruent trials (faster RTs for emotion than neutral trials), though fearful faces did produce more orienting than happy faces (at least in Exp.3), despite having equal arousal ratings.

Our study also makes a contribution to the literature with regard to the timing of the integration between gaze and emotion cues. Our results demonstrate that, contrary to the 300ms threshold proposed for such an integration (Graham et al., 2010), gaze cues interact with fearful and happy expressions at SOAs as short as 200ms (the earliest SOA tested), persisting up until SOAs of 700ms (the longest tested). These results are in line with recent neuroimaging studies reporting multi-cue integration as early as 200ms (Conty et al., 2012). They are also in line with a large ERP literature suggesting that both facial expressions and gaze direction are discriminated before 200ms (Calvo and Numenmaa, 2015; Itier & Batty, 2009), making it very likely that the two start integrating around this time. However, we were not able to find support for the idea that gaze and fearful cues are integrated more quickly than gaze and happy cues, as increased gaze cuing for both started at 200ms. Intuitively, a fast reaction in response to a fearful expression would be advantageous for survival, as it would orient attention faster to environmental threats. Although faster orienting in response to happy expressions is unlikely advantageous in the same manner, it is likely useful for other reasons. For example, an averted gaze combined with a happy expression could indicate a reward in the environment, or the initiation of a social interaction, which could be beneficial to attend to quickly. Finally, using social cues to infer another's emotional response to an unfamiliar object is a useful way to quickly learn the threat or reward value of the object without a direct interaction.

The learning of associations between emotional reactions and objects in the periphery appears to be mediated by the amygdala, which displays increased activity in response to happy and fearful expressions when directed towards objects relative to just the presentation of the emotional expressions (Hooker et al., 2006). Many other studies have also reported amygdala involvement in reward processing (e.g. Ambroggi, Ishikawa, Fields, & Nicola, 2008; Holland & Gallagher, 2004; Murray, 2007; Sander et al., 2003), suggesting that the amygdala plays an important role in using emotional reactions to learn both positive and negative associations. This research, along with studies demonstrating that the amygdala displays sensitivity to gaze direction (Sauer, Mothes-Lasch, Miltner & Straube, 2014), positive and negative facial expressions (Breiter et al., 1996; Yang et al., 2002; Wang et al., 2014) and interacts with the social orienting network (Hoffman et al., 2007; Kawashima et al., 1999; N'Diaye et al., 2009), makes the amygdala a strong candidate for mediating the emotional modulation of the gaze cuing effect. If this is the case, it is possible that the greater impact of fearful expressions reflects greater or different amygdala activation in response to fear cues than happy cues. For example, Hoffman et al., (2007) and Murray (2007) reported distinct patterns of amygdala activity for threatening versus other types of arousing face stimuli suggesting that different amygdala areas may be recruited for varying types of emotional stimuli. Future neuroimaging studies investigating emotional modulation of the gaze-orienting effect can further speak to this.

CONCLUSION

Previous gaze-orienting and emotion literature has emphasized the theoretical significance of making a distinction between emotional expressions that signal threat versus no threat. The implicit assumption in this distinction is that there is an adaptive mechanism that engages only during threatening situations. The present study provides support for the idea that emotional modulation of attention orienting by gaze cues is not just about threat. While fearful expressions produce greater attention orienting than happy expressions, happy expressions also orient attention more than neutral expression. Although these results cannot speak to the mechanism by which happy expressions modulate the gaze cuing effect, nor explain the etiology of the difference between happy and fearful gaze cuing effects, they provide support for an emotional orienting mechanism that reacts to both positive and negative expressions. The magnitude difference between attention orienting by fearful and happy expressions likely reflects a quantitative difference in the level of engagement in response to happy versus fearful faces, possibly mediated by the amygdala.

DISCLOSURE STATEMENT

We report no potential conflicts of interest.

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Table 1. *Participants' mean ratings of valence and arousal for each sequence type (standard errors to the mean in parenthesis).*

Measures	Fear	Neutral Tongue	Happy
Valence	3.16(.09)	4.73(.12)	7.18(.11)
Arousal	6.38(.13)	3.31(.16)	6.13(.19)

Notes: valence measured from: 1/ very negative to 9/ very positive; arousal measured from: 1/very unarousing to 9/ very arousing

Figure captions

Figure 1. Sample stimuli and sample trial used in Experiments 1-4. In Experiment 1, only Fear and Neutral tongue conditions were used; in Experiment 2, only Happy and Neutral tongue conditions were used; in Experiment 3, Fear, Happy and Neutral tongue conditions were used; in Experiment 4, Fear, Happy, Neutral tongue and Classic Neutral conditions were used. In Experiments 1 and 2, SOAs (from gaze shift onset until target onset) ranged from 300ms to 700ms, while in Experiments 3 and 4, SOAs ranged from 200ms to 350ms. In the stimuli validation study, the last frame was only presented for 400ms and there was no target presented.

Figure 2. Results for Exp.1 (error bars represent standard error of the mean). **a)** Reaction times during congruent and incongruent trials for Fear and Neutral tongue faces at each SOA. **b)** The difference between congruent and incongruent reaction times (gaze cuing effect) by expression at each SOA. **c)** Mean congruent and incongruent reaction times by expression, collapsed across all SOAs. **d)** Overall gaze cuing effect for fearful and neutral tongue expressions, collapsed across SOA.

Figure 3. Results for Exp.2 (error bars represent standard error of the mean). **a)** Reaction times during congruent and incongruent trials for Happy and Neutral tongue faces at each SOA. **b)** The congruent and incongruent reaction time difference (gaze cuing effect) by expression at each SOA. **c)** Mean congruent and incongruent reaction times by expression, collapsed over all SOAs. **d)** Gaze cuing effect for Happy and Neutral tongue expressions averaged across all SOAs.

Figure 4. Results for Exp.3 (error bars represent standard error of the mean). **a)** Reaction times during congruent and incongruent trials for each expression and SOA. **b)** The congruent and incongruent reaction time difference (gaze cuing effect) by expression at each SOA. **c)** Mean congruent and incongruent reaction times for each expression, collapsed over all SOAs. **d)** Overall gaze cuing effect for each expression, collapsed over all SOAs.

Figure 5. Results for Exp.4 (error bars represent standard error of the mean). **a)** Reaction times during congruent and incongruent trials for all SOAs and expressions. **b)** Congruent and incongruent reaction time difference (gaze cuing effect) at every SOA for each expression. **c)** Congruent and incongruent reaction times by expression, averaged across all SOAs. **d)** Mean gaze cuing effect across all SOAs for each expression.