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Relationship between types of anxiety and the ability to recognize facial expressions

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ABSTRACT

This study examined whether three subtypes of anxiety (trait anxiety, state anxiety, and social anxiety) have different effects on recognition of facial expressions. One hundred and thirty-eight participants matched facial expressions of three intensity levels (20 %, 40 %, 100 %) with one of the six emotion labels ("happy", "sad", "fear", "angry", "disgust", and "surprise"). While using a conventional method of analysis we were able to replicate some significant correlations between each anxiety type and recognition performance found in the literature. However, when we used partial correlation to isolate the effect of each anxiety type, most of these correlations were no longer significant, apart from the negative correlations between Beck Anxiety Inventory and reaction time to fearful faces displayed at 40 % intensity level, and the correlations between anxiety and categorisation errors. Specifically, social anxiety was positively correlated with misidentifying a happy face as a disgust face at 40 % intensity level, and state anxiety negatively correlated with misidentifying a happy face as a sad face at 20 % intensity level. However, these partial correlation analyses became non-significant after p value adjustment for multiple comparisons. Our eye tracking data also showed that state anxiety may be associated with reduced fixations on the eye regions of low-intensity sad or fearful faces. These analyses cast doubts on some effects reported in the previous studies because they are likely to reflect a mixture of influences from highly correlated anxiety subtypes.

Anxiety is related both to an attentional bias, in which cognitive resources are selectively allocated to threat information (Bar-Haim et al., 2007), and to an interpretation bias, which is a tendency to interpret daily-events and information as being negative and threatening (Calvo & Castillo, 2001). Collectively these biases are called cognitive bias.

Anxieties are subdivided into different types. Trait anxiety is a relatively stable anxiety-proneness that reflects individual differences in perceiving threats, stress, and dangers, whereas state anxiety is an anxious emotional state felt in a particular situation or event (Spielberger et al., 1983). Both trait and state anxiety are generalized anxiety. Social anxiety or social phobia, on the other hand, is characterised by a marked fear of being judged in a negative manner by others. People with social anxiety feel a strong need to appear in a favourable way in the eyes of others and tend to show excessive insecurity about the ability to do so (Clark & Wells, 1995).

Studies have indicated that different types of anxiety could lead to the different cognitive bias. Trait anxiety tends to show attentional bias by directing more attention towards threat-related information at an early stage of information processing (e.g., Broadbent & Broadbent, 1988; Mogg et al., 1995). Social anxiety, on the other hand, is strongly associated with interpretation bias particularly of ambiguous social information (e.g., McManus et al., 2000; Voncken et al., 2007). People suffering from social anxiety tend to avoid attention from others or threat-related information (Bögels & Mansell, 2004; Clark & Wells, 1995), and tend to display heightened vigilance to threat (Bantin et al., 2016; Günther et al., 2021). Studies appear to indicate an initial vigilance to threat, followed by a later avoidance (Bögels & Mansell, 2004). Thus, findings in social anxiety shows a fluid picture with respect to initial vigilance.

In this study, we are mainly interested in how the anxiety-related cognitive bias affects the recognition of facial expressions of emotion. As one of the most common social information around us, facial expressions contain important information about an individual's feeling or

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social judgment. Therefore, the ability to recognize facial expressions correctly and timely is essential for maintaining a good relationship with others. Given that the distorted perception of facial expressions has been observed in heightened anxiety (Doty et al., 2013; Hunter et al., 2009), finding the relationship between the cognitive bias and various types of anxiety in facial expression recognition should be helpful for revealing the influence of anxiety on facial expression interpretation.

As social anxiety is strongly related to interpretation bias (Chen et al., 2020), we can assume that socially anxious people are likely to recognize negative expressions more accurately compared with other expressions, or to miscategorise a neutral or positive expression as a negative one. It is therefore meaningful to measure not only categorisation accuracy for each facial expression label, but also the proportion of miscategorisation, which identifies which emotion label is incorrectly given to a specific type of facial expression. Although this can be an optimal index of the interpretation bias for recognizing emotional expressions, only a handful studies have used this to measure its relationship with generalized anxiety (Green & Guo, 2018), state anxiety (Attwood et al., 2017), and social anxiety (Torro-Alves et al., 2016). In addition, only the study by Green and Guo (2018) used inferential statistics to analyze the index. This makes it difficult to draw a conclusion from most of these studies. Green and Guo (2018) studied the correlation between the miscategorisation index and the scores from Beck Anxiety Inventory, and found that this anxiety measure was negatively correlated with misinterpreting fear or surprise as sadness. In addition, Gutiérrez-García and Calvo (2017), and Suslow et al. (2019) also used discrimination indexes (hits and false alarms) to calculate associations with anxiety. To extend their work, we also used the miscategorisation index here to study the effect of interpretation bias for emotion recognition in social anxiety.

However, research on the influence of anxiety on facial expression recognition has generated some inconsistent findings. For example, Doty et al. (2013) found a positive correlation between trait anxiety and the accuracy of identifying fearful faces when participants judged whether a briefly presented face with fearful, happy or neutral expression was fearful. Although this was consistent with Surcinelli et al. (2006), who also reported that individuals with high-trait anxiety identified fearful face more accurately than those with low-trait anxiety, the difference between high- and low-trait anxiety was not found in Cooper et al. (2008). More recently, Park et al. (2016) identified a link between trait anxiety and negative interpretation of surprised faces. Consistent with this, Mendes Ferrer Rosa et al. (2017) found an association between trait anxiety and more accurate recognition of angry, fearful, and happy faces. However, a later study by Suslow et al. (2019) found no relationship between trait anxiety and recognition of emotional faces.

Similar to the findings on trait anxiety, research on effects of social anxiety on facial expression recognition has also generated mixed findings. Yoon and Zinbarg (2007) asked participants to create a story based on a pair of sequentially presented face images. They found that social anxiety was correlated with negative interpretations of the facial expression including neutral faces. Others have reported that socially anxious individuals were more accurate at recognizing happy, sad and fearful faces than the normal controls (Hunter et al., 2009). These individuals were particularly sensitive to angry faces, which they could recognize even when the expression was shown at a very low level (25 %) of intensity (Torro-Alves et al., 2016). However, Philippot and Douilliez (2005) failed to replicate the difference between social phobics and normal controls. Douilliez et al. (2012) also found no effect of social anxiety on the evaluation of disapproval to facial expressions.

What might be the cause of these inconsistent results in research on trait and social anxiety? Research findings on cognitive bias might offer some clues. According to Williams et al.'s (1997) cognitive bias model, high-trait anxiety is associated with attentional bias towards threat-related information, which is assumed to arise at an early or pre-attentive stage of information processing. It is plausible that anxious individuals amplify the perceived threatening expressions before they allocate attentional resources to it. If this were the case, they would be able to recognize these threatening faces faster and more accurately, and to evaluate these faces more emotionally intensive than positive or neutral faces. However, this does not necessarily mean the heightened attentional bias towards threatening expressions would lead to an increased categorisation accuracy for other non-threatening negative expressions (e.g., sadness, disapproval) or positive expressions.

Apart from behavioural measures, we have used eye-tracking measures in this study. Recently, eye-tracking protocol has been incorporated with the facial expression categorisation task to investigate possible anxiety-related attentional bias (e.g., Green & Guo, 2018; Horley et al., 2003). Although participants tend to scan all key internal facial features (i.e., eyes, nose, mouth) while viewing expressive faces, they fixate more on the local facial regions that are most characteristic for each facial expression (Eisenbarth & Alpers, 2011; Guo, 2012, 2013). Local regions such as the mouth in happy faces and the eyes in angry faces contain diagnostic information for recognizing these facial expressions (Calvo & Nummenmaa, 2008; Smith et al., 2005). Interestingly, anxiety level could bias this expression-dependent gaze allocation. For instance, a social phobic tends to avoid looking at the eye region (Horley et al., 2003). In non-clinical population, those with higher generalized anxiety level show increased tendency of gazing at the nose region (Green & Guo, 2018). However, there is also considerable overlap among anxiety types. For example, interpretation biases are not restricted to socially anxious individuals, because these are also observed in trait anxiety (Park et al., 2016). Our current study attempted to extend this literature by examining how different anxiety subtypes (social, trait and state anxiety) are associated with the bias of gaze allocation. We also examined how face-viewing gaze distribution is related to facial expression categorisation performance.

In addition to these questions, we have tried to examine an issue related to the emotional intensity of facial expressions in prior research. Most studies used only high intensity facial expressions (e.g., Cooper et al., 2008; Doty et al., 2013; Surcinelli et al., 2006; Yoon & Zinbarg, 2007). Philippot and Douilliez (2005) pointed out that these extreme stimuli not only had limited ecological validity, but also could produce ceiling effects. Moreover, Heinrichs and Hofmann (2001) suggested that social anxiety tended to lead interpretation bias especially towards ambiguous stimuli. Taking these observations into consideration, for each expression label we used two lower emotional intensities (20 % and 40 %) along with the full intensity level (100 %) in our expression recognition test.

Furthermore, a recent study reported that heightened state anxiety (induced via 7.5 % CO_2 gas mixtures) could impair recognition performance for most facial expressions except for sadness (Attwood et al., 2017). The authors concluded that unlike trait anxiety, state anxiety had a different influence on facial expression recognition. This is consistent with some other evidence that state anxiety could facilitate recognition of negative facial expressions (e.g., Surcinelli et al., 2006). On the other hand, Rusting (1999) suggested that current mood state could intensify the effect of trait vulnerability in cognitive processing. Hence, we decided to investigate influence of state anxiety on the recognition of facial expression in comparison to influence of trait anxiety and social anxiety.

Another common issue of the existing research is that although there are correlations among self-reported scores of trait anxiety, social anxiety, and state anxiety, their mutual influence was often not excluded in data analyses. High correlations between social anxiety and trait anxiety have been reported in a couple of studies, such as $r = 0.74$ in Rapee and Medoro (1994), and $r = 0.53$ in Maisel et al. (2016). Both studies used the Fear of Negative Evaluation Scale (Watson & Friend, 1969) to measure social anxiety and the State-Trait Anxiety Inventory (Speilberger et al., 1983) to measure trait anxiety. Some of these past findings could have been based on mixed effects from different types of anxiety, such as those of trait and social anxiety. Some studies did attempt to control for this. For example, Hunter et al. (2009) controlled for STAI-t.

Following the same idea to remove the influence of the specific anxiety from the other types of anxiety, we employed partial correlation analyses, using the degree of social and state anxiety as control variables to investigate the influence of trait anxiety on the dependent variables. Likewise, we also used the degree of trait and state anxiety as controls to investigate the influence of social anxiety, and the degree of social and trait anxiety as controls to investigate the influence of state anxiety.

In summary, the present study aimed to examine the influence of three types of anxiety (trait, state, and social anxiety) on the recognition of facial expressions. We presented six common types of facial expression (happy, sad, anger, fear, disgust, and surprise) at three different emotional intensities (20 %, 40 %, and 100 %), and measured expression categorisation accuracy and bias, expression intensity rating, reaction time, and associated face-viewing gaze allocation. The relation between these measurements and anxiety types were then examined in detail with partial correlation analyses.

Derived from the existing research, our hypotheses were that trait anxiety would be associated with oversensitive detection of threat-related facial expressions (e.g., higher detection rate and faster reaction time for fear and anger), whereas social anxiety would be associated with disgust and anger (e.g., higher detection rate and faster reaction time for disgust and anger). We also predicted that these effects should be more pronounced when facial expressions have low intensity because these would make the expression more ambiguous. For miscategorisation, we predicted the general anxiety would be negatively correlated with misinterpreting fear or surprise as sad following Green and Guo (2018), but social anxiety to be positively correlated with misinterpreting nearly neutral or disgusted expression as fear or anger.

1. Methods

A total of 138 undergraduates (107 females) took part in the experiment. Results from three participants were excluded from data analysis because they failed to complete questionnaires. The mean age of the remaining participants was 20.2 ± 2.8 (Mean ± SD) years old. To fit our inclusion criteria, all participants were required to confirm that they had no history of neuropsychiatric disorders (e.g., depression, anxiety disorder and social phobia) and had normal or corrected-to-normal visual acuity. The Ethical Committee in Department of Psychology, Bournemouth University, and School of Psychology, University of Lincoln (PSY171834) approved this study. Written informed consent was obtained from each participant prior to the study, and all procedures complied with the British Psychological Society Code of Ethics and Conduct.

Grey-scale western Caucasian expressive face pictures, consisting of 4 female and 4 male models, were selected from the Karolinska Directed Emotional Faces (Lundqvist et al., 1998). The image dataset consisted of 28 models, who posed 1 neutral and 6 high-intensity facial expressions (happy, sad, fear, angry, disgust, and surprise). External features (e.g., hair) and the background of each picture were replaced with a homogeneous grey background by processing in Adobe Photoshop. For each of the six expressions of each model, Morpheus Photo Morpher was used to create 3 levels of intensity (20 %, 40 %, and 100 %) by morphing the emotional face with the neutral face (Guo, 2012). Fig. 1 shows an example face with these manipulations. This resulted in a total of 144 face images (6 expressions × 3 intensities × 8 models). Additionally, we chose 4 pictures from another two different models as practice trials. All face images were presented once in a random order at the centre of screen with the resolution of 430 × 568 pixels (16° × 21°) on the screen with 1980 × 1080 resolution.

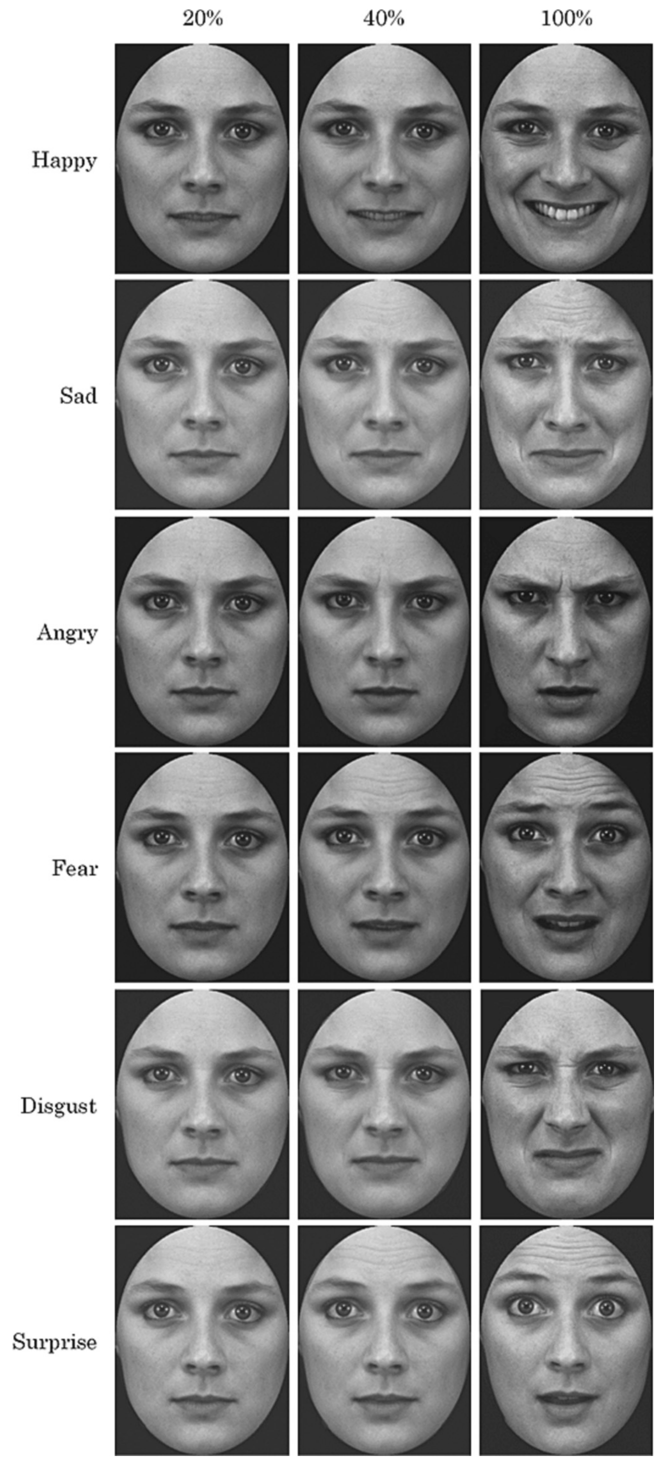

Fig. 1. An example face with six emotional expressions at three intensity levels.

1.1. Procedure for collecting behavioural data

At the beginning of the experiment, participants were shown 12 face images sampled from Ekman and Friese (1976) Pictures of Facial Affect. The images consisted of one male and one female model, with each showing 6 basic emotional expressions (happy, sad, fear, angry, disgust, and surprise). For each face model, the 6 expressions were shown on 3 separate displays, with each display showing 2 images of different expressions side by side and 6 expression labels on the right-hand side. For example, the first display would consist of a pair of a sad and a surprised face, the second display a happy and fearful face, and the third display an angry and disgusted face. For each display, participants were asked to choose one label from the 6 options to describe each of the pair as accurately as possible without time constraint. Once they made their choices for both faces, the correct answers were given for each face. This was repeated for all pairs of 12 face images in 6 displays. This initial procedure was to ensure that the participants understood the facial expression categories and the labels used in this study.

A self-paced expression categorisation task was then carried out. Because this part of the task was slightly different from the initial introduction phase above, participants were given practice trials. As illustrated in Fig. 2, each trial started with a fixation cross at the center of the screen for 1 s, followed by a single face image. Participants were told to judge the facial expression as quickly and as accurately as possible by pressing the spacebar. The face image was cleared once the spacebar was pressed. Participants were then required to specify which expression they had identified by pressing one of 6 numeric keys (1-happy, 2-sad, 3-angry, 4-fear, 5-disgust, 6-surprise) on the keyboard. The key for each expression was displayed on the screen. Following this, another response screen instructed the participant to specify the intensity of the expression on a 9-point scale. The testing session consisted of 4 practice trials and 144 main trials (8 faces × 6 expressions × 3 intensity levels). The order of these trials was random for each participant.

After the facial expression test, participants were asked to complete four questionnaires: (1) The Brief Fear of Negative Evaluation Scale (BFNE; Leary, 1983). This was used to measure the level of social anxiety. It consisted of 12 items. Each one was rated on a 5-point scale ranging from 1 = "Not at all characteristic of me" to 5 = "Extremely characteristic of me"). (2) The Beck Anxiety Inventory (BAI; Beck et al., 1988). This questionnaire focused on somatic symptoms of anxiety, which discriminates between anxiety and depression. It included 21 statements with a 4-point scale ranging from 0 = "Not at all" to 3 "Severely - it bothered me a lot". Participants were required to rate how they have been bothered by those symptoms during the past month. (3) The State-Trait Anxiety Inventory Form Y-II (STAI-t; Spielberger et al., 1983). This consisted of 20 items presenting anxiety proneness with a 4-point scale ranging from 1 = "Almost never" to 4 = "Almost always". (4) The State-Trait Anxiety Inventory Form Y—I (STAI-s; Spielberger et al., 1983). This consisted of 20 items representing subjective feelings of apprehension, tension, and worry with a 4-point scale ranging from 1 = "Not at all" to 4 = "Very much so". It measures how stated symptoms were felt at the time.

1.2. Procedure for collecting eye movement data

For 69 participants (48 females, mean age 20.42 ± 2.8), their gaze was also monitored during the facial expression categorisation task. They sat in a chair with their head restrained by a chin-rest, and viewed the screen binocularly (1024 × 768 pixels, 30 cd/m^2 background luminance, 100 Hz frame rate, Mitsubishi Diamond Pro2070SB). Horizontal and vertical eye positions from the dominant eye (determined through the Hole-in-Card test) were measured using a Video Eyetracker Toolbox with 250 Hz sampling frequency and up to 0.25° accuracy (Cambridge Research Systems, UK). Eye movement signals were first calibrated by instructing the participant to follow a fixation point (FP, 0.3° diameter, 15 cd/m^2 luminance) displayed randomly at one of 9 positions (3 × 3 matrix) across the monitor (distance between adjacent FP positions was 10°). After the calibration procedure, the participant pressed the response box to initiate a trial. The trial was started with an FP displayed 10°left or right to the screen centre to minimize central fixation bias. If the participant maintained fixation for 1 s, the FP disappeared and a face image was presented at the centre of the screen. The participant was instructed to make the same behavioural judgment as described above, and to respond by pressing a button on the response box (for collecting reaction time data) with the dominant hand followed by a verbal report of the perceived expression and its intensity. The reported responses were typed into the eye-tracking software developed in MATLAB by the researcher. The face image disappeared immediately after manual response and the gaze tracking was stopped.

The collected eye movement data were analysed off-line. The software developed in MATLAB computed horizontal and vertical eye displacement signals as a function of time to determine eye velocity and position. Fixation locations were then extracted from the raw eye

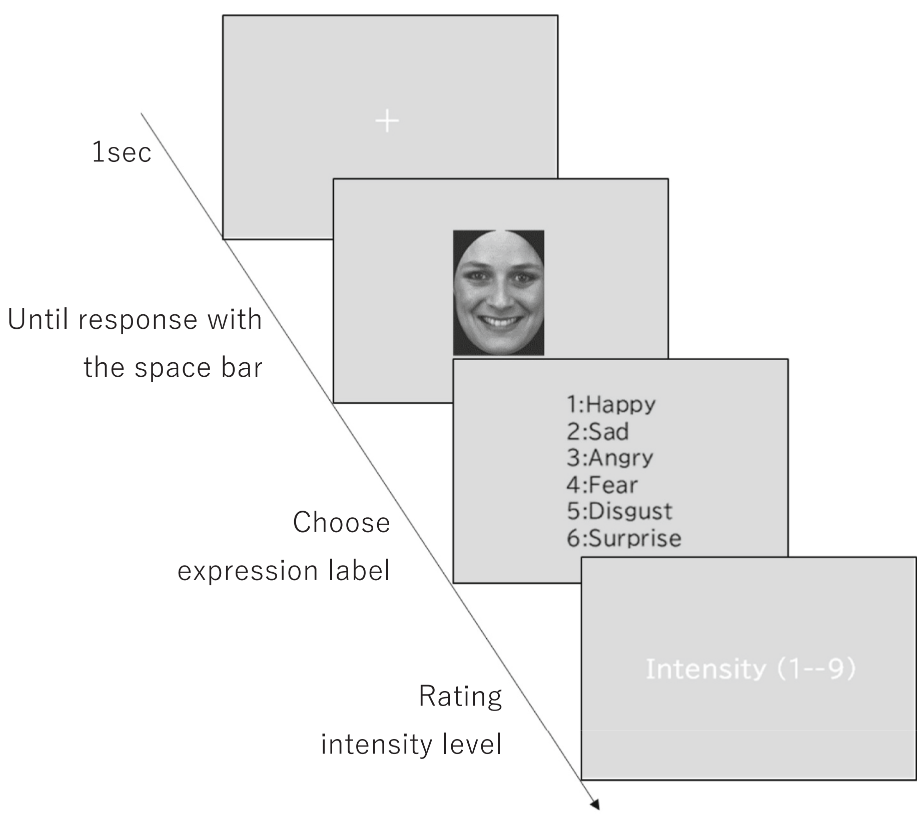

Fig. 2. The procedural of the self-paced expression categorisation task.

tracking data using velocity (<0.2° eye displacement at a velocity of <20°/*sec*) and duration (>50 msec) criteria (Guo et al., 2006). While determining gaze allocation within key facial features (i.e., eyes, nose, and mouth), a consistent criterion was adopted to define boundaries between local facial features for different faces (for details see Guo et al., 2010). Each fixation was then characterised by its location among feature regions and its time of onset relative to the start of the trial. The viewing time (fixation time) directed at each feature was normalized to the total face-viewing time sampled in that trial.

1.3. Data analysis

Accuracy scores for the 18 conditions (6 facial expressions × 3 intensity levels) were calculated by taking the proportion of correctly categorised expression out of the eight trials (i.e., eight faces) for each condition. We first did this for each participant before computing the mean accuracy scores across participants. We also calculated categorisation bias scores for each participant and each facial expression (e.g., surprise) at each intensity level separately by counting the number of the times where this expression was mistakenly categorised as a different expression (e.g., surprise categorised as anger). The count was then divided by the number of trials in that condition to derive a bias score. Scores of individual participants were later used in correlation analysis with anxiety scores.

Reaction time response was based on the difference between stimulus onset and the button press on the spacebar or response box. Only reaction time data for the correct responses were included in statistical analysis.

2. Results

2.1. Main effects: facial expression categorisation performance

Results of the facial expression categorisation are summarised in Table 1. We employed a 6 (expression) × 3 (intensity) repeated-measures analysis of variances (ANOVA) for categorisation accuracy, the intensity rating, and reaction time data. Bonferroni adjustments was used for multiple comparisons.

2.1.1. Categorisation accuracy

ANOVA showed significant main effects of Expression, $F(5, 670) = 154.52$, $p < .001$, $\eta_p^2 = 0.54$, and Intensity, $F(2, 268) = 2277.41$, $p < .001$, $\eta_p^2 = 0.94$. Post-hoc tests with Bonferroni adjustment revealed that happy and sad were categorised more accurately than all other emotional expressions (all p's < 0.05). The other facial expressions were categorised more accurately in the order of angry, disgust, surprise, and fear (all p's < 0.05). Furthermore, expressions with 100 % intensity attracted the highest categorisation accuracy, followed by 40 % intensity, and then by 20 % intensity (all p's < 0.001). The Expression × Intensity interaction was also significant, $F(10, 1340) = 63.66$, $p < .001$, $\eta_p^2 = 0.32$ (Fig. S1). Analysis of this interaction by pairwise comparison revealed that at 20 % intensity level, sad had the highest categorisation accuracy, followed by happy and angry, then by disgust, and finally by fear and surprise (all p's < 0.01). At 40 % intensity level, happy, angry and sad had similarly high categorisation accuracy, followed by disgust and surprise, and then by fear (all p's < 0.05). At 100 % intensity level, happy, surprise, disgust, angry and sad were categorised more accurately than fear (all p's < 0.05).

2.1.2. Intensity rating

ANOVA also showed significant main effects of Expression, $F(5, 670) = 91.67$, $p < .001$, $\eta_p^2 = 0.41$, and Intensity, $F(2, 268) = 2258.14$, $p < .001$, $\eta_p^2 = 0.94$. Post-hoc tests revealed that surprise was rated higher than all other expressions (all p's < 0.001). Sad was rated stronger than happy, fear and angry (all p's < 0.05). Angry and surprise were rated stronger than fear (all p's < 0.001). Furthermore, expressions with 100 % intensity attracted the highest intensity rating, followed by 40 % intensity, and then by 20 % intensity (all p's < 0.001). The Expression × Intensity interaction was also significant, $F(10, 1340) = 50.60$, $p < .001$, $\eta_p^2 = 0.27$ (Fig. S2). At 20 % intensity level, participants rated disgust and sad as being more intense than the other expressions, and angry more intense than happy and surprise (all p's < 0.05). At 40 % intensity level, they also rated disgust and sad as being more intense than other expressions (all p's < 0.001), and fear, angry and surprise more intense than happy (all p's < 0.05). At 100 % intensity level, they rated happy and disgust as being more intense than other expressions (all p's < 0.001), surprise more intense than sad and fear (all p's < 0.05), and angry more intense than fear ($p < .001$).

2.1.3. Reaction time

ANOVA again showed significant main effects of Expression, $F(5, 670) = 16.64$, $p < .001$, $\eta_p^2 = 0.11$, and Intensity, $F(2, 268) = 132.04$, $p < .001$, $\eta_p^2 = 0.50$. Post-hoc tests revealed that participants reacted the fastest to sad, and the slowest to fear (all p's < 0.01). They also reacted the fastest to 100 % expression intensity level, and the slowest to 20 % intensity level (all p's < 0.001). The Expression × Intensity interaction was also significant, $F(10, 1340) = 12.70$, $p < .001$, $\eta_p^2 = 0.09$ (Fig. S3). At 20 % intensity level, participants reacted significantly faster to sad, followed by angry and disgust, and then by happy, fear, and surprise expressions (all p's < 0.05). At 40 % intensity level, fear expression was

Table 1
Mean proportion of expression categorisation accuracy, mean score of intensity rating, and mean seconds of reaction time (s).

Intensity level	Type of index	Happy	Sad	Angry	Fear	Disgust	Surprise
20 %	Accuracy	0.48	0.69	0.48	0.15	0.36	0.14
		(0.23)	(0.18)	(0.24)	(0.16)	(0.23)	(0.14)
	Rating	2.51	3.13	2.87	2.65	3.28	2.55
		(0.94)	(1.24)	(1.13)	(1.10)	(1.11)	(1.05)
	RT	3.21	2.40	2.77	3.06	2.74	3.24
		(1.80)	(1.22)	(1.58)	(1.87)	(1.44)	(2.66)
40 %	Accuracy	0.86	0.77	0.78	0.52	0.71	0.69
		(0.17)	(0.14)	(0.20)	(0.24)	(0.17)	(0.18)
	Rating	3.95	4.64	4.31	4.30	5.57	4.48
		(1.30)	(1.25)	(1.21)	(1.18)	(1.12)	(1.18)
	RT	2.26	2.02	2.20	2.61	2.21	2.38
		(1.34)	(1.07)	(1.06)	(1.37)	(1.25)	(1.50)
100 %	Accuracy	0.99	0.87	0.91	0.60	0.92	0.95
		(0.03)	(0.14)	(0.13)	(0.25)	(0.14)	(0.09)
	Rating	7.52	6.83	7.02	6.61	7.66	7.12
		(1.04)	(1.15)	(1.09)	(1.13)	(0.92)	(1.01)
	RT	1.35	1.69	1.78	2.20	1.75	1.59
		(1.05)	(0.90)	(0.87)	(1.22)	(0.90)	(0.96)

Note. The value in parenthesis is standard deviation.

reacted slower than other expressions except for surprise (all p's < 0.05). At 100 % intensity level, fear was reacted slower than the other expressions (all p's < 0.01), and happy face was reacted slower than angry and disgust (all p's < 0.05).

2.1.4. Categorisation bias scores

Results of the categorisation bias are shown in Table 2. Because categorisation errors were very low (0 to 8 %) when facial expressions were shown at 100 % intensity, we only present the categorisation bias results at 20 % and 40 % intensity levels.

2.2. Effects of anxiety

To compare our results to those obtained in previous studies, we first calculated Pearson correlation between the scores of questionnaires (BFNE, BAI, STAI-t, STAI-s) and the response measures in the expression categorisation test (i.e., categorisation accuracy, intensity rating, and reaction time). We also calculated the correlations between the scores of questionnaires.

The results for the first of these correlation analyses are shown in Table 3. The correlation between the facial expression categorisation accuracy and scores of questionnaires showed significant results only when facial expressions were at the 20 % intensity level, where higher STAI-t and STAI-s scores were correlated with poorer accuracy for recognizing sad expression ($r = -0.179$ and -171, $p = .038$ and 0.047, respectively).

For the intensity rating results, we found a positive correlation between scores of STAI-t and intensity rating of the angry expression when the expression was shown at 100 % level of intensity ($r = 0.178$, $p = .039$).

For the reaction time, we found a negative correlation between BAI scores and reaction time of recognizing fear expression at 40 % and 100 % intensities ($r = -0.207$ and $-$ 0.178, $p = .016$ and 0.039, respectively).

It is worth noting that due to large number of correlation analyses, all correlation coefficients in Table 3 were not significant when adjusted for p-values using the false discovery rate (FDR) with Benjamini-Hochberg method (Benjamini & Hochberg, 1995).

As Table 4 shows, all questionnaires showed good Cronbach's internal consistency coefficient alpha scores (≥ 0.84), except for STAI-s, which scored 0.70. High correlations were found between all pairs of questionnaires.

Since the four questionnaire measures were highly correlated with each other, the significant Pearson correlations could be spurious. As detailed in the Introduction, we attempted to resolve this issue by removing the effect of social and state anxiety from the correlation of generalized anxiety (and vice versa). After applying partial correlation analyses, we found no significant results except for a negative correlation between BAI and reaction time for fearful faces at 40 % of intensity ($r = -0.195$, $p = .024$).

2.3. Categorisation bias and anxiety

To examine to what extent anxiety affected systematic categorisation bias, for those expressions attracting >5 % categorisation bias scores, we first calculated Pearson correlation between the categorisation bias and anxiety scores. Results in Table 5 show that at the 20 % intensity level, BFNE, BAI, and STAI-t scores correlated positively with miscategorising sadness as anger. Furthermore, STAI-t correlated negatively with miscategorising fearful faces as sad faces, and STAI-s correlated negatively with miscategorising happy faces as sad faces. As we reported in Table3, both STAI-t and STAI-s correlated negatively with correct categorisation of sad faces. At 40 % intensity level, BFNE correlated positively with miscategorising the happy expression as disgust. Following these, partial correlation analyses were conducted between anxiety scores and categorisation bias only for those pairs showing significant Pearson correlation. The results showed that the positive correlation between BFNE and miscategorising happiness as disgust ($r = 0.200$, $p = .022$) at the intensity level of 40 %, and the negative correlation between STAI-s and miscategorising happiness as sadness at the intensity level of 20 % ($r = -0.188$, $p = .031$) were still significant. However, due to large number of correlation analyses, all correlation coefficients were not significant when adjusted for p-values using the false discovery rate (FRD) with Benjamini-Hochberg method (Benjamini & Hochberg, 1995).

2.4. Analysis of gaze allocation

In agreement with previous studies (Green & Guo, 2018; Guo, 2012), when viewing expressive faces, participants allocated majority of viewing time at three key internal facial features, namely the eyes, the nose, and the month (98 % ± 1.83). As intensity of a facial expression had little impact on the proportion of viewing time directed at specific local facial features (Guo, 2012), we merged different intensities for each expression and submitted the results to a 3 (facial feature) × 6 (expression) ANOVA. This revealed a significant main effect of facial feature, $F(2,130) = 12.43$, $p < .001$, $\eta_p^2 = 0.16$, and a significant interaction, $F(10, 650) = 23.2$, $p < .001$, $\eta_p^2 = 0.26$, whereas the main effect of expression was non-significant, $F(5, 325) = 0.71$, $p = .62$, $\eta_p^2 = 0.01$. Across all expressions, eyes (36.65 % ± 2.5) and nose (40.42 % ± 2.73) attracted longer viewing time than mouth (20.83 % ± 1.93; all p's $<$ 0.05). Among individual expressions, eyes in fear, anger, sad and surprise attracted longer viewing time than in happy and disgust expressions (all p's < 0.05); nose in sad, disgust and anger attracted longer viewing time than in fear, happy and surprise expressions (all p's $<$ 0.05); and mouth in happy attracted the longest viewing time, followed by disgust, and then by surprise, fear, anger and sad expressions (all p's < 0.05).

Although the proportion of viewing time directed at a given facial feature varied greatly across individual participants (eyes: 3–89 %, nose: 7–94 %, mouth 0–78 %, Table 6), two-tailed Pearson correlation analysis between participants' expression categorisation accuracy and proportion of viewing time at the eyes, nose and mouth regions did not

Table 2
Confusion matrix of categorisation bias at 20 % and 40 % intensity level.

	Intensity level = 20 %						Intensity level = 40 %					
	Happy	Sad	Angry	Fear	Disgust	Surprise	Happy	Sad	Angry	Fear	Disgust	Surprise
Happy	48 %	19 %	10 %	7 %	13 %	3 %	85 %	2 %	2 %	3 %	5 %	2 %
Sad	4 %	69 %	17 %	3 %	7 %	0 %	1 %	77 %	4 %	6 %	11 %	1 %
Angry	5 %	34 %	48 %	4 %	8 %	1 %	0 %	12 %	78 %	2 %	7 %	1 %
Fear	14 %	49 %	11 %	15 %	6 %	5 %	3 %	10 %	3 %	52 %	5 %	27 %
Disgust	6 %	25 %	29 %	3 %	36 %	1 %	2 %	7 %	18 %	2 %	71 %	1 %
Surprise	11 %	46 %	9 %	15 %	4 %	14 %	4 %	3 %	1 %	23 %	0 %	69 %

Note: The categorisation bias scores were calculated by averaging individual scores for each facial expression at each intensity level across all participants. Individual participant's score for each displayed emotion at each intensity level was determined by counting the absolute number of specific miscategorisations (e.g., happy mistakenly categorised as sad) and dividing this number by the total number of trials per emotion condition and intensity level.

Table 3
Correlation Coefficients between Anxiety Scores and Each Index across Each expression and Intensity Levels.

	Happy			Sad			Angry			Fear			Disgust			Surprise		
	20 %	40 %	100 %	20 %	40 %	100 %	20 %	40 %	100 %	20 %	40 %	100 %	20 %	40 %	100 %	20 %	40 %	100 %
Accuracy																		
BFNE	−0.021	−0.052	0.083	−0.088	−0.142	0.062	0.067	−0.027	−0.028	0.163	−0.073	−0.024	0.106	0.071	0.048	−0.035	0.016	−0.060
BAI	−0.089	−0.069	−0.034	−0.103	−0.045	0.076	0.125	0.094	0.022	0.099	0.016	0.095	0.032	−0.007	0.079	−0.004	0.154	−0.003
STAI-t	−0.001	−0.049	0.014	−0.179*	−0.101	0.078	0.148	0.051	0.041	0.146	−0.027	−0.052	0.083	0.070	0.103	0.015	0.093	−0.038
STAI-s	0.140	0.032	0.006	−0.171*	−0.007	0.011	0.067	−0.005	−0.101	0.057	−0.049	−0.067	0.088	0.028	0.038	−0.038	0.078	0.034
Intensity rating																		
BFNE	−0.100	−0.028	0.138	−0.059	0.076	0.148	−0.010	0.016	0.107	0.023	0.015	0.068	0.030	0.058	0.015	0.011	0.018	0.034
BAI	−0.091	−0.052	0.004	−0.055	0.029	0.081	−0.020	−0.021	−0.035	−0.027	−0.025	0.026	−0.042	−0.015	0.015	−0.007	−0.008	−0.032
STAI-t	−0.058	−0.020	0.054	−0.053	0.164	0.151	0.008	0.038	0.178*	−0.019	0.056	0.092	0.037	0.143	0.123	0.002	0.074	0.140
STAI-s	−0.040	−0.055	0.096	0.000	0.106	0.078	0.071	0.060	0.146	−0.001	0.075	−0.014	0.102	0.079	0.095	0.040	0.036	0.099
Reaction time																		
BFNE	0.035	−0.079	−0.014	−0.072	−0.007	−0.061	−0.075	−0.010	−0.104	−0.020	−0.057	−0.093	−0.032	−0.087	−0.059	−0.051	−0.066	0.006
BAI	0.072	−0.035	0.005	−0.075	−0.025	−0.034	−0.162	−0.052	−0.138	0.060	−0.207*	−0.178*	−0.084	−0.098	−0.051	−0.043	−0.040	0.030
STAI-t	0.069	0.007	−0.018	−0.026	−0.011	0.014	−0.065	0.007	−0.142	0.084	−0.098	−0.094	−0.001	−0.059	−0.023	−0.024	−0.043	0.038
STAI-s	−0.041	−0.013	−0.036	0.013	−0.034	0.121	−0.069	0.063	−0.091	0.064	−0.062	−0.055	0.018	0.051	−0.007	−0.053	−0.082	0.132

* $p < .05$.

Table 4
Correlations between Questionnaires and Alpha Coefficient.

	BFNE	BAI	STAI-t	STAI-s
BAI	0.319**	–		
STAI-t	0.547**	0.585**	–	
STAI-s	0.303**	0.415**	0.685**	–
Alpha coefficient	0.87	0.91	0.84	0.70

Values in the table represent r value. * $p < .05$, ** $p < .01$.

reveal any significant correlations (all p's > 0.05; see Table S1), suggesting that individuals' gaze allocation had little impact on their expression recognition performance.

For anxiety measurements, STAI-s, BAI and BFNE scores did not correlate with viewing time at the eyes, nose or mouth regions (Table S1). On the other hand, individuals' STAI-t level seemed to influence face-viewing gaze allocation. In general, those with higher trait anxiety tended to look more at the nose in sad and fear expressions (sad: $r = 0.247$, $p = .046$; fear: $r = 0.248$, $p = .044$). Partial correlation further confirmed that higher STAI-t scoring was associated with longer viewing time at the nose in sad faces ($r = 0.252$, $p = .043$; Table S2).

3. Discussion

The present study aimed to examine the influence of different types of anxiety on the recognition of facial expressions. We presented six common types of facial expression (happy, sad, anger fear, disgust, and surprise) at three different emotional intensities (20 %, 40 %, and 100 %), and measured expression categorisation accuracy, intensity rating, reaction time, categorisation bias, and associated face-viewing gaze allocation. In our data analyses, we employed two different methods. The first was Pearson correlation. We used this to compare our results with previous studies. However, the results from this method could be spurious because they could be based on the mixed effects from different anxiety subtypes. To correct this problem, we also used partial correlation as our second method of analysis. This allowed us to separate the independent effects of each anxiety subtype.

When we used the first correlation method, we found some consistent and some conflicting results with the literature that investigated the relationship between anxiety and recognition of facial expressions. Specifically, our results showed that individuals with high trait or state anxiety were less likely to recognize the sad expression at a low intensity (20 %). This corresponded well with the findings by Palm et al. (2011) who also reported that individuals with generalized anxiety disorder showed poorer detection accuracy for sad expressions. However, unlike Attwood et al. (2017), who found state anxiety to be associated with a decrease of sensitivity for all facial expressions, we found only such effect on sad expressions. Furthermore, as some previous studies (e.g., Cooper et al., 2008; Philippot & Douilliez, 2005; Suslow et al., 2019) and we expected, there was no correlation between recognition accuracy of high-intensity (100 %) facial expressions and different subtype anxiety measurements in our results, suggesting the possible limitation of using maximum intensity of facial expressions in anxiety research.

We also found a positive correlation between intensity rating of 100 % angry faces and STAI-t, and negative correlations between reaction times for the 40 % and 100 % intensity level of fearful faces and BAI. These results were congruent with our hypothesis that the effects would be shown in intensity rating or reaction time to negative facial expressions. However, contrary to our prediction based on the prior research such as Doty et al. (2013) and Surcinelli et al. (2006), who reported better categorisation accuracy for fearful faces among individuals with high trait anxiety, we did not find a similar effect of anxiety on categorisation accuracy. The lack of accuracy effects in our results may be explained by Williams et al.'s (1997) cognitive bias model, according to which the attentional bias associated with trait anxiety occurs at the pre-attentive stage that affects more on processing time than on accuracy for

Table 5
Correlation (r) between categorisation bias score and anxiety measures.

		Intensity level = 20 %						Intensity level = 40 %					
		Happy	Sad	Angry	Fear	Disgust	Surprise	Happy	Sad	Angry	Fear	Disgust	Surprise
BFNE	Happy	−0.021	−0.052	−0.039	0.077	0.041		−0.052				0.201 *	
	Sad		−0.088	0.231		−0.146			−0.142		0.003	0.025	
	Angry	−0.079	−0.005	0.067		−0.091			0.082	−0.027		−0.008	
	Fear	−0.036	−0.111	0.053	0.163	−0.037	0.004		−0.013		−0.073		0.141
	Disgust	−0.034	−0.151	0.045		0.106			−0.087	−0.066		0.071	
	Surprise	−0.012	0.044	−0.040	0.070		−0.035				0.016		0.016
BAI	Happy	−0.089	−0.004	0.127	−0.035	0.108		−0.069				0.092	
	Sad		−0.103	0.191 *		−0.051			−0.045		0.071	−0.104	
	Angry	−0.035	−0.114	0.125		0.063			−0.106	0.094		0.042	
	Fear	−0.047	−0.044	−0.029	0.099	0.063	−0.018		−0.003		0.016		0.010
	Disgust	−0.023	−0.044	0.044		0.032			0.005	−0.003		−0.007	
	Surprise	−0.017	0.032	−0.047	−0.049		−0.004				−0.106		0.154
STAI_t	Happy	−0.001	−0.168	0.090	0.076	0.066		−0.049				0.071	
	Sad		−0.179 *	0.213 *		−0.008			−0.101		−0.020	0.005	
	Angry	−0.036	−0.110	0.148		−0.024			−0.008	0.051		−0.016	
	Fear	0.008	−0.179 *	0.023	0.146	0.094	0.023		−0.062		−0.027		0.156
	Disgust	0.041	−0.160	0.069		0.083			−0.117	−0.041		0.070	
	Surprise	−0.010	−0.074	0.026	0.037		0.015				−0.090		0.093
STAI_s	Happy	0.140	−0.250	0.109	−0.037	0.051		0.032				0.072	
	Sad		−0.171 *	0.097		0.073			−0.007		0.014	−0.006	
	Angry	−0.025	−0.038	0.067		−0.039			−0.020	−0.005		0.055	
	Fear	0.016	−0.115	0.083	0.057	0.072	−0.035		0.031		−0.049		0.079
	Disgust	0.066	−0.111	0.003		0.088			−0.072	−0.045		0.028	
	Surprise	−0.090	0.052	0.029	−0.050		−0.038				−0.158		0.078

Values in the table represent r value. * $p < .05$, ** $p < .01$.

those facial expressions.

The categorisation bias results revealed that higher trait anxiety and social anxiety were associated with misinterpreting a sad expression as an angry expression at 20 % level of intensity. This may suggest that individuals with these anxieties are more sensitive about other people's angry emotion.

However, the effects we have described so far were based the correlation analyses that could have mixed the effects of several subtypes of anxiety. When we used partial correlation to tackle this issue, most of these effects have disappeared. One result that survived this analysis was the correlation between BAI scores and reaction time for fearful expression at 40 % level of intensity. The result showed that trait anxiety is associated with faster recognition of fearful expression, which is consistent the hypothesis that trait anxiety may speedup detection of threat stimuli (Williams et al., 1997).

The fact that most correlations disappear after applying partial correlation suggests the possibility that the significant findings obtained by previous studies may have implicated complex effects of several anxiety subtypes. As observed in the present study, trait, state, and social anxieties are highly correlated. To separate effect of a specific anxiety from other subtypes, it is useful to use the partial correlation method to exclude the effect influenced by other types of anxiety. However, it may not always be the case. For example, Hunter et al. (2009) did control for STAI, but still found significant effects of social anxiety.

With partial correlation analysis, we found some significant correlations between expression categorisation bias and anxiety. Specifically, individuals with higher social anxiety scores tended to misinterpret happy as disgust at the 40 % intensity level. According to the multidimensional theory of emotion (Russell & Bullock, 1985), both happy and disgust are arousal emotions, but disgust is classified as a negative whereas happy a positive one emotion. It is possible that socially anxious participants tend to interpret a positive emotion of a moderate intensity as a negative one.

On the other hand, participants scoring high in state anxiety were unlikely to miscategorise happiness as sadness. Interestingly, previous research by Attwood et al. (2017) has reported that increased state anxiety leads to less accurate recognition of happiness, and increased bias to perceive anger rather than happiness in faces morphed with happy and angry expressions. Taken our study and Attwood et al. (2017) together, it seems that state anxiety increases the possibility of miscategorising happiness as high-arousal negative expression (e.g., anger), but not as low-arousal negative expression (e.g., sadness).

The eye-tracking data showed correlations only with trait anxiety. The lack of correlation with social anxiety is incongruent with Horley et al. (2003) who used patients with social phobia. However, there is an important difference between the present study and Horley et al.'s. Here, participants were instructed to respond fast, and then the face stimulus disappeared. Hence, there might not be enough time to dwell on facial features in the present experiment. It is possible that gaze effects of anxiety only occur with longer presentation durations. The results of the present study showed that individuals with higher trait anxiety tended to look more at the nose region in (especially) sad and fear faces. This typical eye-avoidance behaviour indicates those anxious participants might consider the eyes as emotive or provocative stimuli and hence avoid them when they perceive emotional signal in other's face. The nose could be a distractive object because it conveys little information about emotion.

One finding of this study was the influence of anxiety subtypes on the misinterpretation of facial expression. However, these subtypes of anxiety had no effects on expression recognition accuracy or intensity rating when their mutual effect of subtypes was controlled. Taken together the inconsistent findings from the present and pervious results, we may now have sufficient evidence to conclude that recognition accuracy is not a sensitive index to measure the effect of anxiety on facial expression recognition.

These results led us reconsider the kind of influence each subtype of

Table 6
Proportion of viewing time at the eyes, nose and mouth regions across all participants. Data in each cell was expressed as minimum − maximum (mean ± SD).

	All expressions	Happy	Sad	Anger	Fear	Disgust	Surprise
Eyes	3–89 % (37 % ± 20)	1–82 % (32 % ± 21)	5–90 % (37 % ± 21)	2–93 % (38 % ± 21)	2–91 % (39 % ± 21)	1–85 % (34 % ± 20)	4–89 % (40 % ± 20)
Nose	7–94 % (40 % ± 22)	7–94 % (39 % ± 23)	6–93 % (42 % ± 23)	5–96 % (41 ± 22)	7–90 % (39 % ± 22)	4–99 % (42 % ± 23)	6–95 % (39 ± 23)
Mouth	0–78 % (21 % ± 16)	0–82 % (27 % ± 18)	0–69 % (18 % ± 15)	0–82 % (19 % ± 16)	0–77 % (19 % ± 16)	0–85 % (22 % ± 17)	0–70 % (20 % ± 15)

anxiety could have. Our data showed that social anxiety could be related to miscategorising a low-intensity (40 %) happy face as a disgust face. Evidence from prior research also appeared to show that measuring miscategorisation is quite effective for indexing the influence of social anxiety on facial expressions. For example, Heuer et al. (2010) reported that individuals with high social anxiety tended to misinterpret disgust as contempt. This kind of misinterpretation of facial expression could reflect the bias of social anxiety. This is consistent with the observation that socially anxious people are sensitive to responses from others that they may interpret as signs of disapproval and consequently they may try to avoid that social situation (Clark & Wells, 1995).

While assessing the relationship between miscategorisation and anxiety, we found most significant correlations were shown for facial expressions at a low level of intensity such as at 20 % or 40 %. Similar results can also be found in the literature. Several studies that used low intensity facial expressions have supplied stable evidence between anxiety and facial perception. Bui et al. (2017) reported the effect of generalized anxiety on misidentification of low intensity facial expressions, while Torro-Alves et al. (2016) reported the effect of social anxiety with similar manipulation. As Philippot and Douilliez (2005) observed, anxious individuals rarely misinterpret extreme stimuli. Along with these past findings our results reassure the importance of assessing anxiety with low intensity facial expressions. However, we should also point out that the correlations between miscategorisations of facial expression and anxiety scores in our study were rather weak. The performed larger number of correlation analysis (e.g., Table 5) were also susceptible to type I error (false-positive) without *p*-value adjustment or type II error (false-negative) with p-value adjustment (e.g., via false discovery rate). Hence the findings from this part of analyses should be considered with caution.

It is also worth noting that the correlation for sad faces and general anxiety might be influenced by depressive symptoms. Because STAI is confounded with depression, it is a limitation that our study did not investigate the depression.

In sum, the present results suggest that social anxiety, trait anxiety, and state anxiety create biases for recognizing facial expressions in different ways. Their effects are likely to be observed from miscategorisation of expression and eye-tracking when the intensity level of facial expression is fairly weak. Furthermore, our partial correlation analysis suggests a possibility that the results of some previous studies only reflect certain complex effects of anxiety without differentiating the involvement of its subtypes. Future research could further verify this hypothesis and extend the key findings of this study to patient population who display more severe symptoms of these anxiety subtypes.

Declaration of competing interest

We have no known conflict of interest to disclose. We know of no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2023.104100.

References

Attwood, A. S., Easey, K. E., Dalili, M. N., Skinner, A. L., Woods, A., Crick, L., … Munafò, M. R. (2017). State anxiety and emotional face recognition in healthy volunteers. *Royal Society Open Science, 4*(5), Article 160855. https://doi.org/10.1098/rsos.160855

Bantin, T., Stevens, S., Gerlach, A. L., & Hermann, C. (2016). What does the facial dot-probe task tell us about attentional processes in social anxiety? A systematic review. *Journal of Behavior Therapy and Experimental Psychiatry, 50*, 40–51.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat–related attentional bias in anxious and nonanxious individuals: A meta–analytic study. *Psychological Bulletin, 133*(1), 1–24. https://doi.org/10.1037/0033–2909.133.1.1

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology, 56*(6), 893–897. https://doi.org/10.1037/0022–006X.56.6.893

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B (Methodological), 57*, 289–300.

Bögels, S. M., & Mansell, W. (2004). Attention processes in the maintenance and treatment of social phobia: Hypervigilance, avoidance and self–focused attention. *Clinical Psychology Review, 24*(7), 827–856. https://doi.org/10.1016/j.cpr.2004.06.005

Broadbent, D., & Broadbent, M. (1988). Anxiety and attentional bias: State and trait. *Cognition and Emotion, 2*(3), 165–183. https://doi.org/10.1080/02699938808410922

Bui, E., Anderson, E., Goetter, E. M., Campbell, A. A., Fischer, L. E., Barrett, L. F., & Simon, N. M. (2017). Heightened sensitivity to emotional expressions in generalised anxiety disorder, compared to social anxiety disorder, and controls. *Cognition & Emotion, 31*(1), 119–126. https://doi.org/10.1080/02699931.2015.1087973

Calvo, M. G., & Castillo, M. D. (2001). Selective interpretation in anxiety: Uncertainty for threatening events. *Cognition and Emotion, 15*(3), 299–320. https://doi.org/10.1080/02699930126040

Calvo, M. G., & Nummenmaa, L. (2008). Detection of emotional faces: Salient physical features guide effective visual search. *Journal of Experimental Psychology: General, 137*(3), 471–494. https://doi.org/10.1037/a0012771

Chen, J., Short, M., & Kemps, E. (2020). Interpretation bias in social anxiety: A systematic review and meta–analysis. *Journal of Affective Disorders, 276*(1), 1119–1130. https://doi.org/10.1016/j.jad.2020.07.121

Clark, D. M., & Wells, A. (1995). A cognitive model of social phobia. In R. G. Heimberg, M. R. Liebowitz, D. A. Hope, & F. R. Schneier (Eds.), *Social phobia: Diagnosis, assessment, and treatment* (pp. 69–93). The Guilford Press.

Cooper, R. M., Rowe, A. C., & Penton-Voak, I. S. (2008). The role of trait anxiety in the recognition of emotional facial expressions. *Journal of Anxiety Disorders, 22*(7), 1120–1127. https://doi.org/10.1016/j.janxdis.2007.11.010

Doty, T. J., Japee, S., Ingvar, M., & Ungerleider, L. G. (2013). Fearful face detection sensitivity in healthy adults correlates with anxiety–related traits. *Emotion, 13*(2), 183–188. https://doi.org/10.1037/a0031373

Douilliez, C., Yzerbyt, V., Gilboa-Schechtman, E., & Philippot, P. (2012). Social anxiety biases the evaluation of facial displays: Evidence from single face and multi–facial stimuli. *Cognition and Emotion, 26*(6), 1107–1115. https://doi.org/10.1080/02699931.2011.632494

Eisenbarth, H., & Alpers, G. W. (2011). Happy mouth and sad eyes: Scanning emotional facial expressions. *Emotion, 11*(4), 860–865. https://doi.org/10.1037/a0022758

Ekman, P., & Friese, W. V. (1976). *Pictures of facial affect*. Palo Alto, CA: Counsulting Psychologists Press.

Green, C., & Guo, K. (2018). Factors contributing to individual differences in facial expression categorisation. *Cognition and Emotion, 32*(1), 37–48. https://doi.org/10.1080/02699931.2016.1273200

Günther, V., Kropidlowski, A., Schmidt, F. M., Koelkebeck, K., Kersting, A., & Suslow, T. (2021). Attentional processes during emotional face perception in social anxiety disorder: A systematic review and meta-analysis of eye-tracking findings. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 111*, Article 110353.

Guo, K. (2012). Holistic gaze strategy to categorize facial expression of varying intensities. *PLoS One, 7*(8), Article e42585. https://doi.org/10.1371/journal.pone.0042585

Guo, K. (2013). Size–invariant facial expression categorization and associated gaze allocation within social interaction space. *Perception, 42*(10), 1027–1042. https://doi.org/10.1068/p7552

Guo, K., Mahmoodi, S., Robertson, R. G., & Young, M. P. (2006). Longer fixation duration while viewing face images. *Experimental Brain Research, 171*(1), 91–98. https://doi.org/10.1007/s00221–005–0248–y

Guo, K., Tunnicliffe, D., & Roebuck, H. (2010). Human spontaneous gaze patterns in viewing of faces of different species. *Perception, 39*(4), 533–542. https://doi.org/10.1068/p6517

Gutiérrez-García, A., & Calvo, M. G. (2017). Social anxiety and threat-related interpretation of dynamic facial expressions: Sensitivity and response bias. *Personality and Individual Differences, 107*, 10–16.

Heinrichs, N., & Hofmann, S. G. (2001). Information processing in social phobia: A critical review. *Clinical Psychology Review, 21*(5), 751–770. https://doi.org/10.1016/S0272–7358(00)00067–2

Heuer, K., Lange, W.-G., Isaac, L., Rinck, M., & Becker, E. S. (2010). Morphed emotional faces: Emotion detection and misinterpretation in social anxiety. *Journal of Behavior Therapy and Experimental Psychiatry, 41*(4), 418–425. https://doi.org/10.1016/j.jbtep.2010.04.005

Horley, K., Williams, L. M., Gonsalvez, C., & Gordon, E. (2003). Social phobics do not see eye to eye: A visual scanpath study of emotional expression processing. *Journal of Anxiety Disorders, 17*(1), 33–44. https://doi.org/10.1016/s0887–6185(02)00180–9

Hunter, L. R., Buckner, J. D., & Schmidt, N. B. (2009). Interpreting facial expressions: The influence of social anxiety, emotional valence, and race. *Journal of Anxiety Disorders, 23*(4), 482–488. https://doi.org/10.1016/j.janxdis.2008.10.004

Leary, M. R. (1983). A brief version of the fear of negative evaluation scale. *Personality and Social Psychology Bulletin, 9*(3), 371–375. https://doi.org/10.1177/0146167283093007

Lundqvist, D., Flykt, A., & Öhman, A. (1998). *The Karolinska directed faces – KDEF*. Psychology section, Karolinska Institute: CD ROM from Department of Clinical Neuroscience (ISBN 91–630–7164–9).

Maisel, M. E., Stephenson, K. G., South, M., Rodgers, J., Freeston, M. H., & Gaigg, S. B. (2016). Modeling the cognitive mechanisms linking autism symptoms and anxiety in adults. *Journal of Abnormal Psychology, 125*(5), 692–703. https://doi.org/10.1037/abn0000168

McManus, F., Clark, D. M., & Hackmann, A. (2000). Specificity of cognitive biases in social phobia and their role in recovery. *Behavioural and Cognitive Psychotherapy, 28*(3), 201–209. https://doi.org/10.1017/S1352465800003015

Mendes Ferrer Rosa, N., Ferreira Borges, V., Cheffer, L., Torro Alves, N., & Estanislau, C. (2017). Symptoms of anxiety and depression modulate the recognition of facial emotion. *Universitas Psychologica, 16*(4), 328–333.

Mogg, K., Bradley, B. P., & Williams, R. (1995). Attentional bias in anxiety and depression: The role of awareness. *British Journal of Clinical Psychology, 34*(1), 17–36. https://doi.org/10.1111/j.2044–8260.1995.tb01434.x

Palm, M., Elliott, R., McKie, S., Deakin, J., & Anderson, I. (2011). Attenuated responses to emotional expressions in women with generalized anxiety disorder. *Psychological Medicine, 41*(5), 1009–1018. https://doi.org/10.1017/S0033291710001455

Park, G., Vasey, M. W., Kim, G., Hu, D. D., & Thayer, J. F. (2016). Trait anxiety is associated with negative interpretations when resolving valence ambiguity of surprised faces. *Frontiers in Psychology, 7*, 1164.

Philippot, P., & Douilliez, C. (2005). Social phobics do not misinterpret facial expression of emotion. *Behavior Resarch and Therapy, 43*(5), 639–652. https://doi.org/10.1016/j.brat.2004.05.005

Rapee, R. M., & Medoro, L. (1994). Fear of physical sensations and trait anxiety as mediators of the response to hyperventilation in nonclinical subjects. *Journal of Abnormal Psychology, 103*(4), 693–699. https://doi.org/10.1037/0021–843X.103.4.693

Russell, J. A., & Bullock, M. (1985). Multidimensional scaling of emotional facial expressions: Similarity from preschoolers to adults. *Journal of Personality and Social Psychology, 48*(5), 1290–1298. https://doi.org/10.1037/0022-3514.48.5.1290

Rusting, C. L. (1999). Interactive effects of personality and mood on emotion–congruent memory and judgment. *Journal of Personality and Social Psychology, 77*(5), 1073–1086. https://doi.org/10.1037/0022–3514.77.5.1073

Smith, M. L., Cottrell, G. W., Gosselin, F., & Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychological Science, 16*(3), 184–189. https://doi.org/10.1111/j.0956–7976.2005.00801.x

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A (1983). *Manual for the State–Trait Anxiety Inventory; Mind Garden*. Palo Alto, CA: Consulting Psychologists Press.

Surcinelli, P., Codispoti, M., Montebarocci, O., Rossi, N., & Baldaro, B. (2006). Facial emotion recognition in trait anxiety. *Journal of Anxiety Disorders, 20*(1), 110–117. https://doi.org/10.1016/j.janxdis.2004.11.010

Suslow, T., Hußlack, A., Bujanow, A., Henkelmann, J., Kersting, A., Hoffmann, K. T., … Günther, V. (2019). Implicitly and explicitly assessed anxiety: No relationships with recognition of and brain response to facial emotions. *Neuroscience, 408*, 1–13.

Torro-Alves, N., Bezerra, I. A.d. O., Claudino, R. G.e., Rodrigues, M. R., Machado-de-Sousa, J. P., Osório, F.d. L., & Crippa, J. A. (2016). Facial emotion recognition in social anxiety: The influence of dynamic information. *Psychology & Neuroscience, 9*(1), 1–11. https://doi.org/10.1037/pne0000042

Voncken, M. J., Bögels, S. M., & Peeters, F. (2007). Specificity of interpretation and judgemental biases in social phobia versus depression. *Psychology and Psychotherapy, 80*(3), 443–453. https://doi.org/10.1348/147608306X161890

Watson, D., & Friend, R. (1969). Measurement of social–evaluative anxiety. *Journal of Consulting and Clinical Psychology, 33*(4), 448–457. https://doi.org/10.1037/h0027806

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1997). *Cognitive psychology and emotional disorders* (2nd ed.). Chichester: Wiley.

Yoon, K. L., & Zinbarg, R. E. (2007). Generalized anxiety disorder and entry into marriage or a marriage–like relationship. *Journal of Anxiety Disorders, 21*(7), 955–965. https://doi.org/10.1016/j.janxdis.2006.10.006