Individual differences in the emotional modulation of gaze-cuing

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ABSTRACT:

Gaze-cuing refers to the spontaneous orienting of attention towards a gazed-at location, characterized by shorter response times to gazed-at than non-gazed at targets. Previous research suggests that processing of these gaze cues interacts with the processing of facial expression cues to enhance gaze-cuing. However, whether only negative emotions (which signal potential threat or uncertainty) can enhance gaze-cuing is still debated, and whether this emotional modulation varies as a function of individual differences still remains largely unclear. Combining data from seven experiments, we investigated the emotional modulation of gaze-cuing in the general population as a function of participant sex, and self-reported subclinical trait anxiety, depression, and autistic traits. We found that i) emotional enhancement of gaze-cuing can occur for both positive and negative expressions, ii) the higher the score on the Attention to Detail subscale of the Autism Spectrum Quotient, the smaller the emotional enhancement of gaze-cuing, especially for happy expressions, and iii) emotional modulation of gaze-cuing does not vary as a function of participant anxiety, depression or sex, although women display an overall larger gaze-cuing effect than men.

KEYWORDS:

emotional expression, gaze-cuing, individual differences, sex differences, subclinical anxiety and depression, autism spectrum quotient

INTRODUCTION

People spontaneously orient their attention in the direction of other people's gaze. This basic form of social attention, called gaze-cuing, is a well-studied phenomenon indexed by faster detection of gazed-at than non-gazed-at peripheral targets in gaze-cuing paradigms (Friesen & Kingstone, 1998; Driver et al., 1999; Frischen et al., 2007). Akin to gaze following and joint attention, gaze-cuing is often considered a stepping stone towards making sophisticated inferences about others' mental states (e.g., he is looking at the car, so he is thinking about it; she is looking away, so she is not paying attention to me; Baron-Cohen, 1995). Recent research supports the idea that intact gaze-cuing is important for social functioning. Indeed, alterations in gaze-cuing are associated with reduced social competence (Hayward & Ristic, 2017) and increased psychopathy traits (Hoppenbrouwers et al., 2017) in neurotypical individuals, and have been documented in those with autism spectrum disorder (e.g. Uono, Sato, and Toichi, 2009; Gillespie-Lynch, Elias, Escudero, Hutman & Johnson, 2013), a condition characterized by social impairment.

Facial expressions provide important clues regarding an individual's affective state (Ekman & Friesen, 1971). When combined with gaze cues, they offer insight into an individual's affective response to the object they are gazing at. For instance, someone looking towards an object and then expressing fear is typically interpreted as the person being afraid of the object, which signals possible danger. In contrast, the expression of joy in a similar scene would signify that the object is potentially pleasurable. Being able to appropriately integrate facial expressions and gaze cues thus allows the perceiver to understand the attitude of the gazer toward the object, as well as the possible quality of the object (e.g., dangerous or pleasurable). For that reason, it has been suggested that facial expressions could boost attention orienting, especially if this could help with survival. In particular, quick orienting towards the focus of fearful gaze could be orienting to an environmental threat, which would require fast detection (e.g., Holmes et al., 2006; Tipples, 2006; Graham, Friesen, Fichtenholtz, & LaBar, 2010).

Support for this view is provided by studies reporting larger gaze-cuing with fearful compared to neutral expressions (Fichtenholtz, Hopfinger, Graham, Detwiler, & LaBar, 2009; Graham et al., 2010; Holmes, Mogg, Garcia, & Bradley, 2010; Lassalle & Itier, 2013; 2015a; 2015b; Neath, Nilsen, Gittsovich, & Itier, 2013; Putman, Hermans, & Van Honk, 2006; Tipples, 2006), although some studies have also reported a similar effect with surprise (Bayless et al., 2011; Lassalle & Itier, 2013; 2015a; Neath et al., 2013) and anger (Holmes et al., 2006; Lassalle & Itier, 2013;

2015a). In contrast, most studies have failed to find statistically significant modulation of gaze-cuing by happiness, a positive and non-threatening expression (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; see Table in Appendix for summarized data from other seminal gaze-cuing papers). These findings have led to the generally accepted view that the emotional modulation of gaze-cuing predominantly reflects attention orienting to threat or potential threat.

Recently, however, McCrackin and Itier (2018) showed that happy expressions can also increase gaze-cuing compared to neutral faces, albeit to a lesser extent than fearful faces. They used dynamic sequences in which gaze shifts occurred prior to the expression, as if the person was reacting to an object in the environment, a sequence which has been shown to elicit the largest cuing effects (Lassalle & Itier, 2015a). They also controlled for perceived motion inherent to this type of sequence by using neutral faces with a tongue protrusion (see McCrackin & Itier, 2018 for more details). They found that the largest gaze-cuing effect occurred in response to fearful expressions, followed by happy expressions, which themselves elicited a larger gaze-cuing effect than neutral faces with tongue protrusion. This pattern was seen with stimulus onset asynchronies (cue to target time intervals) as short as 200ms and up to 700ms. In contrast to a strict threat/non-threat explanation of gaze-cuing modulation by facial expressions, they proposed an “emotion gradient” response (McCrackin & Itier, 2018), whereby positive expressions also enhance gaze-cuing relative to neutral expressions, but to a lesser degree than threat-related expressions. This emotion gradient response still fits with the idea that it may be adaptive to orient more to emotional than neutral gaze-cues, as orienting toward objects producing a positive affective response could lead to a potential reward or social interaction.

Although McCrackin and Itier (2018) suggested that controlling for apparent motion in this dynamic gaze-cuing paradigm helped reveal the happy-neutral difference in gaze-cuing, they also suggested that the small effect size for this comparison might be part of the reason why previous studies failed to report this effect statistically. If there is indeed an emotion gradient, emotional modulation by happy expressions will simply be harder to detect in individual studies due to the small effect size. This idea is supported by the observation that the neutral<happy<fearful gradient of gaze-cuing effect was observed in two previous studies. These studies reported a significant fear-neutral difference but a non-significant happy-neutral difference (Neath et al., 2013; Lassalle & Itier, 2015a). They used the same dynamic sequence as McCrackin & Itier (2018) yet did not control for apparent motion. If effect size is the main reason why the neutral-happy difference does not reach significance, a large enough sample size should allow for detection of the emotion

gradient even without controlling for apparent motion. One goal of the present study was to test this idea by grouping together several experiments using the same dynamic sequence as the McCrackin and Itier (2018) study, but no control for apparent motion.

The second goal of the present study was to capitalize on this large sample to investigate whether the emotional modulation of gaze-cuing varies as a function of several individual differences. Previous studies with smaller samples have reported a relationship between fearful gaze-cuing and self-reported anxiety level, which has been interpreted as support for the theory that anxious individuals allocate increased attention to threat-related stimuli. Fox, Mathews, Calder, and Yiend (2007), Holmes, Richards, and Green (2006) and Mathews et al. (2003) reported that enhanced gaze-cuing by fear was found only for highly-anxious individuals as measured by the State-Trait Anxiety Inventory (STAI; Speilberger et al., 1983). Putman et al. (2006) and Tipples (2006) reported that their fear effect was present for neurotypical individuals, but positively correlated with STAI and Emotionality, Activity and Sociability Temperament Survey (EAS; Buss & Plomin, 1984) scores, respectively.

However, the relationship between anxiety and fearful gaze-cuing has not been replicated in recent studies using the dynamic gaze-cuing sequence with gaze shifting before the onset of the expression (e.g. Lassalle & Itier, 2015b; Neath et al., 2013), despite this sequence eliciting the largest emotional effects on gaze-cuing (Lassalle & Itier, 2015a). Is it possible that the earlier studies reporting significant correlations may have been detecting relations linked to the type of sequence used. For example, Fox et al. (2007) presented the emotional expression before the gaze shift, while Holmes et al. (2006), Mathews et al. (2003) and Tipples (2006) presented the gaze shift with a concurrent emotional expression (see Table in Appendix). Another possibility is that the STAI, the most commonly used anxiety measure in previous gaze-cuing and emotion research, may be detecting a unique construct that relates to gaze-orienting, whereas the STICSA (State-Trait Inventory for Cognitive and Somatic Anxiety, Ree et al., 2008), which was used in Lassalle & Itier (2015b) and Neath et al., (2013), does not. Some have reported that the STAI does not differentiate well between anxiety and depression (Kennedy, Schwab, Morris, & Beldia, 2001), so it could even be driven by depression, which was not measured in any of those studies. All the present experiments included the STICSA self-report measure of trait anxiety (Ree et al, 2008), and many included the self-report Center for Epidemiologic Studies Depression Scale (CESD; Radloff, 1977), allowing us to investigate whether high anxiety traits, depression, or both, increase the gaze-cuing effect for fearful faces, denoting a possible threat in the environment. Based on Lassalle & Itier (2015b) and Neath et al., (2013), we predicted no significant correlation between STICSA anxiety scores and gaze-cuing for any emotion. It was unclear whether depression scores may or may not be related to gaze-cuing by various emotions.

Participant sex is another individual difference which appears to modulate gaze-cuing, as larger neutral gaze-cuing effects have been reported for women compared to men (Alwall, Johansson and Hansen, 2010, Bayliss et al., 2005; Feng et al. 2011, Deaner et al. 2007; Hayward & Ristic, 2017). These findings may align with data suggesting that women display a higher sensitivity to social cues (e.g. Hall, 1978), and Alwall et al's (2010) observation that women are considered to be more social than men. Feng et al. (2011) proposed that enhanced gaze-cuing in women may result from earlier maturation in the visual spatial attention network. Importantly, to the best of our knowledge, all these studies have only used neutral faces. In addition to replicating the sex difference in neutral gaze-cuing effect, we investigated whether women would also show enhanced emotional modulation of gaze-cuing relative to men. We predicted that they would, based on data suggesting that women display an advantage in the perception of facial expressions (e.g. Hall & Matsumoto, 2004, McClure, 2000, McClure et al. 2004).

Finally, individual differences in subclinical autistic-traits have been reported to impact neutral gaze-cuing. Bayliss et al. (2005) and Hayward and Ristic (2017) reported that higher overall scores on the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), a self-report measure that quantifies subclinical autistic traits, were associated with smaller gaze-cuing effects. In contrast, Bayliss & Tipper (2006) failed to replicate this effect, potentially because of a smaller sample size (N=48) than those in the other studies (80 in Bayliss et al., 2005 and 64 in Hayward & Ristic, 2017). As far as we know, only one previous study has examined the impact of subclinical autistic traits on the emotional modulation of gaze-cuing. In a sample of 68 participants, Lassalle and Itier (2015b) found that gaze-cuing for happy faces, but not fearful faces, was smaller in individuals with high AQ scores than those with low AQ scores. The happy gaze-cuing effect was negatively related to the overall AQ score, as well as to the Attention to Detail and Imagination subscale scores. These correlations remained after controlling for participants' anxiety, as measured by the STICSA. The authors proposed that these correlations might reflect a decreased reward association when viewing a happy face, while orienting in response to fearful faces might be preserved because it has more direct relevance for survival. However, studies investigating emotional expression processing in individuals with a diagnosed ASD have indicated that autistic traits are associated with impairments in processing other emotional expressions, including fear (Harms, Martin, & Wallace, 2010), and a lack of increased gaze-cuing for fearful compared to neutral faces has been reported in a group of individuals with ASD (Uono et al., 2009). Furthermore, if the emotion gradient hypothesis is correct, emotional modulation by fearful and happy expressions may reflect differing levels of engagement from the same brain areas, which would make it unlikely that subclinical autistic traits might affect responses to one expression but not the other. We predicted that our large sample size would reveal correlations between AQ scores and both happy and fearful expressions.

In summary, whether happy expressions also increase gaze-cuing compared to neutral faces in the absence of a control for apparent motion, remains unclear. There is preliminary evidence that participants' sex and subclinical autistic traits modulate *neutral* gaze-cuing, but how these individual differences, as well as individual differences in anxiety and depression, modulate *emotional* gaze-cuing, remain largely unclear. Pooling data from seven experiments to obtain a robust sample size, the present study focused on the modulations of the gaze-cuing effect with neutral, happy and fearful facial expressions. We predicted the following: 1) Emotional modulation of gaze-cuing occurs for both fearful and happy expressions, with fear cuing effect > happy cuing effect> neutral cuing effect. 2) Women have a larger gaze-cuing effect and stronger emotional modulation of gaze-cuing than men. 3) Self-reported trait anxiety as measured by STICSA scores is not related to increased emotional modulation of gaze-cuing by fearful expressions but depression scores might be. 4) Higher scores on the Autism Quotient are associated with decreased emotional modulation of gaze-cuing by all expressions, although the relationship might be strongest for happy expressions.

METHODS

Data from 7 experiments run in our lab over the past few years were aggregated to obtain large sample sizes. Three of these experiments were taken from separately published studies (Experiments 1-2 from McCrackin & Itier, 2018 and Experiment 3 from Neath et al., 2013 –adult group only); the rest represent unpublished data sets.

Participants

All experiments received ethics clearance by the University of Waterloo Research Ethics Board. Participants were 18-29 year-old undergraduate and graduate students from the University of Waterloo who provided written informed consent upon arrival and received course credit, or were paid $10 an hour, for their time. They reported having lived in Canada or the United States for at least 5 years (Experiments 1-2) or being born and raised in North America (Experiments 3-7).

All individuals had normal or corrected-to-normal vision, reported no history of psychiatric or neurological illness, no consumption of psychiatric medication or daily recreational drug use, and no past loss of consciousness spanning over 5 minutes. In Experiments 1-2 participants' ability to identify emotional expressions was at least 7 on a Likert scale ranging from 0 (very poor) to 10 (extremely good). In Experiments 3-7 participants were given a recognition test with 40 emotional faces. They were asked to circle which of five emotion words each face was expressing, and only those who achieved at least 50% accuracy per emotion were included. Thus, none of the participants had serious issues with decoding facial expressions.

Across all experiments, 226 participants were tested. Of those, five were excluded for failing to complete the experiment, four for having a target localization accuracy of less than 80%, one due to a saving error, and five for exceeding experimental group reaction time means (deviating by more than 2.5 SD). This left a final sample of 211 participants available for the present study. Table 1 displays the final number of participants and the male/female ratio from each experiment, along with mean age and scores on the various scales used (see details below). The number of participants included varied with each analysis, as detailed later.

Self-report measures

The trait portion of the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree et al., 2008) assesses cognitive and somatic symptoms of anxiety as they pertain to one's mood in general (21 questions). Scores range from 21 to 84 with scores of 43 indicating probable cases of clinical anxiety disorders (Van Dam, Gros, Earlywine & Antony, 2013). All experiments included the STICSA (see Table 1 for score ranges in each study).

The Autism-Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) consists of a set of 50 items probing cognitive and behavioural subclinical autistic traits in the domains of Attention to Detail, Attention Switching, Social Skills, Imagination and Communication. Two methods of scoring have been used to assess these traits. The Binary scoring system used by Baron-Cohen et al. (2001) involves scoring an item as 1 for any endorsement of the autistic trait (i.e. a 'slightly agree' or 'definitely agree' response), with a score of 0 for other responses ('slightly disagree' or 'definitely disagree'). Overall binary AQ scores range from 0-50 and a score of 32 or higher indicates a high likelihood of having an Autism Spectrum Disorder (Baron-Cohen et al., 2001). This scoring has traditionally been used in the gaze-cuing literature (Bayliss et al., 2005; Hayward & Ristic, 2017), and so we included it here. However, as Austin (2005) pointed out, the degree of endorsement of each item contains valuable information which can further discriminate between participants. Austin (2005) recommended scoring each subscale with a four-point scoring system, which scores the degree of each response (‘definitely disagree’, ‘slightly disagree’, ‘slightly agree’, ‘definitely agree’) from 1-4 for each item (Austin, 2005). With this scoring, higher item-item correlations are obtained and overall AQ scores range from 50-200. In the present study we also included this scoring method to further elucidate the relationship between individual differences in autistic traits and the gaze-cuing effect[1]. The AQ was included in Experiments 4-7 (Table 1).

The Center for Epidemiologic Studies Depression Scale (CESD; Radloff, 1977) is a measure of self-reported depression. The CESD consists of 20 items probing negative mood and functional impairment in the last week. Scores range from 0 to 60, with a suggested clinical cut-off of 16 or higher. This scale was included in Experiments 1-2 and 4-5 (Table 1).

Stimuli

For the present study, we selected only incongruent and congruent happy, fearful and neutral trials amongst the possible emotion trials available in each experiment (Table 1). We describe only the details relevant to these trials below. Note that all conditions were within-subject conditions in each original experiments and are thus kept as within-subject factors for the current study.

For all experiments, the same pictures of four female and four male identities expressing fear, joy or no emotion (neutral) were taken from the NimStim database (Tottenham et al., 2009)[2].The ears, hair and clothes were removed, leaving the face in an oval (see Figure 1). The pupils of direct gaze pictures were moved to the right and left corners of the eyes to create averted left and averted right gaze images for each facial expression and identity. The GNU Image Manipulation Program (GIMP, version 2.8.0) and Photoshop Version 11.0 were used for photo editing. There was one direct gaze image (direct neutral) and six averted gaze images (4 emotions -fearful, happy, neutral- x 2 gaze directions -left, right-) per identity.

All images were converted to greyscale and, in each study, the SHINE toolbox (Willenbockel et al., 2010) was used to equalize the Root Mean Square (RMS) contrast and pixel intensity (PI) for

[1] Note that the AQ 4-point scoring has been used in other fields, e.g. in studies investigating face recognition (Halidays et al., 2014; Rhodes et al., 2013; Valla et al, 2013)

[2] Identities: 02, 03, 06, 09, 20, 22, 24, 27. 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.

each of the gaze and emotion picture categories (paired t-tests confirmed no significant differences in RMS or PI between conditions, $p > .1$). Experiments 1-2 also controlled for any facial asymmetry that could affect the allocation of attention by flipping each image about the y-axis to double the number of images (e.g. the flipped averted left neutral was also used as a second averted right neutral image).

Experimental Design and Procedure

All experiments were programmed using Experiment Builder (SR Research), with the exception of Experiment 3, which was programmed using Presentation Software (Neurobehavioural Systems). Participants completed a target localization task while fixating on a dynamic cuing sequence, which created the appearance of a face averting its gaze and then reacting with a fearful or happy expression or not reacting at all (neutral expression). Faces were presented centrally on a grey (Exp. 3) or white (all other experiments) background.

Every trial (Figure 1) started with a randomly jittered fixation cross, which remained on screen for the entire session for all experiments but Exp.3, where it disappeared at the onset of the first face image. The dynamic face sequence immediately followed, beginning with a neutral direct gaze face, followed by the same neutral face with an averted gaze, and ending with the averted-gaze face expressing an emotion (happiness, fear) or remaining still (neutral; see Figure 1). The target was a black asterisk presented equally on the left and right sides of the screen, centered vertically. Participants were instructed to press a key corresponding to the side that the target appeared on. When the target was on the side that the face looked towards, the trial was congruent. An incongruent trial occurred when the target was on the opposite, non-gazed-at side. Trial presentation was randomized within each block so that there were an even number of congruent right, congruent left, incongruent right and incongruent left trials. Specific frame timing and key response details can be found for each experiment in Table 1. For Experiments 1 and 2, only trials with a 500ms stimulus-onset asynchrony (SOA; the timing between the gaze shift and target presentation) were selected; the SOA was 500ms for all trials in all the other studies.

Upon arriving to the lab, participants gave written informed consent before receiving instructions to complete the target-localization task as quickly and accurately as possible. The importance of fixating on the fixation cross was stressed and they were informed that the faces' gaze direction did not predict where the target would appear. Participants were familiarized with the task through a set of practice trials.

Data Analysis

Correct responses occurred when the key response matched the side of the screen that the target was presented on. Only correct responses with reaction times less than 2.5 standard deviations away from each participant's mean for each condition were kept (Selst & Jolicoeur, 1994). Averaged reaction times for congruent and incongruent trials within the happy, fearful, and neutral conditions were used for the current analyses. The original number of trials available for each condition varied with the experiment (Table 1).

All statistical analyses were performed using SPSS Statistics 25. To test the effects of participant sex and facial expression on the gaze-cuing effect, only participants with all three conditions (fear, happy and neutral trials) were kept, resulting in a sample of 148 (using data from Experiments 3-7). A mixed-model 2 (sex) x 2(congruency) x 3(emotion) ANOVA was run on the mean reaction times with expressions and congruency as within-subject factors and sex as a between-subject factor. Initially, the between-subject factor Experiment (with 5 levels) was also used to ensure no differences between experiments. Results confirmed a lack of any interaction between Experiment and the other factors. The analysis was thus performed again without the Experiment factor and those results are reported below. All follow-up paired comparisons were Bonferroni corrected. For effect sizes, we reported partial eta square[3] (η_p^2) values for ANOVA main effects and interactions, as given in SPSS 25, as well as Cohen's *d* for paired comparisons.

As there were differences in which self-report measures and emotion conditions were available for each experiment (Table 1), we were unable to investigate the relationships between self-reported subclinical anxiety, depression, autistic traits and gaze-cuing in a single multiple regression model. Instead, we initially conducted separate correlation analyses for each gaze-cuing score and questionnaire score to maximize sample sizes. The Shapiro-Wilk normality test indicated that the distributions of the self-report measures and gaze-cuing effect scores were not normally distributed, so Spearman correlations were performed.

To investigate relationships between anxiety and gaze-cuing, we first performed a correlation analysis between participants' STICSA scores and their gaze-cuing effect scores ($RT_{incongruent}$ - $RT_{congruent}$) for each emotion separately (neutral, happiness, fear), as done in past studies. For fear, data were taken from Experiments 1, 3, 4, 5, 6, and 7 (N=181). For happiness, data were

[3] Note that this effect size measure may be calculated differently across other packages; we kept this one for consistency with our previously published papers in which we reported those values.

taken from Experiments 2, 3, 4, 5, 6 and 7 (N=178), and for neutral, from Experiments 3, 4, 5, 6, and 7 (N=148).

Correlations between the CESD and fearful gaze-cuing were performed with participants from Experiments 1, 4, and 5 (N=108), while correlations with happy gaze-cuing included data from Experiments 2, 4 and 5 (N=105), and correlations with neutral gaze-cuing used Experiments 4 and 5 (N=75).

For the Autism Quotient (AQ), we used both the four-point and binary AQ scoring to examine the relation between gaze-cuing and overall AQ, as well as gaze-cuing and each of the five AQ subscales: Social Skills, Attention Switching, Attention to Detail, Communication and Imagination ($p<.01$ was used for the 5 sub-scales to control for the number of correlations run). The AQ scores were correlated separately with fearful, happy and neutral gaze-cuing scores from Experiments 4, 5, 6, and 7 (N=126). As these studies also included the STICSA questionnaire, and as autistic traits are often comorbid with anxiety (Joshi et al., 2013), we also ran partial correlations to see if the relationships between AQ and gaze-cuing held after controlling for trait anxiety (STICSA scores).

Based on the findings from our correlation analysis with the AQ (see below), we further investigated how autistic traits modulate emotional gaze-cuing with regression analyses on a smaller sample of participants (Experiments 4-7, N=126) who had a gaze-cuing score for each emotion, as well as STICSA and AQ scores. Neutral gaze-cuing scores, STICSA scores, participant sex, and AQ subscale scores were used in a stepwise multiple regression analysis to predict fearful and happy gaze-cuing scores. Separate models with fearful gaze-cuing scores and happy gaze-cuing scores as the dependent variable were run. The final model for each emotion was achieved in five steps, with neutral gaze-cuing scores added in step one, participant sex entered in step two, STICSA scores entered in step three, and four-point Imagination, Communication, Social Skills and Attention Switching subscales added in step four. In the final step, the four-point Attention to Detail subscale was added to see if it could predict variance above that of the other AQ subscales in step four. This ensured that any variance in gaze-cuing predicted by the Attention to Detail subscale was specific to that subscale and not simply an issue of collinearity between the AQ subscales. The addition of neutral gaze-cuing scores in the model allowed us to investigate whether or not AQ could uniquely predict *emotional* gaze-cuing, while the additions of STICSA score and participant sex ensured that the variance predicted by AQ was unique from that of any comorbid anxiety or participant sex.

RESULTS

Predictions for the ANOVA analysis: 1) Emotional modulation of gaze-cuing occurs for both fearful and happy expressions, with the fear cuing effect > happy cuing effect > neutral cuing effect. 2) Women have a larger gaze-cuing effect and stronger emotional modulation of gaze-cuing than men.

The gaze-cuing effect was demonstrated by a main effect of congruency, $F(1, 146) = 366.40$, $MSE = 223.09$, $p < .001$, $\eta_p^2 = .72$, due to faster congruent (M = 316ms, SE = 3ms) than incongruent (M = 336ms, SE = 4) reaction times. This effect of congruency interacted with participant sex, $F(1, 146) = 5.74$, $MSE = 223.09$, $p = .018$, $\eta_p^2 = .038$, such that women had a larger gaze-cuing effect than men (Figure 2a).

There was also a main effect of emotion, $F(1.91, 278.78) = 53.95$, $MSE = 240.44$, $p < .001$, $\eta_p^2 = .027$, due to faster RTs for fearful and happy face trials compared to neutral face trials ($ps < .001$), with no difference between fearful and happy face trials. An emotion by participant sex interaction, $F(2, 292) = 3.10$, $MSE = 240.44$, $p = .046$, $\eta_p^2 = .021$, simply reflected a larger emotion effect in women than in men.

Most importantly, there was a congruency by emotion interaction, $F(2, 292) = 42.28$, $MSE = 70.27$, $p < .001$, $\eta_p^2 = .23$, which was further investigated with separate ANOVAs for congruent and incongruent trials. There was a main effect of emotion for both congruent, $F(1.95, 284.59) = 82.42$, $MSE = 163.13$, $p < .001$, $\eta_p^2 = .36$, and incongruent trials, $F(1.94, 283.88) = 16.91$, $MSE = 147.58$, $p < .001$, $\eta_p^2 = .10$, as seen in Figure 2b. Paired comparisons for congruent trials indicated that both fear and happy congruent RTs were significantly faster than neutral congruent RTs ($ps < .001$, fear congruent - neutral congruent Cohen's $d = 1.04$; happy congruent – neutral congruent $d = .95$), while happy and fear congruent RTs were not significantly different ($p = .29$, $d = .12$). Paired comparisons for incongruent trials revealed that both fearful and happy incongruent RTs were significantly faster than neutral incongruent RTs ($ps < .01$, fear incongruent - neutral incongruent d =.33, happy incongruent – neutral incongruent d = .57), but not significantly different from each other ($p = .11$, $d = .18$).

For comparability with previous research, we also performed a within-subjects ANOVA on the gaze-cuing effect scores ($RT_{incongruent} - RT_{congruent}$), using the factor emotion. As depicted in Figure 2c, there was a main effect of emotion ($F(2, 292) = 42.28$, $MSE = 140.53$, $p < .001$, $\eta_p^2 = .23$), with a clear fear>happy>neutral cuing effect gradient. Paired comparisons confirmed that the fear cuing effect (*M* = 26ms, *SE* = 1ms) was larger than both happy (*M* = 20ms, *SE* = 1ms; fear-happy *d*=.35) and neutral (*M* = 13ms, *SE* = 1ms; fear-neutral *d*=.74) cuing effects (*ps* <.001), and that the happy cuing effect was also larger than the neutral cuing effect (*p* <.001, *d*=.43). We also report in Table 2 the congruency by emotion interaction for each experiment separately, along with Bonferroni corrected paired comparisons and effect sizes. Despite the emotion gradient being clearly seen for each experiment with the group means (Figure 3), the happy-neutral difference was not always significant in each experiment analysed separately. Importantly, the congruency by emotion by sex interaction was not significant (*p*=.54), indicating that the sex difference in gaze-cuing reported earlier was consistent across emotions.

To summarise, as predicted, a clear emotion gradient emerged, with largest gaze-cuing effect for fearful faces, followed by happy faces, itself larger than the neutral face gaze-cuing effect. Gaze-cuing was also larger for women than men, as predicted, but contrary to prediction, this effect did not vary with the emotion condition.

Predictions for the correlation analyses: 3) Depression, but not self-reported trait anxiety, might be related to increased emotional modulation of gaze-cuing by fearful expressions. 4) Autistic traits are associated with decreased emotional modulation of gaze-cuing by both happy and fearful expressions.

Despite having large samples, we failed to find any relationship between gaze-cuing and self-reported trait anxiety or depression (see Table 3 for details). We did, however, find significant relationships between AQ scores and gaze-cuing (Table 3). There were negative correlations between the happy gaze-cuing effect and both the binary (r_s = -.24, *p* = .006) and four-point (r_s = -.29, *p* = .001, Figure 4a) Attention to Detail subscale scores. There were also significant negative correlations between the fear gaze-cuing effect and the four-point overall AQ score (r_s = -.21, *p* = .020), and the four-point Attention to Detail score (r_s = -.25, *p* = .006, Figure 4b). Finally, there was a significant negative correlation between the neutral gaze-cuing effect and the overall four-point AQ score (r_s = -.19, *p* = .030).

As seen in Table 4, controlling for anxiety eliminated the correlations between overall AQ scores and gaze-cuing effects. The negative correlations remained significant between the Attention to Detail scores and the happy gaze-cuing effect (binary: r_s = -.25, *p* = .004; four-point r_s = -.29, *p* = .001).

In summary, anxiety traits and depression were not related to gaze-cuing in any way in the present study. In contrast, significant negative correlations were found between the AQ attention to detail subscale scores and gaze-cuing effects obtained for fearful and happy expressions, the correlation for happy faces remaining after trait anxiety was controlled for.

Results for the regression analysis

The five-step models significantly predicted fearful (F(8, 117) = 5.97, p<.001) and happy (F(8, 117) = 6.23, p<.001) gaze-cuing scores, accounting for approximately 25% of their variance (Table 5). Neutral gaze-cuing scores were significant predictors for both fearful and happy gaze-cuing scores, while STICSA scores, participant sex, and the Communication, Imagination, Social Skills and Attention Switching four-point AQ subscales failed to predict a significant amount of variance above that, as indicated by non-significant R^2 change statistics (Table 5). In contrast, the four-point Attention to Detail subscale[4] in step five predicted significantly more variance in happy, but not fearful, gaze-cuing scores. Higher happy gaze-cuing scores were predicted by lower Attention to Detail scores (unstandardized B = -.795, SE= .30; standardized β = -.209, t = -2.62, p=.01).

DISCUSSION

Spontaneous orienting of an observer's attention towards the direction signaled by gaze is a basic form of social attention believed to play a major role in more complex social cognitive tasks. The integration of gaze cues with facial expressions offers further insight into the gazer's affective response to environmental objects and has been suggested to modulate gaze-oriented attention. Most studies have shown an increase in gaze-cuing for fearful, angry, and surprised expressions, but not for happy expressions (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; see Appendix), suggesting that only expressions denoting a possible danger or uncertainty can boost gaze-oriented attention. However, McCrackin and Itier (2018) recently showed that happy expressions can also reliably enhance gaze-cuing but to a lesser extent than fearful expressions. They proposed an "emotion gradient" response rather than a strict threat/non-threat response for this gaze-cuing enhancement by facial expressions, and suggested that previous studies might

[4] Note that, while not reported here, similar findings were obtained by running the analyses with the binary subscales instead of the four-point subscales.

have failed to find a reliable increase in gaze-cuing by happy expressions because of its small effect size. One goal of the present study was to test this idea and replicate this increase in gaze-cuing by happy expressions. To overcome the small effect size, we included a very large sample, obtained by combining participants from five different experiments.

We used the dynamic sequence that has been shown to elicit the largest gaze-cuing modulation by emotional expressions (Lassalle & Itier, 2015a), wherein the gaze shift precedes the expression of emotion, as if the person reacted to an object in the environment (same sequence as used by McCrackin and Itier, 2018). We replicated the gradient effect in gaze-cuing where happy expressions produced an intermediate gaze-cuing effect -- larger than the gaze-cuing effect elicited by neutral faces, but smaller than that elicited by fearful expressions.

Importantly, none of the participants included in McCrackin and Itier (2018) were included in this analysis, and apparent motion was not controlled for in the present study. McCrackin and Itier (2018) showed that a gaze-cuing enhancement by happy expressions can be seen over SOAs ranging from 200-700ms, when a neutral movement is used to control for the apparent motion inherent to this dynamic gaze-cuing paradigm. That is, happy expressions elicited larger gaze-cuing than neutral faces with a tongue protrusion regardless of the SOA used. However, when directly compared to neutral faces without tongue protrusion (i.e. the same neutral condition as used here, hereafter "classic neutral" condition), they failed to find a larger gaze-cuing effect for happy faces. It is important to highlight that this lack of effect was reported in an experiment that included short SOAs from 200-350ms (Exp.4 of that paper). Unfortunately, this study did not include an experiment directly comparing happy and classic neutral conditions at longer SOAs. The present findings suggest that the happy-classic neutral comparison can be significant at longer SOAs, and thus that emotional enhancement of gaze-cuing by happy expressions can be detected even without controlling for apparent motion, at least when using a 500ms SOA. These results support the assertion that other studies using the same dynamic sequence may have had difficulties finding an increase in gaze-cuing effect by happy expressions at that SOA (e.g. Neath et al., 2013; Lassalle & Itier, 2015a) because of the small effect size for happy expressions (McCrackin & Itier, 2018).

It is important to note that when each experiment was analyzed separately (Table 2), we found a significant difference between happy and neutral gaze-cuing in three of them (Exps. 4, 5 and 6). While two of the three had relatively large sample sizes (*n*= 40 and 36), Experiment 6 had a medium sample size (*n*=27) yet still elicited a significant happy effect. This suggests that sample size is not the only factor at play. There may be another individual difference beside AQ that affects the emotional modulation of gaze cuing by happy expressions, which remains to be determined. Alternatively, trial number might be another factor at play. An important difference between this experiment and previous experiments that reported null results with a comparable sample size is the large number of trials per condition (64 trials for happy conditions, 192 for neutral conditions; see Appendix Table for the trials per condition in other seminal gaze-cuing papers). While in some cases, the number of trials per condition does not seem to be the deciding factor (see McCrackin & Itier, 2018, Exp.3, for more discussion on this point[5]), large trial numbers reduce the error when calculating the means for each emotion, which likely increases the likelihood of detecting a significant difference between them. Trial number might thus compensate for medium sample sizes in some experiments, although not always (e.g. Exp.7 with the same large number of trials and n=23, in which the happy effect was not significant, see Table 2). Future studies will have to further elucidate the role of trial number in this happy effect and possibly uncover other factors at play, including other individual differences than the ones tested here (see below).

McCrackin and Itier (2018) also found that, in congruent trials, both happy and fearful faces elicited faster responses than neutral-tongue expressions regardless of the SOA used (and also compared to classic neutral faces at shorter SOAs). This finding, also found in the present study with classic neutral faces and 500ms SOA, replicates previous studies (Lassalle & Itier, 2013, 2015a, 2015b) and suggests that emotional enhancement works by speeding responses to gazed-at (congruent) targets. In contrast, responses to incongruent trials did not vary with facial expressions in the experiments using long SOAs but did in the experiments using short SOAs. In particular, at short SOAs, responses were shorter for happy, fearful and neutral-tongue faces compared to classic-neutral expressions, suggesting that apparent motion affects responding to incongruent trials at those short SOAs (McCrackin & Itier, 2018). In incongruent trials, attention is first oriented towards the gazed-at location and then has to be oriented back to the target location. Although we do not know for sure, it is possible that at short SOAs, for classic-neutral faces with no apparent motion, participants have not had enough time to re-orient their attention in the incongruent condition, while at longer SOAs they have. For faces expressing an emotion and for neutral-tongue faces, however, apparent motion seems to speed up this attention reorienting at short SOAs. Overall, McCrackin and Itier's (2018) findings suggest that, at short SOAs, gaze-cuing enhancement by happy expressions can only be observed after controlling for apparent

[5] However, while we credited Graham et al. (2010) with 96 trials per condition in that paper, we now believe the number is really 48, based on their description, which means that trials per condition could explain key differences between our findings in McCrackin & Itier (2018) and their findings.

motion to eliminate this confounding effect on incongruent reaction times. At longer SOAs such as the 500ms SOA used here, apparent motion does not seem to be critical and a reliably larger gaze-cuing effect for happy compared to classic neutral expressions can be found.

The emotional modulation of gaze-cuing is thought to be mediated by interactions between the amygdala, a subcortical structure implicated in emotion processing (Pessoa & Adlophs, 2010), and a complex cortical network implicated in gaze-cuing, including the superior temporal sulcus, inferior parietal lobule and intraparietal sulcus (Itier and Batty, 2009, Frischen, Bayliss, and Tipper, 2007). In this framework, fearful and happy expressions could engage the same network to a different extent (quantitative view), or engage slightly different brain networks (qualitative view), resulting in the gaze-cuing gradient reported here. We propose that the differential engagement of the same brain network depending on the facial expression seen, is the most parsimonious explanation and aligns with recent neuroimaging research suggesting that the amygdala is responsive to both positive and negative emotional expressions (eg. Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; Hooker, Germine, Knight, & D'Esposito, 2006; Juruena et al., 2010; Murray, 2007; Sander, Grafman, & Zalla, 2003). Future neuroimaging studies could test this quantitative hypothesis directly.

The other main goal of the present study was to examine individual differences in the emotional modulation of gaze-cuing. Some studies have suggested that the integration of emotional expression and gaze cues is modulated by individual differences in anxiety (Fox, Mathews, Calder, & Yiend, 2007; Holmes, Richards, & Green, 2006, Mathews et al. 2003; Putman et al., 2006; Tipples, 2006) and autistic traits (Lassalle & Itier, 2015). However, those studies are scarce and replication is necessary. Furthermore, while sex differences in gaze-cuing have been reported for neutral faces, no previous studies have investigated sex differences in how emotion might modulate gaze-cuing. In the present study, we combined data from seven experiments to investigate these relations.

Contrary to previous research, we found no evidence that emotional modulation of gaze-cuing, especially the gaze-cuing enhancement with fearful expressions, varies as a function of self-reported trait anxiety. It is possible that previous findings may have been driven by traits that typically co-occur with high anxiety (e.g. depression, neuroticism, introversion). However, because we found no relation between our measures of subclinical depression and gaze-cuing, it is unlikely that comorbid heightened depression was the main factor driving the relationship between anxiety and gaze-cuing for fearful faces in previous reports.

Another possibility is that the self-report measures of anxiety used in previous studies (the STAI or the EAS) were able to pick up on subtle differences which related to the emotional modulation of gaze-cuing that our anxiety measure (the STICSA) failed to capture. For example, while the STICSA has been established as a robust measure of anxiety and is used clinically (Grös, Antony, Simms & McCabe, 2007), the STAI has been shown to assess two different dimensions of anxiety vulnerability: anxiety reactivity and anxiety perseveration (Rudaizky, Page, & MacLeod, 2012; Rudaizky & MacLeod, 2013). It is unclear how the STICSA assesses these dimensions, and one dimension may affect gaze-cuing more than the other. Anxiety reactivity refers to the probability of experiencing anxious responses, while anxiety perseveration refers to the length of these responses. As Rudaizky et al., (2012) and Rudaizky and MacLeod (2013) propose, anxiety reactivity may reflect differences in automatic attention to threat stimuli, while perseveration may reflect later, conscious control of attention. As the gaze-cuing paradigm is thought to tap into spontaneous attention orienting, it may be modulated by anxiety reactivity, but not perseveration, a possibility that future studies could explore.

A third possibility is that the previously reported anxiety effects were tied to specific characteristics of the gaze-cuing sequences used. The main difference between the present study and these early studies concerns the dynamic properties of the cuing sequence. In all the experiments that we included, the trials began with a neutral face that averted gaze, and then reacted emotionally or not at all (neutral faces). This created a dynamic sequence perceived as someone looking to the side and reacting to something in that location, which Lassalle and Itier (2015a) reported to be the sequence that produces the most reliable emotional enhancement in neurotypical individuals (sequence "Emo second" in the Appendix Table). In contrast, Holmes et al. (2006) presented static images of emotional faces with an averted gaze ("Emo concurrent" sequence), while Fox et al. (2007) used a paradigm where the emotional expression was presented before the gaze shift ("Emo first" sequence). Others presented participants with an initial neutral face with direct gaze, followed by either a face with averted gaze concurrently displaying an emotional expression (Mathews et al., 2003, Tipples, 2006) or a gaze shift which happened concurrently with a series of expression frames increasing in emotional intensity (Putman et al., 2006). Perhaps these earlier studies found an enhanced gaze-cuing for fear only in highly-anxious individuals (Fox, Mathews, Calder, & Yiend, 2007; Holmes, Richards, & Green, 2006; Mathews et al. 2003), or a general effect that was greater in those with high anxiety (Putman et al., 2006; Tipples, 2006), because they were tapping into a sensitivity to emotional expressions in highly-anxious individuals for these specific cue sequences. Indeed, those with high anxiety have been found to show exaggerated responses to static emotional faces (eg. Bishop, Duncan

& Lawrence, 2004; Phan, Fitzgerald, Nathan & Tancer, 2006; Stein, Simmons, Feinstein & Paulus, 2007, Thomas et al, 2001), and might not require the same dynamic sequence properties for emotional modulation of gaze-cuing. The present lack of correlation between gaze-cuing with fearful faces and trait anxiety is in line with two other studies using the same dynamic cue sequence and SOA (the “Emo second” sequence, Neath et al., 2013; Lassalle & Itier, 2015b).

Finally, the lack of relationship between anxiety and gaze cuing for fearful faces might be linked to task demands. Anxiety effects have been shown to be weaker when task demands are low. Becker (2009) and Hass, Amso and Fox (2017) demonstrated that most individuals are faster to find a target in a visual search task when it follows a fearful face. However, Haas, Amso and Fox (2017) found that highly anxious individuals actually showed worse visual search performance after seeing threat-related face primes. Interestingly, the effect of anxiety emerged as task demands increased, suggesting that a certain level of difficulty may be required to measure the impact of subclinical anxiety. It is possible that the target localization task we used was simply not challenging enough for anxiety effects to emerge. Indeed, Pecchinenda and Petrucci (2016) demonstrated that the emotional modulation of gaze-cuing can be modulated by cognitive load, and so further investigation into how cognitive load may mediate the relationship between anxiety and emotional gaze-cuing is warranted.

A separate question we examined in the present study concerned sex differences in the emotional modulation of gaze-cuing. Aligning with previous reports (Alwall, Johansson and Hansen, 2010, Bayliss et al., 2005; Feng et al. 2011, Deaner et al. 2007; Hayward & Ristic, 2017), we found a larger gaze-cuing effect in women than in men, which others have taken to be the result of earlier maturation of the visual spatial attention network (Feng et al., 2011) or the result of women being more sensitive to social information (Alwall et al., 2010). However, these previous studies only used neutral faces, while ours included happy and fearful expressions in addition to neutral faces. Despite previous literature suggesting that there is an emotional expression processing advantage in women (Hall & Matsumoto, 2004, McClure, 2000, Thayer & Johnson, 2000), we found no difference in the emotional modulation of the gaze-cuing effect between men and women. If the amygdala does mediate emotional modulation of the gaze-cuing effect, then these findings would predict that there are no detectable sex differences in amygdala response or in connectivity between the amygdala and the core gaze-cuing network when viewing a gaze-cuing sequence with facial emotions. However, this has yet to be studied and cannot be addressed with a solely behavioral design.

Finally, we examined the relation between subclinical autistic traits and gaze-cuing. Overall Autism Quotient (AQ) scores were found to be negatively related to neutral gaze-cuing. This is in line with Bayliss et al. (2005) and Hayward and Ristic (2017), who reported gaze-cuing scores to be negatively related to AQ score for neutral faces. The overall AQ score was also negatively related to fear gaze cuing and the Attention to Detail subscale of the AQ was negatively related to both fearful and happy gaze-cuing. These findings are partially in line with those reported by Lassalle and Itier (2015b), who found a significant correlation between the happy gaze-cuing effect and overall AQ score, and correlations between the happy gaze-cuing effect and the Attention to Detail and Imagination subscales. The present findings in a larger sample suggest that the Attention to Detail relationship for happy faces is real, and persists after controlling for self-reported trait anxiety. We found further support for this idea in our regression analysis, when scores on the Attention to Detail subscale significantly predicted variance in happy gaze-cuing effect scores above what would be predicted from neutral gaze-cuing scores, and above what anxiety and gender would predict. This suggests that this subscale is tapping into something about *emotional* gaze-cuing in particular. This relationship might, however, be restricted to happy expressions (as reported by Lassalle and Itier, 2015b), as the correlation we found between the Attention to Detail subscale and fearful gaze-cuing was no longer significant after controlling for anxiety, and the Attention to Detail subscale failed to predict unique variance in gaze-cuing scores in our regression analysis.

It is important to note, however, that some of our correlations were significant only with the four-point AQ scores, not with the binary AQ scores, while all those previous studies reported only correlations with binary AQ scores. It is also important to highlight that we reported Spearman correlations here, while the previous groups reported Pearson correlations, which may be a concern if data were not normally distributed. Indeed, in some cases the present study's correlations were significant with Pearson correlations (e.g. the binary overall AQ correlations with the fear gaze cuing effect, r=-.185, p=.038, and happy gaze-cuing effect, r=-.183, p=.040) but not Spearman correlations (Table 3). Finally, beside Lassale and Itier (2015a) and the present study, no other study reported correlations with the AQ subscales. More experiments are needed to ascertain that all these correlations can be replicated.

Keeping these caveats in mind, the correlations with the Attention to Detail subscale seem very plausible. This subscale probes for abnormal (increased) focus on details and, while not all of the questions in this subscale refer to the visual domain (e.g. "I am fascinated by numbers", "I often notice small sounds that others do not"), many may reflect abnormalities in visual attention (e.g. “I tend to notice details that others do not”, “I don’t usually notice small changes in a situation, or a person’s appearance”). In particular, the item: “I usually concentrate more on the whole picture, rather than the small details” may be capturing an individuals’ tendency to use a local versus global processing strategy. The idea that global processing may be necessary for emotional modulation of gaze-cuing is supported by research demonstrating that the eye-region alone does not produce emotional modulation; rather, global processing of the emotional content on the whole face is required (Bayless, Glover, Taylor & Itier, 2011). However, global processing might be more important for happy faces whose smile was situated below the fixation point, than for fearful faces whose wide open eyes were situated at gaze fixation.

The potential relationship between local processing and the emotional modulation of gaze-cuing is of particular interest given that recent theories of autism have shifted from the view that autism is a purely social impairment to the view that the use of different perceptual strategies may also be a key feature (Behrmann, Thomas & Humphreys, 2006). In particular, the use of local over global processing is a core component to the Weak Central Coherence theory (Lopez, Donnelly, Hadwin, & Leekam, 2004, Shah & Frith, 1993, Happé & Frith, 2006; see Happé, 2013 for a brief description), which has garnered much support. This theory defines central coherence as the ability to form meaningful representations by integrating information (Frith, 1989), and proposes that many of the social impairments in autism may stem from bias in attending to local instead of global features. Accordingly, many have found that individuals with autism tend to use local instead of global processing when looking at faces (Teunisee & de Gelder, 2003; Mottron, Arguin, Jemel, & Saumier, 2006), which has previously been shown to impact the ability to correctly identify emotional expressions. Neuroimaging research has also suggested that emotional faces filtered to leave only high spatial frequencies (corresponding to local/detailed information) do not activate the amygdala and fusiform face area (one of the main nodes of the face perception network) to the same extent as images with intact low spatial frequencies (corresponding to global information; Vuilleumier, Armony, Driver & Dolan, 2003; Winston, Vuilleumier, Dolan, 2003). As these areas have been implicated in the emotional modulation of gaze-cuing (Itier and Batty, 2009, Frischen, Bayliss, and Tipper, 2007), this may point to a potential mechanism by which those with higher levels of subclinical autistic traits orient attention to emotional gaze cues less than those with lower autistic traits.

On a final note, we acknowledge that there are some limitations to this study. First, the included experiments were performed over a few years, and it is possible that some participants were included in several experiments. Second, the experiments in the present study and McCrackin and Itier (2018) all used the same Nimstim stimuli. Replication of these findings with a wider range of stimuli is necessary to ensure that the effects reported here generalize, and that we are not reporting a stimulus-specific effect.

CONCLUSION

In summary, the present study replicated the finding that both positive and negative expressions can enhance gaze-cuing (McCrackin & Itier, 2018), supporting the idea of a gradient in the modulation of gaze-cuing by facial expressions rather than the classic threat/non-threat response hypothesis. This emotional modulation occurred equally in men and women, though women demonstrated stronger overall gaze-cuing, as reported before. Contrary to previous findings, emotional modulation was not related to self-reported anxiety, potentially because anxiety modulates gaze-cuing in a manner that is dependent on the dynamic properties of the gaze-cuing sequence, because of insufficiently challenging task demands, or because our anxiety measure (STICSA) did not capture specific dimensions captured by the more widely used STAI questionnaire. Depression also did not seem related to gaze-cuing. Finally, increased autistic traits, indicated by higher scores on the Attention to Detail Autism Spectrum Quotient subscale, were associated with decreased gaze-cuing in response to both fearful and happy faces, although the relationship seems stronger for happy faces. In accordance with the Weak Central Coherence theory of autism, this relation may be because those who score higher on Attention to Detail have an increased tendency to use a local processing strategy, resulting in decreased emotional expression processing. While our results cannot speak to the mechanism behind these relationships with individual differences, preliminary neuroimaging findings suggest that individual differences in emotional modulation of gaze-cuing may be driven by altered interactions between the amygdala and a core network consisting of the superior temporal sulcus, inferior parietal lobule and intraparietal sulcus.

DISCLOSURE STATEMENT

We report no potential conflicts of interest.

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REFERENCES

Alwall, N., Johansson, D., & Hansen, S. (2010). The gender difference in gaze-cueing: Associations with empathizing and systemizing. *Personality and Individual Differences*, *49*(7), 729-732.

Austin, E. J. (2005). Personality correlates of the broader autism phenotype as assessed by the Autism Spectrum Quotient (AQ). Personality and Individual Differences, 38(2), 451-460.

Baron-Cohen S. Mindblindness: An Essay on Autism and Theory of Mind. MIT Press; Cambridge: 1995.

Baron-Cohen, S. (2003). The Essential Dflerence: Male and Female Brains and the Truth about Autism.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from asperger syndrome/high-functioning autism, malesand females, scientists and mathematicians. *Journal of autism and developmental disorders*, *31*(1), 5-17.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger syndrome or high–functioning autism, and normal sex differences. Philosophical Transactions of the Royal Society of London B: Biological Sciences, 358(1430), 361-374.

Bayless, S. J., Glover, M., Taylor, M. J. & Itier, R. J. (2011). Is it in the eyes? Dissociating the role of emotion and perceptual features of emotionally expressive faces in modulating orienting to eye gaze. *Visual cognition*, *19*(4), 483–510.

Bayliss, A. P., Pellegrino, G. D., & Tipper, S. P. (2005). Sex differences in eye gaze and symbolic cueing of attention. The Quarterly Journal of Experimental Psychology, 58(4), 631-650.

Bayliss, A. P., & Tipper, S. P. (2006). Predictive gaze cues and personality judgments: Should eye trust you?. Psychological Science, 17(6), 514-520.

Becker, M. W. (2009). Panic search: Fear produces efficient visual search for nonthreatening objects. *Psychological Science*, *20*(4), 435-437.

Buss, A. H., & Plomin, R. (1984). The EAS Temperament scale.*Temperament: Early developing personality traits*.

Connor, K. M., Davidson, J. R., Churchill, L. E., Sherwood, A., Weisler, R. H., & FOA, E. (2000). Psychometric properties of the social phobia inventory (SPIN). *The British Journal of Psychiatry*, *176*(4), 379-386.

Deaner, R. O., Shepherd, S. V., & Platt, M. L. (2007). Familiarity accentuates gaze cuing in women but not men. *Biology Letters*, *3*(1), 65-68.

Driver IV, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E. & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual cognition*, *6*(5), 509–540.

Ekman, P. & Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of personality and social psychology*, *17*(2), 124.

Feng, Q., Zheng, Y., Zhang, X., Song, Y., Luo, Y. J., Li, Y., & Talhelm, T. (2011). Gender differences in visual reflexive attention shifting: Evidence from an ERP study. *Brain research*, *1401*, 59-65.

Fichtenholtz, H. M., Hopfinger, J. B., Graham, R., Detwiler, J. M. & LaBar, K. S. (2009). Event-related potentials reveal temporal staging of dynamic facial expression and gaze shift effects on attentional orienting. *Social neuroscience*, *4*(4), 317–331.

Fox, E., Mathews, A., Calder, A. J. & Yiend, J. (2007). Anxiety and sensitivity to gaze direction in emotionally expressive faces. *Emotion*, *7*(3), 478.

Friesen, C. K. & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic bulletin & review*, *5*(3), 490–495.

Graham, R., Kelland Friesen, C., Fichtenholtz, H. M. & LaBar, K. S. (2010). Modulation of reflexive orienting to gaze direction by facial expressions. *Visual Cognition*, *18*(3), 331–368.

Grös, D. F., Antony, M. M., Simms, L. J., & McCabe, R. E. (2007). Psychometric properties of the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA): comparison to the State-Trait Anxiety Inventory (STAI). Psychological assessment, 19(4), 369.

Gillespie-Lynch, K., Elias, R., Escudero, P., Hutman, T., & Johnson, S. P. (2013). Atypical gaze following in autism: A comparison of three potential mechanisms. Journal of autism and developmental disorders, 43(12), 2779-2792.

Hall, J. A. (1978). Gender effects in decoding nonverbal cues. *Psychological bulletin*, *85*(4), 845.

Hall, J. A., & Matsumoto, D. (2004). Gender differences in judgments of multiple emotions from facial expressions. *Emotion*, *4*(2), 201.

Halliday, D. W., MacDonald, S. W., Sherf, S. K., & Tanaka, J. W. (2014). A reciprocal model of face recognition and autistic traits: evidence from an individual differences perspective. PLoS One, 9(5), e94013.

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: a review of behavioral and neuroimaging studies. *Neuropsychology review*, *20*(3), 290-322.

Haas, S. A., Amso, D., & Fox, N. A. (2017). The effects of emotion priming on visual search in socially anxious adults. *Cognition and emotion*, *31*(5), 1041-1054.

Hayward, D. A., & Ristic, J. (2017). Feature and motion-based gaze cuing is linked with reduced social competence. *Scientific Reports*, *7*, srep44221.

Hietanen, J. K. & Leppänen, J. M. (2003). Does facial expression affect attention orienting by gaze direction cues? *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6), 1228.

Holmes, A., Mogg, K., Garcia, L. M. & Bradley, B. P. (2010). Neural activity associated with attention orienting triggered by gaze cues: A study of lateralized ERPs. *Social neuroscience*, *5*(3), 285–295.

Holmes, A., Richards, A. & Green, S. (2006). Anxiety and sensitivity to eye gaze in emotional faces. *Brain and cognition*, *60*(3), 282–294.

Hoppenbrouwers, S. S., Munneke, J., Kooiman, K. A., Little, B., Neumann, C. S., & Theeuwes, J. (2017). Fearful Faces do Not Lead to Faster Attentional Deployment in Individuals with Elevated Psychopathic Traits. *Journal of Psychopathology and Behavioral Assessment*, 1-9

Hori, E., Tazumi, T., Umeno, K., Kamachi, M., Kobayashi, T., Ono, T., & Nishijo, H. (2005). Effects of facial expression on shared attention mechanisms. Physiology & behavior, 84(3), 397-405.

Joshi, G., Wozniak, J., Petty, C., Martelon, M. K., Fried, R., Bolfek, A., ... & Caruso, J. (2013). Psychiatric comorbidity and functioning in a clinically referred population of adults with autism spectrum disorders: a comparative study. *Journal of Autism and Developmental Disorders*, *43*(6), 1314-1325.

Kennedy, B. L., Schwab, J. J., Morris, R. L., & Beldia, G. (2001). Assessment of state and trait anxiety in subjects with anxiety and depressive disorders. *Psychiatric Quarterly*, *72*(3), 263-276.

Lassalle, A. & Itier, R. J. (2013). Fearful, surprised, happy, and angry facial expressions modulate gaze-oriented attention: Behavioral and ERP evidence. *Social neuroscience*, *8*(6), 583–600.

Lassalle, A. & Itier, R. J. (2015a). Emotional modulation of attention orienting by gaze varies with dynamic cue sequence. *Visual Cognition*, 1–16.

Lassalle, A. & Itier, R. J. (2015b). Autistic traits influence gaze-oriented attention to happy but not fearful faces. *Social neuroscience*, *10*(1), 70–88.

Mathews, A., Fox, E., Yiend, J. & Calder, A. (2003). The face of fear: Effects of eye gaze and emotion on visual attention. *Visual Cognition*, *10*(7), 823–835.

McClure, E. B. (2000). A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents.

McClure, E. B., Monk, C. S., Nelson, E. E., Zarahn, E., Leibenluft, E., Bilder, R. M., ... & Pine, D. S. (2004). A developmental examination of gender differences in brain engagement during evaluation of threat. *Biological psychiatry*, *55*(11), 1047-1055.

Neath, K., Nilsen, E. S., Gittsovich, K. & Itier, R. J. (2013). Attention orienting by gaze and facial expressions across development. *Emotion*, *13*(3), 397.

Pecchinenda, A., & Petrucci, M. (2016). Emotion Unchained: Facial Expression Modulates Gaze Cueing under Cognitive Load. *PloS one*, *11*(12), e0168111.

Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: from a'low road'to'many roads' of evaluating biological significance. *Nature reviews neuroscience*, *11*(11), 773.

Posner, M. I. (1980). Orienting of attention. *Quarterly journal of experimental psychology*, *32*(1), 3–25.

Putman, P., Hermans, E. & Van Honk, J. (2006). Anxiety meets fear in perception of dynamic expressive gaze. *Emotion*, *6*(1), 94.

Radloff, L. S. (1977). The CES-D scale: A self-report depression scale for research in the general population. *Applied psychological measurement*, *1*(3), 385-401.

Rhodes, G., Jeffery, L., Taylor, L., & Ewing, L. (2013). Autistic traits are linked to reduced adaptive coding of face identity and selectively poorer face recognition in men but not women. Neuropsychologia, 51(13), 2702-2708.

Ree, M. J., French, D., MacLeod, C. & Locke, V. (2008). Distinguishing cognitive and somatic dimensions of state and trait anxiety: Development and validation of the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA). *Behavioural and Cognitive Psychotherapy*, *36*(03), 313–332.

Selst, M. V., & Jolicoeur, P. (1994). A solution to the effect of sample size on outlier elimination. *The quarterly journal of experimental psychology*,*47*(3), 631-650.

Spielberger, C. D., & Gorsuch, R. L. (1983). *State-Trait Anxiety Inventory for Adults: Manual and Sample: Manual, Instrument and Scoring Guide*. Consulting Psychologists Press.

Tipples, J. (2006). Fear and fearfulness potentiate automatic orienting to eye gaze. *Cognition \& Emotion*, *20*(2), 309–320.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., ... & Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry research*, *168*(3), 242-249.

Uono, S., Sato, W., & Toichi, M. (2009). Dynamic fearful gaze does not enhance attention orienting in individuals with Asperger's disorder. *Brain and cognition*, *71*(3), 229-233.

Van Dam, N. T., Gros, D. F., Earleywine, M., & Antony, M. M. (2013). Establishing a trait anxiety threshold that signals likelihood of anxiety disorders. *Anxiety, Stress & Coping*, *26*(1), 70-86.

Valla, J., Maendel, J., Ganzel, B., Barsky, A., & Belmonte, M. K. (2013). Autistic trait interactions underlie sex-dependent facial recognition abilities in the normal population. *Frontiers in psychology*, *4*, 286.

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: the SHINE toolbox. *Behavior Research Methods*, *42*(3), 671-684.