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RESEARCH ARTICLE

Extraction of mean emotional tone from face arrays in social anxiety disorder

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Background: Social anxiety disorder (SAD) is characterized by intense fear when facing a crowd. Processing biases of crowd-related information have been suggested as contributing to the etiology and maintenance of the disorder. Here we tested whether patients with SAD display aberrant patterns of extracting the mean emotional tone from sets of faces.

Methods: Twenty-one participants with SAD and 24 unanxious control participants had to determine the average emotion expression of sets of six different morphed faces ranging from happy to angry. In 20% of trials the six faces were randomly sampled from the entire happy–angry range. The remaining 80% of trials, considered the critical trials, had an emotional outlier: five faces were sampled from one-half of the emotional range, whereas the sixth face was sampled from the opposite emotional range.

Results: Participants with SAD were less accurate than controls in extracting the mean emotional tone from sets of faces. Unanxious participants underweighted negative outliers and overweighed positive outliers when extracting the mean, whereas participants with SAD exhibited no such biases.

Conclusions: Results suggest a possible mechanism associated with the anxiety experienced by socially anxious individuals when facing a crowd.

KEYWORDS
average extraction, cognitive bias, cognitive processing, crowd evaluation, facial expression, social anxiety disorder

1 | INTRODUCTION

Humans are efficient in extracting central tendency representations from sets of similar objects such as different-sized circles (Ariely, 2001), sets of numbers (Brezis, Bronfman, & Usher, 2015; Brezis, Bronfman, Jacoby, Lavidor, & Usher, 2016; Malmi & Samson, 1983; Pica, Lemer, Izard, & Dehaene, 2004), and most relevant to the current study, sets of morphed faces varying in emotionality between two extremes (Haberman & Whitney, 2007, 2009). This remarkable ability occurs even when observers cannot report anything about the individual identities comprising the set (Ariely, 2001; Chong & Treisman, 2005; Haberman & Whitney, 2007, 2009). These results reveal a powerful mechanism allowing individuals to extract summary statistics (subject, however, to some discounting of outliers; Haberman & Whitney, 2010; Li, Herce Castanon, Solomon, Vandormael, & Summerfield, 2017), from a broad range of visual stimuli including emotional expressions. However, less is known about the potential implications of dysfunction and aberrations in this mechanism. Here, we tested the capacity of patients with social anxiety disorder (SAD) to extract the mean emotional tone from a set of faces ranging from threat (angry) to positive (happy) expressions.

SAD is characterized by intense fear of social situations (American Psychiatric Association, 2013). A hallmark of SAD is fear of being negatively evaluated by others, which makes appearance in front of crowds one of the most dreaded situations for patients with SAD (Gilboa-Schechtman, Presburger, Marom, & Hermesh, 2005). But why are crowds so intimidating for individuals with SAD? It has been suggested that anomalies in the processing of crowd-related information contributes to the etiology and maintenance of the disorder. The way socially anxious individuals perceive the overall emotion of crowds has been proposed as one possible faulty process in SAD (Yang, Yoon, Chong, & Oh, 2013). Overly negative perception of a crowd's emotional tone may result in a tendency to perceive crowds as more criticizing, threatening, and hostile, which may contribute to elevated anxiety in social situations (Gilboa-Schechtman et al., 2005).

Three lines of research appear to converge on a positivity bias in unanxious participants and a balanced/non-biased processing in SAD: crowd ratings, free-viewing, and visual search. Research examining crowd-ratings (e.g., positive/negative judgments) typically reports a tendency among socially anxious individuals to rate facial crowds as more negative compared with unanxious controls (Gilboa-Schechtman et al., 2005; Yang et al., 2013). Yang et al. (2013) examined two important factors that may contribute to the aberrant crowd evaluation in SAD: emotional-bias versus reduced sensitivity in distinguishing the crowds. Their results indicated no difference in precision, but rather a difference in bias. Specially, whereas low anxiety participants were biased towards positive crowd ratings, high anxiety participants showed no bias. Lack of a positive bias in SAD was also recently demonstrated in a free-viewing eye-tracking task (Lazarov, Abend, & Bar-Haim, 2016) in which participants freely viewed mixed matrices of threat and neutral facial expressions. Unanxious participants dwelled longer on neutral relative to threat faces, whereas participants with SAD did not show this self-serving bias, dwelling equally on both stimuli types. In visual search, where emotional (happy or angry) targets appear among neutral distractors, provides a similar pattern. Unanxious participants show an advantage for happy compared to angry targets (Calvo & Nummenmaa, 2008), whereas an inverse pattern emerges among anxious participants (Eastwood et al., 2005; Matsumoto, 2010).

Although these findings indicate that aberrant crowd-related processing in SAD is associated with lack of a self-serving positive bias, the precise cognitive mechanisms underlying this pattern are unknown. One possibility is that the biased evaluation of a set of emotional faces is driven by biased perception of the individual faces. Alternatively, participants with SAD may differ from unanxious controls in the way they weight the emotion-value of positive/negative faces, in particular for outliers (Haberman & Whitney, 2010).

To explore the contribution of these alternative mechanisms to aberrant crowd evaluation, as well as the possibility of a reduced precision (increased noise) in the process of weighted averaging, we applied a design similar to that of Haberman and Whitney (2010). We presented sets of emotional faces manipulated via morphing to fall on a continuum ranging from angry to happy. Rather than ask participants to make a binary happy/angry decision regarding the set display we asked participants to report the average emotion of the set using an analogue slide bar (Figure 2). This design allowed us to obtain objective measures of task performance by comparing the actual average of a given set with the average reported by the participant. Furthermore, this design afforded extraction of latent parameters that correspond to each of the potentially contributing factors associated with crowd processing delineated above: (a) precision (or noise in averaging), (b) bias in the perception of single elements, and (c) deviant weights given to emotional outliers.

Based on prior research (Calvo & Nummenmaa, 2008; Eastwood et al., 2005; Lazarov et al., 2016; Matsumoto, 2010; Yang et al., 2013) we expected to find that, unlike unanxious participants who give more weight to positive compared with negative outliers (or have a general bias towards positive emotions), participants with SAD will show unbiased weighting of outlier emotions (or less general bias). To distinguish between groups in general bias and in weighting of outliers, we applied two types of trials: (a) critical outlier trials with five faces from one side of the emotional range (happy *or* angry) and a sixth face (the outlier) from the other half; and(b) baseline trials in which all faces were randomly selected from the whole range. We made use of computational modeling to extract parameters that correspond to noise, bias, and decision weights.

2 | METHOD

2.1 | Participants

Participants were 21 treatment-seeking individuals with SAD (13 males, mean age = 30.31 years, SD = 10.97, range = 21–55) and 24 unanxious controls (9 males, mean age = 26.58 years, SD = 4.25, range = 21–37). Unanxious control participants were recruited through ads in social media. Participants' characteristics and social anxiety scores by group appear in Table 1.

SAD and exclusionary diagnoses were ascertained using the Mini-International Neuropsychiatric Interview (M.I.N.I., Sheehan et al., 1998). The M.I.N.I. was administered by a clinical psychologist trained by a PhD-level senior psychologist with extensive expertise in clinical assessments using the M.I.N.I. Inter-rater reliability of .85 or higher was established before proceeding with study recruitment. SAD diagnosis was further ascertained using the Liebowitz Social Anxiety Scale Interview (LSAS; Liebowitz, 1987), with a cutoff score ≥50 as an inclusion criterion for the SAD group. This score reflects an optimal balance between specificity and sensitivity in SAD diagnosis (Mennin et al., 2002; Taylor, Bomyea, & Amir, 2010). Exclusion criteria were: (a) age not between 18 and 60 years, (b) present/past psychotic episode, (c) severe comorbid depression, (d) high suicide risk, (e) comorbid posttraumatic stress disorder, obsessive-compulsive disorder, tic disorder or Tourette's syndrome, (f) neurologic condition (e.g., epilepsy, brain injury), and (g) drug or alcohol misuse. Of the 21 participants with SAD, eight also met criteria for a past/present depressive episode, four for dysthymia, six for generalized anxiety disorder, and four for panic disorder. Six were using a stable dose of Selective Serotonin Reuptake Inhibitors. Inclusion criteria for the control group were no current/past psychopathology and LSAS score ≤29, a cutoff score that yields minimal false positive SAD diagnosis (Mennin et al., 2002).

As expected, significant group differences were noted for the clinician-administered and self-reported social anxiety scores (see Measures below). Groups did not differ on gender, age, or education (Table 1). All participants provided written informed consent. The study was approved by the local Institutional Review Board (protocol number 10492788_20150716).

2.2 | Diagnostic and self-report measures

M.I.N.I. (Sheehan et al., 1998). The M.I.N.I. is a structured diagnostic interview assessing 17 different psychiatric disorders according to

TABLE 1 Demographic and psychopathological characteristics of the two groups

	SAD group ($n = 21$)		Control group ($n = 24$)		Statistics	
Measure	M	SD	M	SD	t-value	P
Age	30.31	10.97	26.58	4.25	1.54	.131
Years of education	13.62	2.20	14.29	2.76	−0.89	.376
LSAS-Interview	87.43	17.81	17.58	9.06	16.89	<.001
SPIN	48.62	6.06	10.54	7.57	18.44	<.001

Notes: SAD, Social anxiety disorder; LSAS, Liebowitz Social Anxiety Scale; SPIN, Social Phobia Inventory.

FIGURE 1 Range of faces used in the study

DSM-IV and ICD-10. It is a valid and time-efficient diagnostic interview (Lecrubier et al., 1997; Sheehan et al., 1997).

The clinician-administered version of the LSAS (Liebowitz, 1987). In this 24-item scale, each item depicts a social situation and is rated on two sub-scales: fear and avoidance provoked by the described situation during the passing week. It has high internal consistency, strong convergent and discriminative validity, and high test-retest reliability (Fresco et al., 2001; Heimberg et al., 1999; Sheehan et al., 1998). Cronbach's α in the current sample is .92.

The Social Phobia Inventory (SPIN; Connor et al., 2000). In this 17-item self-report measure of social anxiety, participants rate discomfort experienced during the passing week regarding different social situations. The SPIN has been used in clinical and nonclinical samples showing sound psychometrics (Connor et al., 2000). Cronbach's α in this sample is .86.

2.3 | The emotion averaging task

The emotion averaging task is based on seminal research demonstrating participants' ability to extract the mean emotion of briefly presented sets of morphed faces interpolating between two extreme expressions such as happy and sad (Haberman & Whitney, 2010). Face stimuli (Figure 1) were adopted from a morph-set ranging between happy and angry expressions of single actors (Haberman & Whitney, 2010; Haberman, Harp, & Whitney, 2009), as angry expressions have been implicated as threatening in SAD research (Ohman, 1986; Staugaard, 2010). The morphs sets from Haberman and Whitney (2010) used here were created by linearly interpolating between two emotion extremes of the same actor taken from the Ekman gallery (Ekman & Friesen, 1976). Multiple facial features (e.g., corners of the mouth, bridge of the nose, center of the eye) were matched between the two emotion extreme faces and the software then linearly morphed between the extremes outputting 50 image files ranging from happy to angry nominally separated by arbitrary emotional units (e.g., Face 2 was one emotional unit angrier than Face 1). Face images were grayscale (98% maximum Michelson contrast). The morphed sequences ranged from 1 (happiest) to 49 (angriest). Expression 25 (the exact middle of the sequence) was discarded.

The task consisted of three types of trials each presenting six faces simultaneously: a baseline condition (20% of trials), happy trials (40% of trials), and angry trials (40% of trials). For all trial types, the six faces were of the same actor and were displayed in a circular formation to make sure that each face is equidistant from the fixation point. In baseline trials, six different morphed faces were randomly sampled on each trial from the distribution spanning the entire happy–angry morphed range of one of the actors. In happy trials, five of the six presented faces were randomly sampled from the distribution spanning the range of the happy expressions (Faces 1–24), and the outlier face was randomly sampled from the distribution spanning the range of the angry expressions (Faces 26–49). In angry trials an opposite sampling pattern was symmetrically used. Emotion-outlier trials allow for a sensitive examination of the weights allocated to outlier elements. Baseline trails served as control trials, also making the outlier manipulation less obvious. The ratio of outlier face to amount of displayed faces (1/6) maintained the ration used in previous emotion-outlier studies (Haberman & Whitney, 2010). All trials were randomly intermixed in presentation. Stimuli were presented on a 17″ monitor viewed at a distance of 41 cm, with a screen resolution of 1,024 × 768 pixels and 60 Hz refresh rate.

Participants were first presented with an array of seven face photographs of the same actor arranged in a row with the most right-sided face depicting a happy expression and the most left-sided face depicting an angry expression. The remaining five faces depicted morphs between these endpoints changing gradually from happy to angry (Figure 1). Participants were told that these are the type of facial expressions that will appear during the task and the gradual shift in emotion was pointed out. Participants were further told that during each trial a number of facial expressions ranging from happy to angry would appear for a short time and that they have to report the average expression on each trial. The set-up of a single trial is depicted in Figure 2. Each trial began with a central fixation cross (700 ms), followed by an array of 6 faces (250 ms). Participants were then asked to convey as accurately as possible the emotional-average of the presented array using a visual analog ruler spanning 100 arbitrary units, with each side corresponding to one of the emotions (Figure 2). The numerical value corresponding to the location of the cursor over the ruler was concurrently displayed. Participants reported their answers by pressing the mouse button when reaching the desired location/number.

Participants completed 10 practice trials in which the correct average facial expression appeared on the screen following the trial. Next, participants completed 600 experimental trials with no trial-corrective feedback to allow examination of participants' spontaneous

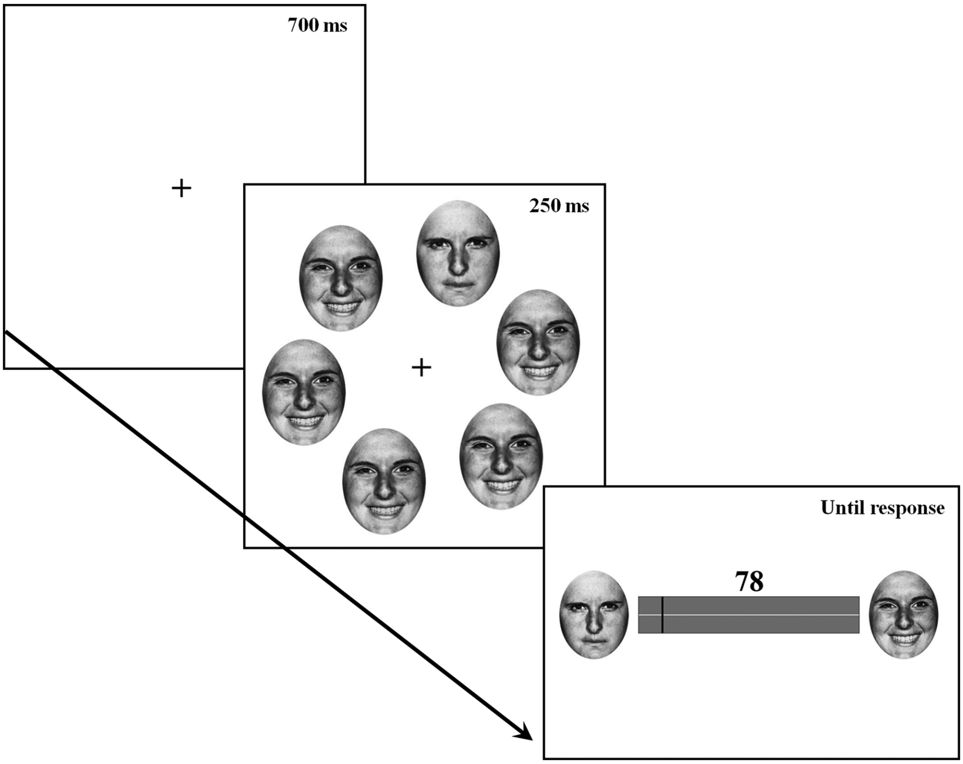

FIGURE 2 Schematic illustration of a typical trial (here, a happy trial with an angry outlier). After a 700 ms fixation cross, participants were presented with the face array for 250 ms, and then asked to estimate the average emotional expression using an analog ruler. In the illustration here, the bar is located on the left hand reflecting a relatively negative estimation of 78 out of 100

evaluation process. Experimental trials were divided into 20 blocks, each terminating with displaying the block-average correlation between the participants' evaluation and the actual average. This feedback was provided to maintain on-task motivation without generating a trial-by-trial corrective process.

2.4 | General procedure

Participants were informed that the purpose of the study is to evaluate the ability of people to report the average emotion of facial expression arrays. After signing informed consent participants underwent clinical assessment and those meeting inclusion criteria completed the emotion averaging task in a subsequent session.

2.5 | Data analysis and computational modeling

Accuracy of average emotion evaluations was quantified by computing, for each participant, the Pearson correlation between the evaluation made and the actual average of the set, across trials. This correlation measures the sensitivity of the subjective evaluations to changes in objective stimuli, rather than shifts of the scale. This provides a strict measure of accuracy. Independent samples *t*-tests and chi-square tests were used to compare between-groups descriptive differences. To estimate general bias in the perception of emotional elements, we applied a *t*-test contrasting the emotion average between the two groups in the baseline trials. To estimate the decision weights given to outliers, we used linear regressions of the actual ratings in the emotional outlier trials based on the emotion values of the six elements. Finally, we used computational modeling to validate the regression results and to extract noise (or variability) parameters for each participant. Best-fitting models were chosen using the Bayesian Information Criterion (for additional information see Supplemental Material).

3 | RESULTS

3.1 | Main analysis

Consistent with previous studies (Haberman & Whitney, 2009; Yang et al., 2013) the correlations between participants' evaluations and the actual mean emotion across trials were *rs* = .61 and .69 for the SAD and control groups, respectively, and significantly above chance for each of the participants (*p*s < .05; see Figure S1 for two examples of a single participant evaluations). Accuracy in the SAD group was lower compared with the control group, $t(43) = 2.75$; $P = .009$, $\eta^2_p = .12$, suggesting less accurate evaluation of the average emotion in SAD. A between-groups comparison of accuracy in the baseline trials again showed that the participants with SAD were less accurate than controls in average emotion extraction, $t(43) = 2.62$; $P = 0.012$, $\eta^2_p = .14$.

Further analysis comparing evaluation accuracy specifically in the outlier trials using a repeated-measures ANOVA with trial type (happy, angry) by group (SAD, control), revealed that participants with SAD were more accurate on angry trials than on happy trials, whereas

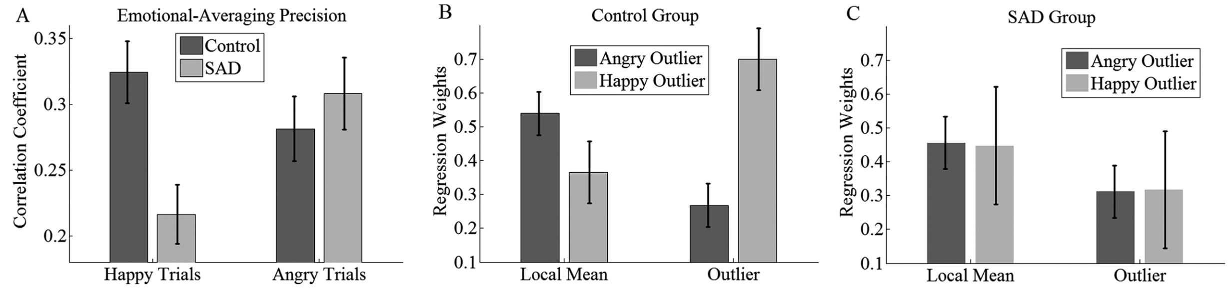

FIGURE 3 Main results of the study. (a) Precision of emotional evaluations (measured by Pearson correlation) for SAD patients (red bars) and controls (blue). SAD patients were more precise on angry trials (trials, in which the average expression was angry) than on happy trials, whereas controls were better on happy trials than on angry trials. (b–c) Regression weights for unanxious controls (b) and SAD patients (c). SAD patients are unbiased in weighting the emotional values of the local average and the emotional outlier, regardless of the outlier's emotional valance. In contrast, unanxious controls overestimate happy outliers (red bar) and underweight angry outliers (blue bar). Black lines denote 1-standard error of the mean

unanxious participants exhibited the opposite pattern, $F(1, 63) = 6.58$; $P = .01$, $\eta^2_{\text{p}} = .095$ (Figure 3a).

To estimate the presence of a general bias in the perception of emotion elements between the two groups we applied a *t*-test to the evaluations in baseline trials. Any difference between the groups' mean evaluations would indicate a systematic shift of the emotion evaluations (i.e., a general bias). This difference was not significant ($P > 0.70$), providing no support for the existence of a general bias. A further analysis tested the existence of a general bias by running a linear regression on the evaluations, based on the emotion values in the baseline trials. In this analysis, the value of the model's intercept directly quantifies the general bias. The results of this analysis were consistent with our previous conclusion of no difference in intercept (general bias) between the groups ($P > 0.40$). To estimate the weights assigned by each group to the emotional expressions in the emotion-outlier trials we computed, for each participant, two linear regressions on the evaluations with two predictors: the local average (the average emotional value of the five similar emotion faces) and the outlier. One regression was carried out for the angry-outlier condition, and one for the happy-outlier condition. Unanxious participants underweighted angry outliers and overweighed happy outliers, $F(1, 23) = 7.82$; $P = .01$; $\eta^2_{\text{p}} = .25$ (Figure 3b). In contrast, participants with SAD assigned unbiased flat weights, which are statistically the same under the two emotion outlier conditions, ($P > .60$; Figure 3c). Importantly, the intercept of the linear regression for the baseline trials, which corresponds to a bias in emotional averaging in general, revealed no group differences, $t(43) = .86$; $P = .40$. Comparing groups only on baseline trials also revealed no group difference in mean emotion evaluations, $t(43) = .09$; $P = .93$.

3.2 | Computational modeling

To better understand the nature of the results, we tested a computational model that assumes that participants with SAD and controls differ in the weights they assign to the outliers, versus the mode-elements in each of the two conditions (angry outlier vs. happy outlier), as well as in a noise-encoding parameter. Using the best fitting parameters of each participant, we simulated, for each actual trial, the average emotion evaluation. We then subjected the evaluations to the analyses that were carried for the SAD and control groups. As seen in Figure 4, this five-parameter model (fitted to individual participants) recovers weight parameters quite similar to the ones obtained in the regression analyses (see Table 2 for group average data). In particular, the fitted parameters confirm that although the controls underweight/overweight the negative/positive outliers, respectively, participants with SAD are more balanced in their weighting, but also more variable (higher noise) in their response. This model accounts well for the qualitative differences observed in the main analysis (Figure 4).

4 | DISCUSSION

The current findings illuminate important aspects in the processing of crowd-related information in SAD. First, individuals with SAD are less accurate in extracting the mean emotional tone from a crowd of faces compared with unanxious controls consistent with findings indicating that high socially anxious participants are less accurate in recognizing emotions correctly (Button, Lewis, Penton-Voak, & Munafo, 2013; Qi et al., 2017). Second, a clear difference emerged in the way participants with SAD and controls weighted outlier emotion faces. Although participants with SAD give roughly equal weights to both positive and angry outliers, unanxious participants are affected by outlier emotion faces when extracting the mean emotional tone, such that they underweight negative outliers and overweight positive outliers, creating a more positive mean impression of the crowds they are facing. This result reflects a positive emotional bias in unanxious participants (but not in SAD), in the evaluations of the emotional sets, and is consistent with previous findings (Yang et al., 2013). Moreover, our weight analysis provides a novel interpretation to this bias, shedding light on the process of attending and weighting the outlier emotions in the set-evaluation. Third, the current results indicate no difference in general bias towards happy emotions between the groups, ruling out the possibility that the observed group differences result from aberrant estimations of the single faces in each presented array.

One may wonder how can participants with SAD have more balanced decision weights than control participants do, and yet their task

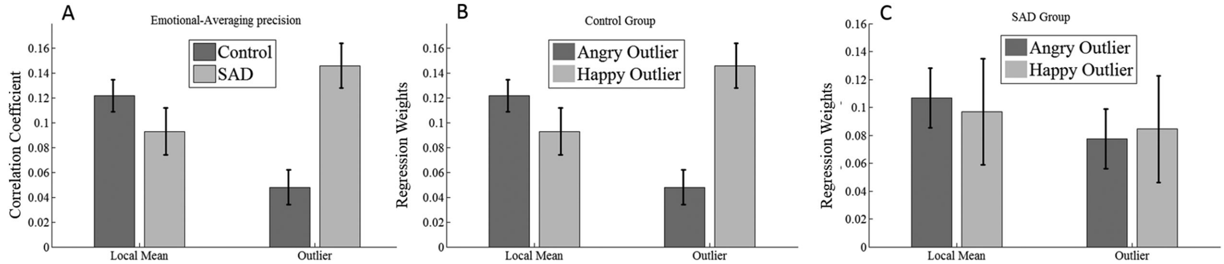

FIGURE 4 Model-generated prediction of the correlations and regression weights. (a) Correlation in happy and angry trials for control and SAD groups. (b–c) Regression weights for control (b) and SAD groups (c). Black lines denote 1-standard error of the mean

TABLE 2 Average data of modeling results of the two groups

Group	Noise	Local-happy trials	Local-angry trials	Outlier-happy trials	Outlier-angry trials	Maximum log likelihood
SAD	8.95	0.62	0.58	0.53	0.40	−537
Control	7.73	0.73	0.57	0.83	0.27	−650

Note: SAD, Social anxiety disorder.

accuracy is lower? Our computational model and analysis affords an answer to this question by isolating latent parameters that correspond to the weights given to emotion outliers and non-outlier elements, as well as to the noisiness of the evaluations which correspond to sensitivity in emotional discrimination. The computational results clearly indicate that in addition to assigning balanced weights, participants with SAD also display a noisier weighting of the emotion expressions, reflecting reduced sensitivity in emotional discrimination of single elements. These two group differences are not mutually exclusive and offer a new mechanistic account of some of the cognitive processes associated with the maintenance of one of the hallmarks of SAD-–anxious interpretation of crowds.

How does it feel to perform in front of a crowd while possessing such aberrations in gauging its average emotional tone? The results suggest that individuals with SAD face several potential setbacks. Not only do they have a general difficulty to accurately extract a central tendency of the emotional tone (increase in the noise parameter), they also do not benefit from the positively skewed cognitive algorithm applied by unanxious individuals when encountering extreme emotion faces, offsetting the influence of extreme negative crowd members and enhancing that of extreme positive members. Instead, it appears that individuals with SAD painfully and more "correctly" integrate extreme emotions within a crowd. Our findings also indicate that individuals with SAD average crowd emotionality more accurately when confronting negative compared with positive crowds, whereas unanxious participants perceive positive crowds more accurately than negative ones. Again, it appears that although patients with SAD are less accurate in overall crowd assessment, they are agonizingly better equipped to perceive the social environment accurately when it is a negative one, exacerbating existing hardship in social environments.

The less biased extraction of emotional tone from face-arrays containing extreme members among participants with SAD suggests that they perceive their social environment more objectively, lacking the positive distortion displayed by unanxious individuals. This finding is in line with Yang et al. (2013), who reported similar lack of a positivity bias in SAD when rating crowds. This result also echoes theories of depressive realism asserting more accurate and realistic inferences among depressed patients relative to non-depressed individuals who are thought to be subject to positive distortions in information processing (Alloy & Abramson, 1979; Matthews & Antes, 1992; Yang et al., 2013). Finally, Lazarov et al. (2016) reported similar findings whereby patients with SAD allocated attention equally to threat and neutral facial expressions in a crowd, whereas unanxious individuals demonstrated a biased viewing pattern favoring neutral faces.

An important question concerns the nature of the equal/flat decision weights that participant with SAD use in their weighting of positive and negative emotion outliers. Although our interpretation above suggests a painful realism (see also Yang et al., 2013), an alternative possibility is that it involves specific properties of our stimuli. Accordingly, participants with SAD might have considered all types of faces equally threatening (e.g., happy faces could have been perceived as mocking; Weeks & Howell, 2014), or faces from the middle of the morph arrays may appear ambiguous also triggering threat. This possibility is in line with research showing that SAD is associated with an attentional bias towards emotional faces in general (Chen, Ehlers, Clark, & Mansell, 2002; Garner, Mogg, & Bradley, 2006; Sposari & Rapee, 2007).

Some limitations should be noted. First, we employed a relatively small sample size that might have left some effects undetected. However, despite the small sample size various significant results emerged, demonstrating different computational patterns between socially anxious and unanxious participants. Moreover, using a computational model we were able to predict our behavioral results providing further support for the observed group differences. Although the model accounts for the central differences in the data, future studies could explore additional mechanisms that may contribute to these effects. Second, the current study focused on social anxiety. However, the same task might yield similar results for other psychopathologies (e.g., generalized anxiety disorder, depression). Future research using the current task in other psychopathologies is needed to determine the specificity of the observed findings. Third, future research could explore whether the averaging aberrations detected here, in patients with SAD, are specific to social stimuli (i.e., emotion faces) or perhaps reflect a more general average extraction deficit in SAD. Fourth, the use of morphed sets of faces allowed us to parametrically vary emotion value to examine the impact of stimuli with non-polarized ambiguous values (which are an important part of our life experience). However, these stimuli do suffer from the limitation of presenting the same actor in all the faces presented in a trial, an unlikely occurrence in real life. Importantly however, the fact that similar results were obtained by Yang et al. (2013), who relied on crowds made of different actors with polarized emotions, suggest that the observed pattern is robust. Future research could replicate the current findings while using crowds comprised of different actors, each with emotional values controlled on the range of morphed faces. Fifth, the present study did not control for participants' current emotional state, which might have affected their perceptions of the presented emotional facial expressions (Frischen, Eastwood, & Smilek, 2008). Future research could acknowledge this possibility by incorporating a state emotionality measure prior to task performance. Finally, the present study measured crowd ratings using a task-tapping automatic process with no additional explicit measures. As previous research and theoretical accounts have demonstrated dissociation between automatic affective processes and intentional cognitive processes (Chaiken & Trope, 1999; Lange et al., 2011; Lange, Keijsers, Becker, & Rinck, 2008), future research could incorporate explicit measures of crowd ratings.

5 | CONCLUSION

The current results indicate that SAD is related to an aberrant pattern of extracting the average emotional tone from arrays of faces. This faulty process results in a more negative crowd perception relative to unanxious individuals who possess a positive computational bias. Although crowd evaluation has been examined in relation to anxiety in prior research (Gilboa-Schechtman et al., 2005; Lange et al., 2011; Lange et al., 2008), the current study is first to test these associations in a clinical sample of patients with SAD, using computational modeling that allows extraction of noise, general bias, and decision weights. The current results carry possible implications for the treatment of SAD. First, the indicated lack of positivity bias in SAD can be integrated into the psychoeducational component of cognitive therapy for SAD. Therapists can use this framework to educate patients about their cognitive processes and discuss the difficulties they may experience when facing crowds. Second, our findings may also suggest a new target for therapeutic intervention aimed at modifying the aberrant computational processes of average extraction of emotional tone from crowds. Research using visual search tasks (Dandeneau & Baldwin, 2004; Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007), and free-viewing tasks (Lazarov, Pine, & Bar-Haim, 2017) has shown efficacy in modifying cognitive patterns and reducing symptoms among anxious individuals. Thus, future research could examine the potential therapeutic effect of cognitive bias modification protocols designed to induce the missing positivity bias in SAD when performing in front of others.

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CONFLICT OF INTEREST

We wish to confirm that there is no known conflict of interest associated with this publication.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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