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INDUCED ANXIETY INFLUENCES THE PERCEPTION OF NEGATIVE FACIAL EXPRESSIONS IN SINGLE FACES AND FACE ENSEMBLES

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INDUCED ANXIETY INFLUENCES THE PERCEPTION OF NEGATIVE FACIAL EXPRESSIONS IN SINGLE FACES AND FACE ENSEMBLES

The visual system enables us to quickly recognize different facial expressions despite the high complexity of human faces. This impressive ability to perceive emotions can be biased by social anxiety, which might lead to an overestimation of social threats from individuals. However, it is still under consideration how state anxiety influences our ability to process and summarize information from a group as an ensemble. The current study aims to examine whether state anxiety impairs our ability to assess the mean emotional expression of multiple faces by intensity overestimation of decreased accuracy. The experiment included two sessions, the first one involved no anxiety induction procedure, while the second session included anxiety induction. In both sessions, participants performed an adjustment task estimating the average emotion intensity for either single face or face ensemble condition. The final sample consisted of 46 individuals (mean age: 21±2.97) who successfully exhibited induced anxiety. The results indicated that anxious perceivers overestimated the average emotional intensity not only in the single face condition but also in the ensemble condition. Furthermore, we have shown that the emotion amplification stemmed from a systematic bias of the average emotion intensity, rather than from impaired accuracy. Our results demonstrate that state anxiety is likely to navigate attention to the faces with the most intensive facial expressions and, subsequently, bias their average impression. Exploring the effects of anxiety on ensemble perception is essential for further revealing the complexities of social cognition and how emotional biases can alter group-level information processing.

JEL Classification: Z.

Keywords: ensemble coding, anxiety, summary statistics, emotion, social cognition.

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Introduction

The visual system is an expert in rapid facial processing and interpretation. It instantly conveys information regarding emotional states of other individuals, which is an essential aspect of social interactions. For instance, research has shown that face processing begins very early in life, and infants prefer faces over other visual stimuli, emphasizing the importance of face recognition for communication (Nelson, 2001). Different facial features, such as symmetry, shape, skin texture, and facial expressions allow us to make assumptions about a person's traits, including their trustworthiness and aggressiveness (Olszanowski et al., 2019; Stirrat & Perrett, 2010).

Facial expressions are important for effective social communication, allowing individuals to respond appropriately to the emotions and intentions of others. Accurate emotion recognition due to face perception might exert a significant impact on social dynamics in communication. People who can effectively recognize and further respond to the emotional cues are often perceived as more empathic, trustworthy and socially competent (Mayer et al., 2011). On the other hand, deficits in emotion recognition lead to misunderstandings and social problems (Marsh & Blair, 2008). These kinds of deficits are especially pronounced in individuals suffering from anxiety, especially social anxiety, and can severely impact their ability to interpret emotional expressions (Gilboa-Schechtman & Shachar-Lavie, 2013; Kang et al., 2019; Meynadasy et al., 2020).

The cognitive model of anxiety offers a framework for prediction and understanding the perceptual biases that were observed in individuals suffering from anxiety (Mathews & Mackintosh, 1998; Mogg & Bradley, 2016). According to these models, anxiety arises by negative biases in processing social information (McNaughton & Gray, 2000), so people with heightened social anxiety commonly exert more attention to negative stimuli (Günther et al., 2021), distorting their perception and interpretation of social cues (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Morgan, 2010). Empirical research demonstrated that individuals in anxiety are more prone to identify threatening stimuli faster and more accurately in comparison with neutral stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van IJzendoorn, 2007; Guo et al., 2019). In contrast to these results that seem to be adaptive, there is compelling evidence that social anxiety might lead to biased and inaccurate emotion processing characterized by an exaggerated perception of threats. Misinterpretations of facial cues result from increased sensitivity, which leads to improper social reactions (Kang et al., 2019; Koizumi et al., 2011; Meynadasy et al., 2020). Furthermore, research has systematically shown that individuals with high social anxiety struggle with inaccurate emotion recognition, unlike those with lower levels of anxiety who tend to evaluate emotional expressions more precisely (Qiu et al., 2018). Thus, the reduced ability to assess emotional information from facial expressions emphasizes the pivotal connection between anxiety and social perception.

Despite extensive research on human emotion processing, the existing literature predominantly focuses on a single face perception. Yet, daily social interactions imply the simultaneous processing of multiple faces, where individuals can extract valuable information in the form of summary statistics or an ensemble representation (Corbett et al., 2024; Whitney & Leib, 2018). The human visual system is capable of rapidly summarizing and averaging various facial features, such as mean emotional intensity (Dandan et al., 2022), face identity (Neumann et al., 2013, 2018), average attractiveness (Lei et al., 2020), and even perceived trustworthiness of a group (Chwe & Freeman, 2023; Marini et al., 2023) at a glimpse. In other words, ensemble coding allows us to efficiently extract socially important information from a group in dynamic social environments.

The influence of emotional states on ensemble perception of faces remains an area of ongoing research. Recent findings suggest that trait anxiety may also play a role in ensemble perception (Yang & Baek, 2022). For instance, Yang and Baek (2022) demonstrated that individuals with low social anxiety exhibit a bias toward perceiving positive facial expressions, while those with high social anxiety do not show this bias and are more attuned to negative emotions. Similarly, Peng et al. (2022) investigated the emotional modulation of attentional mechanisms in ensemble perception, positing that attention and holistic face processing are influenced by emotional valence. Specifically, positive emotions expand the scope of attention and enhance global processing, whereas negative emotions constrict attention and promote local processing. The results revealed that positive emotional states improved visual averaging, while negative emotional states impaired it, suggesting that emotional induction modulates ensemble perception in a significant way (Peng et al., 2022).

Even though there is a lot of research in the area of ensemble perception, it is mainly focused on the low-level feature, so the mechanisms behind face ensemble perception are still under consideration because of the holistic nature of face perception. It means that faces are processed as a whole, rather than its individual parts, therefore it’s complicated to explain the nature of face ensemble perception by the classical theories. For example, according to the Reverse Hierarchy Theory (RHT) (Hochstein & Ahissar, 2002), ensemble perception is driven by feedforward processing. This primary visual processing is based on rapidly transmitted sensory information from lower visual areas with small receptive fields to higher visual areas with large receptive fields. At this stage, the visual system extracts visual features of the scene without focusing on individual objects (Epstein & Emmanouil, 2021), leading to average representation of a visual scene. The Population Response Model utilized the conception of increasing receptive fields as a neuro plausible mechanism that successfully explained results from different low-level feature domains in ensemble perception (Utochkin et al., 2024). Despite the simplicity of the model, the model has theoretical limitations regarding face ensemble perception because of initially processed features at a level with small receptive fields. Therefore, it is problematic to use this model for face ensemble perception due to their theoretical assumption about interconnection between ensemble perception and population receptive fields. In addition to these theoretical restrictions from the computational model, the RHT assumes that once perceptual information is obtained through feedforward processing, feedback mechanisms refine this information by integrating it with higher-order cognitive processes (Lamme & Roelfsema, 2000), and it appears to be a process of identification or recognition.

Based on the aforementioned theory, we assume that emotion recognition occurs during feedback processing, where signals are transmitted from higher-order visual areas back to primary visual areas to access spatially specific details about facial expressions. Therefore, emotion recognition requires focused attention mechanisms to accurately evaluate emotional expressions due to correct feature binding in feedback processing. Does it work similar to face ensemble perception? People might encode either all objects in a set or only a subset, but it is preferable to direct attention to the most silent one. This effect was recently shown by Kanaya and colleagues (2018), examining individuals' accuracy in estimating the mean circle size. The perceivers have a tendency reporting larger average size of the circle set than it actually was, suggesting that perceivers overweight the most salient items within the set (Kanaya et al., 2018). In case of a face ensemble, an estimation of the average could be perceived as more extreme than the true mean because of oversampling or overweighting of the more salient objects in the set of faces (Goldenberg et al., 2021, 2022). This assumption aligns with the subsampling hypothesis of ensemble perception, which suggests that the visual system integrates information from a set of stimuli based on the square root of the total number of stimuli (Ji et al., 2020).

How the state anxiety of participants might change perception of the mean emotion of a group has not been thoroughly studied. If ensemble perception of faces shares similar mechanisms with the recognition of emotions in individual faces, it is plausible to assume that anxiety-inducing conditions amplify average perceived emotion intensity, attracting participant attention toward facial expressions related to anxiety such as expressions of anger or fear. In other words, we expect that this mechanism will produce an effect similar to emotion congruency facilitating the processing of emotions that match the perceiver’s mood (Rusting, 1998). This facilitation may cause different types of biases, increasing perceived intensity of an emotion or changing its recognition accuracy (e.g., Qiao-Tasserit et al., 2017; Trilla et al., 2021).

The current study has directly examined the influence of state anxiety on the ensemble perception of negative emotional faces. We hypothesize that state anxiety biases the ability to estimate negative emotional expressions, leading participants to evaluate average perceived emotion as more intense. The participants' answers were dissociated into two key metrics: the mean error of their responses, which we define as response bias, and response accuracy, calculated as the standard deviation of the error. This distinction allowed us to determine whether the emotion amplification — an increase in perceived emotional intensity — affects both bias and accuracy under neutral versus anxiety-induced conditions. The experimental design was formulated to assess the emotion amplification effect in two contexts: ensemble averaging and individual face presentation. We successfully replicated the congruency effect for the individual face condition, confirming that it is consistently observed and emphasizing its relevance in our experiment, and found the effect of anxiety on emotion evaluation in ensemble condition. Understanding the influence of anxiety on ensemble perception is essential for providing deeper insight into complexities of social cognition. Specifically, this research highlights how emotional biases introduced by anxiety can distort group-level information processing, thereby affecting the interpretation of emotion contexts. These findings provide valuable contributions to the broader understanding of how emotional states shape our perception of collective emotional expressions.

Method

Participants

A total of 96 participants (64 women; mean age = 21.18 years, SD = 3.81) were initially recruited for the experiment. However, only those who demonstrated successful anxiety induction—defined as having a higher anxiety score in the induction phase compared to the non-induction phase—were included in the final analysis. This resulted in a final sample of 44 participants (34 women; mean age = 21.07 years, SD = 2.97). All participants reported having normal or corrected-to-normal vision. The study protocol was reviewed and approved by the Research Ethics Committee of HSE, and all participants provided written informed consent prior to the experiment.

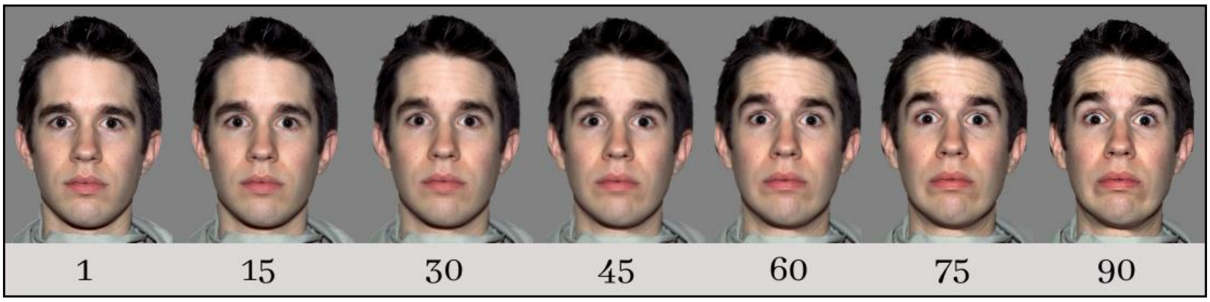

Fig. 1. Stimuli morphing scale.

To induce anxiety in the second session of the experiment, we used an excerpt from I. Bergman's 1968 film "The Hour of the Wolf" (50:40 -54:48). A state of anxiety during the task was maintained by music from the aforementioned film excerpt through the headphones Sony MDR-XB550AP, as well as sounds from the video.

Apparatus

The experiment was performed in a soundproofed room. Stimuli were presented on a monitor LG UltraGear 27” FHD 1920x1080, 240Hz. The experimental program was produced in Psychopy v. 2022.2.4. The participants were located 60 cm away from the monitor. At this distance, 1 pixel subtended approximately 0.023 of visual angle.

Stimulus validation

Before using the excerpt from this film, the video was validated to ensure that the video was anxiety-provoking. Validation was carried out using the questionnaire: EmoS-15 (Lyusin, 2019). The survey consists of 15 items, in each of which the respondent must rate on a five-point scale how much the word presented in the question corresponds to his emotional state at the moment.

A total of 21 people took part in the validation (9 men, 12 women, from 19 to 33 years old). The subjects who participated in the video validation were warned in advance regarding the presence of violent scenes in the video. Each participant was asked to fill out the EmoS-15 questionnaire before and after watching the excerpt from the film.

The questionnaire consists of three main dimensions: positive emotions with high activation, negative emotions with low activation, and tension. The results were analyzed using the paired sample T-test, which compared the questionnaire results before and after watching the video. The results of the analysis showed that in the assessment of positive emotions there were statistically significant changes in the negative direction after watching the video ($t = 5.32$, p-value $< .001$), significant changes were also observed for tension ($t = -4.20$, p-value $< .001$), and separately for the item “anxiety” ($t = -3.60$, p-value $< .001$). There are no statistically significant differences for negative emotions (t = -1.17, p-value = 0.25). Since the ability of the video recording to induce an anxious state is of key importance in this study, based on the analysis, it can be argued that the video is suitable for induction.

Procedure

Before the beginning of the experiment, the individuals were given informed consent, which described the study procedure. The individuals were warned that the experiment included a video with unpleasant and violent content, and that they could refuse to participate in the experiment at any time.

To assess the emotional state, participants were given the EmoS - 15 questionnaire, in which it was necessary to assess how much a certain word corresponds to the emotional state of the individual at the moment (Lyusin, 2019). During the experiment, the participants filled out the questionnaire three times. For the first time they filled out the questionnaire before the beginning of the experiment, after that they completed a training session of the experimental task. In the control condition, after completing training trials, the participants filled out the questionnaire again. In the anxiety induction session, between the training and the second filling out of the questionnaire, the participants were shown a video material designed to induce anxiety. After the second filling out of the EmoS - 15 questionnaire, the main part of the experiment began. Upon completion of the main part, the subjects filled out the questionnaire for the third time (see Fig. 2).

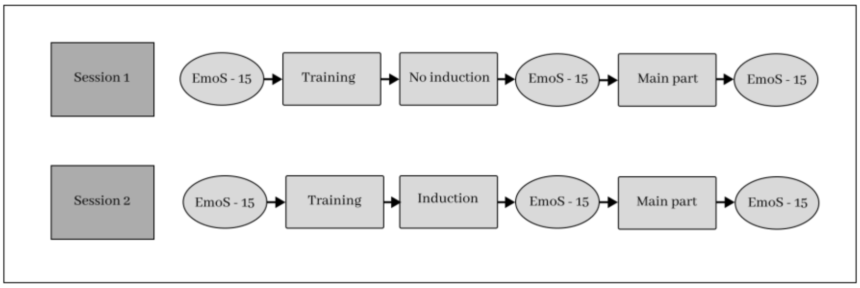

Fig. 2. Experimental procedure flowchart.

There were 120 trials in one session (60 for the emotion of fear, 60 for anger). In each trial, the participants first saw either a single face or an array consisting of twelve faces. The face(s) displayed different intensities of emotions: from neutral to anger or from neutral to fear. The array was presented for 1200 ms. The average emotional intensity for the group of faces was chosen randomly with a step of 15 (thus, the intensity of a single facial emotion or the average intensity level of an ensemble of faces could be 15, 30, 45, 60, 75). Although the mean level of emotional expression intensity was fixed, the individual faces within the ensemble could demonstrate distinct levels of emotional intensity.

In half of the cases, the subjects were shown a single face. In this situation the face was located in the center of the screen. In the case of an ensemble condition, the images were located on a circle with a diameter of 700 pixels or 16.1 visual angles. The center of the circle was located on the zero coordinate axes (see Fig. 3).

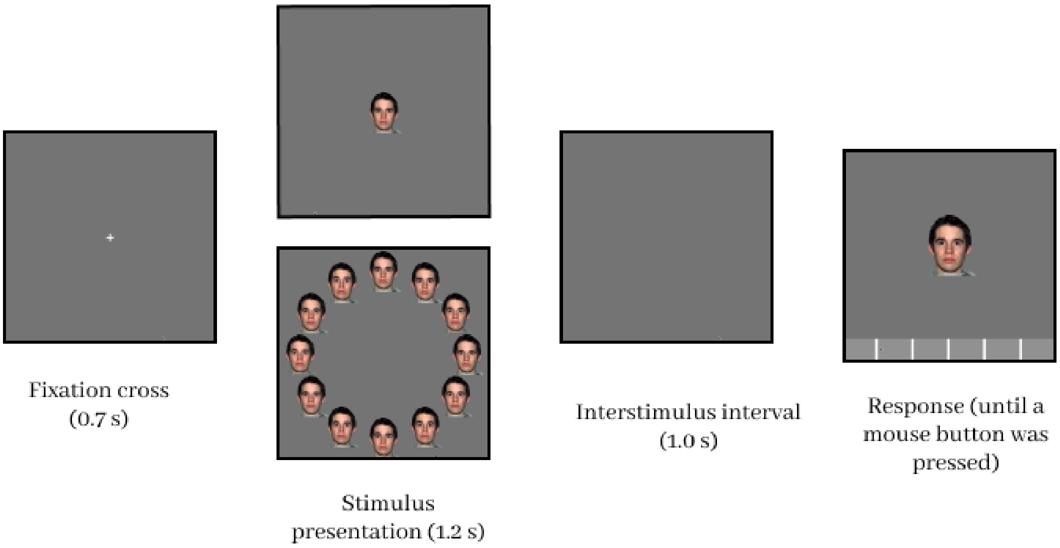

Fig. 3. Sequence of experimental phases: Participants first focused on a fixation cross (0.7 s), followed by the stimulus presentation (1.2 s). A response was then collected until a mouse button was pressed. An interstimulus interval of 1.0 s was presented between trials.

The set consisted of the faces of one actor but with different intensity expressions, so the assessment of the average emotion was as simple as possible and could be performed using a scale from the same face as the set. After the stimuli, there was one second interstimulus interval between the set of faces and the subjects' responses. After ITI, a face would reappear on the screen with a scale displayed beneath it, participants were asked to rate the average emotion expressed in the ensemble on the scale. The minimum value of the scale corresponded to a neutral face, and the maximum value corresponded to the maximum level of emotion. Moving the cursor from left to right along the scale transformed the face gradually from neutral to angry or scared. The participant's task was to adjust the face on the screen with the set of faces seen before. In order to confirm their response, the subject had to click the right mouse button. The interval between the stimulus and the response was made in order to reduce the likelihood of the influence of the intensity of the emotion level of the face appearing during the subject's response on the assessment of the emotion intensity of the stimulus.

Anxiety induction analysis

To assess the effects of the anxiety induction procedure on participants' anxiety levels, paired-samples t-tests were performed comparing EmoS-15 anxiety scores across different experimental stages and conditions (with and without anxiety induction). Before the experiment, no significant differences were observed in the non-induction and the induction condition, $t(48) = -0.693$, $p = .492$, Cohen's $d = -0.099$, indicating that participants' baseline anxiety levels were comparable across both conditions. After the induction procedure, significant differences emerged in the second evaluation of state anxiety that participants took after the anxiety-induced video in the induction condition. Participants reported significantly higher anxiety levels compared to those in the non-induction condition, $t(48) = -12.971$, $p < .001$, Cohen's $d = -1.853$. This anxiety level persisted in the post-experiment evaluation and was significantly higher in the induction condition than in the non-induction condition in the third competition of the test, $t(48) = -9.377$, $p < .001$, Cohen's $d = -1.340$.

These findings confirm that the anxiety induction procedure effectively heightened participants' anxiety levels, and this increase was sustained throughout the experimental session, indicating the successful induction of anxiety.

Analysis

In this experiment, we conducted repeated measures ANOVA to analyze the data in Rstudio v. 2021.09.0, given that two experimental sessions were compared for the same participants. Our primary aim was to assess how anxiety induction influences both response accuracy and bias when participants evaluated emotional intensities of faces.

To quantify response bias, we calculated the normalized response error by subtracting the correct response from the participant's reported response. We performed normalization of the mean error with between-subject variance removed following the Cousineau method (Cousineau, 2005). This technique allowed us to reduce the influence of individual response tendencies and focus on the effects of the experimental factors. Thus, the mean was interpreted as a measure of bias, whereas standard deviation was used as a metric of response accuracy (Iakovlev & Utochkin, 2021)

First, an analysis was conducted for single faces, without distinguishing between emotional expressions, to determine whether the effect of anxiety induction was evident for a single face condition. However, the primary analysis centered on face ensembles, as we hypothesized that anxiety would particularly influence the averaging of emotional intensities across multiple faces, we also examined individual emotional expressions (fear and anger) in ensembles to explore how anxiety might interact with anxiety-related facial expressions.

Results

To evaluate whether participants have a tendency to overestimate the intensity of expressive faces, we examined how response accuracy and bias varied across different experimental conditions. A repeated-measures ANOVA was calculated to examine the bias in perceived emotions intensity (referred as the mean absolute error) with several factors: face presentation condition (single face vs. ensemble of 12 faces), induction condition (before vs. after anxiety induction), and five emotional intensity levels (15%, 30%, 45%, 60%, 75%).

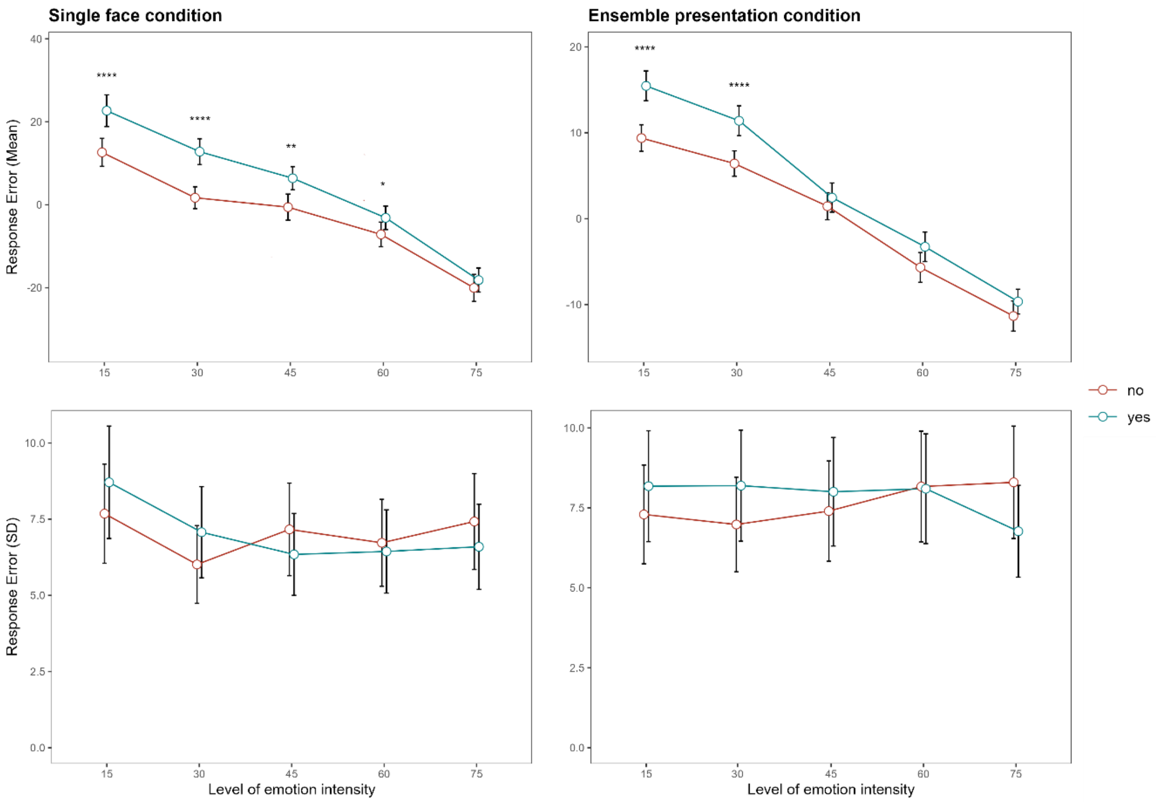

Fig. 4. Response Errors Across Different Levels of Emotion Intensity for Single Face and Ensemble Presentation Conditions with Anxiety Induction. Line plots represent response error (mean and standard deviation) across varying levels of emotion intensity (15, 30, 45, 60, 75) for two conditions: Single face presentation (left) and Ensemble presentation (right). The red lines indicate the absence of anxiety induction, and the blue lines represent the presence of anxiety induction.

Significant differences between conditions are marked by asterisks (*p < .05, **p < .01, ***p < .001).

Focusing on individual face evaluations, there was a significant main effect of anxiety induction on response bias, $F(1, 870) = 47.667$, $p < .001$, $\eta^2_p = .052$. Individuals in the anxiety-induced condition reported higher emotional intensity in comparison with their answers in the neutral condition. Emotional intensity impacted participants' responses significantly, $F(4, 870) = 156.942$, $p < .001$, $\eta^2_p = .419$. The interaction was significant between anxiety induction and emotional intensity $F(4, 870) = 3.140$, $p < .05$, $\eta^2_p = .014$, indicating that the impact of anxiety varied across different intensity levels.

We conducted post-hoc tests with Bonferroni correction to clarify the nature of significant interactions. The anxiety influence was most pronounced at lower intensities and gradually decreased as the emotional intensity increased. At the lowest intensity level (15%), participants in the anxiety induced condition perceived significantly higher intensity of emotion than their answers in the neutral condition, $t(87) = -4.46$, $d = -0.48$, $p < .001$, $MD = -4.85$. This pattern remained persistence for an intensity level of 30%, $t(87) = -5.78$, $d = -0.61$, $p < .001$, $MD = -5.36$. For moderate intensities were found significant differences in 45 %, $t(87) = -3.03$, $d = -0.32$, $p < .005$, $MD = -3.37$) and 60%, $t(87) = -1.10$, $d = -0.21$, $p < .05$, $MD = -1.93$). These findings suggest that anxiety has a stronger effect on emotion evolution when the emotional signals are subtle or less discernible, but this effect weakens as the emotional expressions become more intense and clear.

In addition to response bias, response accuracy was evaluated by using the standard deviation (SD) of errors. Anxiety induced condition significantly affected response accuracy , $F(1, 868) = 6.787$, $p < .05$, $\eta^2_p = .008$, that is similar to emotional intensity, $F(4, 868) = 16.499$, $p < .001$, $\eta^2_p = .071$. The interaction was no significant between anxiety induction and emotional intensity on accuracy, $F(4, 868) = 0.260$, $p = .904$, $\eta^2_p = .001$, indicating that although state anxiety increased bias and decreased accuracy between induction condition, it did not significantly impair participants' ability to evaluate emotions across intensity conditions.

The results from the ensemble condition nearly repeated those observed in the single face condition. The anxiety induction procedure again led participants to report higher average intensity, $F(1, 808) = 38.112$, $p < .001$, $\eta^2_p = 0.052$, and there was a significant influence of emotional intensities, $F(4, 808) = 258.761$, $p < .001$, $\eta^2_p = 0.419$. Moreover, the interaction showed significant results, $F(4, 808) = 3.512$, $p < .01$, $\eta^2_p = 0.014$, suggesting that the anxiety-induced bias extended to the ensemble-averaging process, as it did with individual face perception.

Post-hoc analyses confirmed that anxiety's effect on perceived emotional intensity was most noticeable at lower intensity levels. For example, at an intensity of 15%, participants in the anxious condition perceived significantly higher emotional intensity compared to those in the neutral condition, $t(87) = -3.86$, $d = -0.67$, $p < .001$, $MD = -6.08$. Similarly, for an intensity of 30%, anxiety-induced differences remained significant, $t(87) = -2.11$, $d = -0.44$, $p < .001$, $MD = -4.99$. However, as intensity increased, the anxiety effect became non-significant ($p > 0.05$), except for a near-significant trend at 60% intensity, $t(87) = -0.51$, $d = -0.19$, $p = .07$, $MD = -2.4$.

Significant differences in response accuracy were observed only across the emotional intensity conditions, $F(4, 870) = 29.607$, $p < .001$, $\eta^2_p = 0.120$. No other factors or interactions, including the induction condition or its interaction with emotional intensity, showed statistically significant effects on accuracy ($p > 0.1$). This suggests that while emotional intensity levels influenced how consistently participants evaluated emotional expressions, anxiety induction and other conditions did not have a measurable impact on the overall accuracy of their responses.

Further, we also examined differences in bias across emotion types (fear vs. anger). Anxiety significantly affected the perception of both emotions. In the fear condition, anxiety resulted in higher perceived intensity, $F(1, 430) = 31.073$, $p < .001$, $\eta^2_p = 0.067$, which was similarly observed in the anger condition, $F(1, 430) = 11.311$, $p < .001$, $\eta^2_p = 0.026$. Emotional intensity also significantly influenced bias in both conditions: fear, $F(4, 430) = 147.091$, $p < .001$, $\eta^2_p = 0.578$, and anger, $F(4, 430) = 155.526$, $p < .001$, $\eta^2_p = 0.591$. However, the interaction between emotional intensity and anxiety did not reach statistical significance for anger, $F(4, 430) = 2.028$, $p = .09$, $\eta^2_p = 0.019$, and only approached significance for fear, $F(4, 430) = 2.322$, $p = .056$, $\eta^2_p = 0.021$.

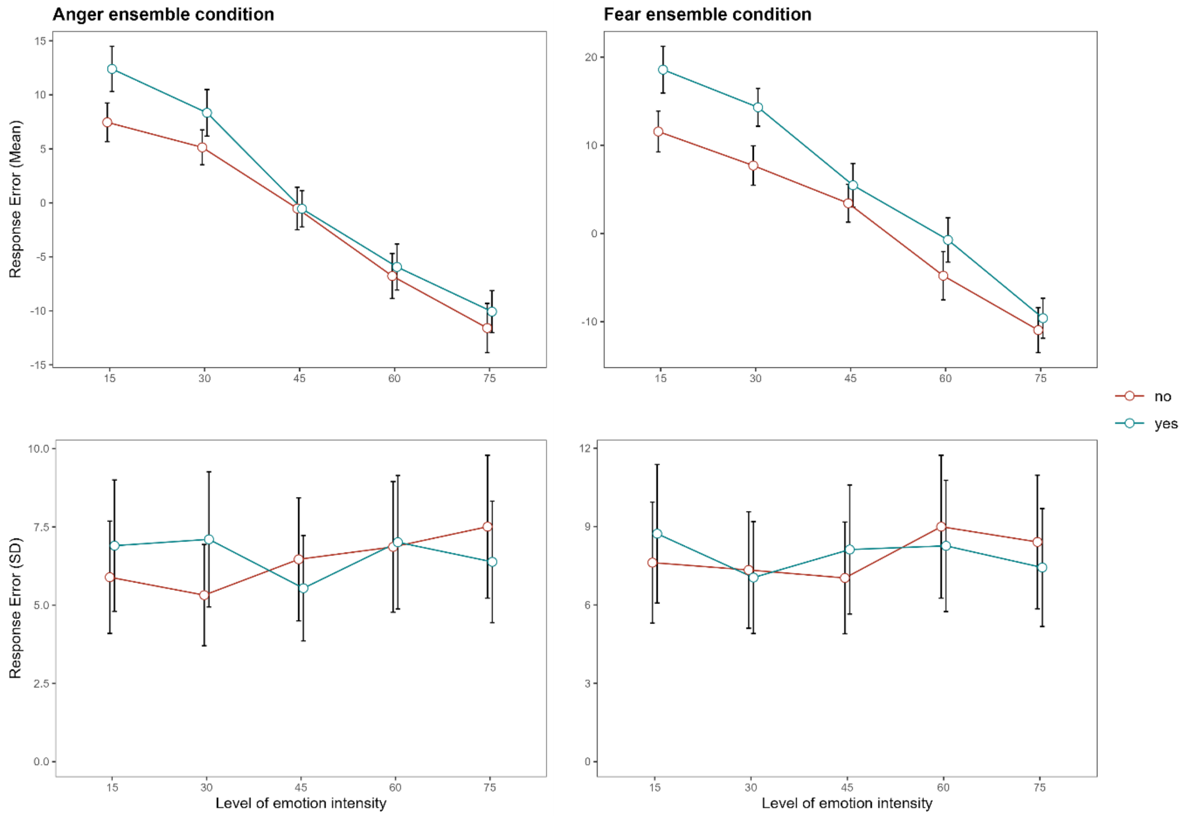

Fig. 5. Response Errors Across Different Levels of Emotion Intensity for Anger and Fear Conditions with Anxiety Induction. Line plots display the response error (mean and standard deviation) as a function of emotion intensity (15, 30, 45, 60, 75) under two ensemble conditions (anger and fear). The red and blue lines represent the conditions without and with anxiety induction, respectively.

A repeated-measures ANOVA on accuracy, measured by SD of errors, revealed no significant main effect of anxiety induction in the fear condition, $F(1, 430) = 0.028$, $p = .867$, $\eta^2_p = .0000657$. In the anger condition, there was an almost significant effect, $F(1, 430) = 3.732$, $p = .054$, $\eta^2_p = .009$, indicating that anxiety had a marginal impact on response variability. Emotional intensity significantly affected accuracy in both fear, $F(4, 430) = 11.648$, $p < .001$, $\eta^2_p = 0.098$, and anger conditions, $F(4, 430) = 18.471$, $p < .001$, $\eta^2_p = 0.147$. However, the interaction between anxiety and emotional intensity did not reach significance in either condition: fear, $F(4, 430) = 1.299$, $p = .270$, $\eta^2_p = 0.012$, and anger, $F(4, 430) = 1.629$, $p = .166$, $\eta^2_p = 0.015$.

Taken together, these results suggest that people in state anxiety respond with robust bias in emotional evaluation, particularly when emotional cues are subtle, meanwhile its influence on accuracy remains quite limited. The anxiety effect diminishes as the emotional intensity becomes more explicit; that might be stemmed from a possible ceiling effect in the processing of extreme emotional expressions.

Discussion

In this study, we examined how state anxiety affects emotion perception in both single-face and ensemble-averaging tasks, analyzing participants' accuracy and perceptual biases in evaluation of emotional intensity. Inducing anxiety at different levels of intensity, we focused on two main phenomena: the crowd amplification effect and the congruency effect for negative emotions. Our findings suggest that state anxiety significantly influences emotional perception across both individual and group contexts, resulting in an overestimation of emotional intensity, however, this effect in the ensemble condition was found only in lower-intensity levels. Particularly, this bias persisted across most intensity levels in single-face evaluations, implying that anxiety may alter both individual emotional evaluation and the perceptual averaging processes inherent in ensemble contexts.

Our results reveal a nuanced interaction between state anxiety and emotional intensity, with anxiety amplifying perceptual biases towards stronger emotional intensity. In the single-face condition, state anxiety led participants to exaggerate perceived emotional intensity (e.g., 15% and 30%), yielding medium-to-large effect sizes (Cohen’s d=−0.48- 0.61). This influence of anxiety diminished as the intensity of an expressed emotion increased, with no significant differences observed between anxious state and neutral state at the highest expression intensities (75%). In contrast, state anxiety effect was more pronounced in the ensemble condition when emotional signals were subtle or ambiguous, supporting prior findings on anxiety’s impact on perceptual sensitivity (Mathews & Mackintosh, 1998). The crowd amplification effect (Goldenberg et al., 2021), observed primarily at low intensities, was characterized by an overestimation of group-level emotional intensity. As emotional cues became more distinct, the amplification effect diminished, suggesting a potential ceiling effect where the perceptual system becomes less susceptible to exaggeration when emotional expressions are fully clear and unambiguous. This trend may be explained by a noise-cancellation mechanism, wherein the visual system mitigates individual noise to provide a reliable ensemble representation (Baek & Chong, 2020). Therefore, when emotional intensity is low, cues may not be sufficiently distinct, and anxious individuals may misinterpret these subtler signals, perceiving the ensemble's average emotion as more intense than it actually is.

It was shown that the effectiveness of averaging might partly depend on the quality of individual representation in ensemble processing. For instance, Lee and Chong (2021) demonstrated that the fast flicker adaptation increased the precision of mean representation, suggesting the decreased influence of early noise on individual representation, and in turn, improved the precision of ensemble representation. Likewise, the increased number of inverted faces in a set degraded the accuracy of discriminating mean facial expressions (Sun & Chong, 2020). Because individual face processing was disturbed by the inversion, adding an inverted face to a set increased noise for individual expressions to be averaged. Subsequently, the added noise reduced the accuracy of the mean computation. In the case of our study, when emotional signals are weak, anxious individuals may find it more challenging to filter out noise effectively, resulting in fixation on ambiguous cues that, due to heightened sensitivity, are perceived as more emotionally intense. This tendency aligns with existing theories on attentional biases under anxiety, which suggest that anxiety enhances sensitivity to threat or ambiguity in emotional signals (Miskovic & Schmidt, 2012). In scenarios with clearer emotional cues, noise cancellation operates more efficiently, allowing the visual system to aggregate information without disproportionately emphasizing any single ambiguous expression. Taken together, the combination of the congruency effect and the noise-cancellation mechanism appear critical for understanding the amplification observed in state anxiety.

Furthermore, the concept of subsampling—where individuals attend to a limited set of features or members within a group to approximate an ensemble—further elucidates the observed effects. Research indicates that rather than processing every face in a crowd, individuals typically focus selectively on a subset (Ji et al., 2020; Myczek & Simons, 2008; Whitney & Leib, 2018). Under anxiety, this selective attention may intensify, leading participants to over-focus on specific faces within an ensemble, especially those with ambiguous expressions, which amplifies the perception of emotional intensity in low-intensity situations. Although it was not investigated with state anxiety, a significant amount of research with trait anxiety introduced results that people with the high level of social anxiety overestimate or wrongly categorize emotional expression (Richards et al., 2002; Yang & Baek, 2022). Our results deepen knowledge about the influence of state anxiety not only on single face perception but also ensemble perception of faces.

While subsampling provides a plausible explanation for the effects of anxiety on ensemble perception, its role remains contested. Some research suggests that ensemble perception might involve holistic processing rather than subsampling alone, depending on attentional resources and perceptual demands (Dandan et al., 2022; Han et al., 2021; Ji et al., 2020). For example, Wolfe et al. (2015) found that foveal input is not essential for ensemble perception of faces, indicating that detailed processing of each face may not be necessary for accurate ensemble perception. In high-anxiety conditions, however, subsampling may exaggerate the effect of anxiety by limiting the focus to fewer faces, thereby amplifying ambiguity-driven biases while neglecting clearer expressions. Such findings point to the importance of attentional allocation and anxiety's role in selectively enhancing attention toward salient or ambiguous cues (Eysenck et al., 2007).

The congruency effect, particularly for threat-related stimuli, also plays a role in anxiety-driven biases. Anxiety often primes individuals to prioritize threat-related cues, resulting in amplified perception of fear over other emotions (Öhman, 2005). This bias towards fear was evident in our findings, as anxiety amplified the perceived emotional intensity of fear more than that of anger. The congruency effect suggests that anxiety's influence is particularly acute for stimuli associated with environmental threats, leading to heightened sensitivity to fear signals over approach-related emotions like anger (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; McTeague & Lang, 2012). Our results support these theories by showing that fear signals, especially under ambiguous conditions, were exaggerated more than anger, aligning with previous research on the salience of threat cues in anxious individuals.

The observed effects of state anxiety on both single-face and ensemble emotional perception provide insight into the broader implications of anxiety on social cognition. The tendency to overestimate emotional intensity, particularly under conditions of uncertainty, suggests that anxiety may alter social perceptions, potentially impacting real-world interactions and judgments in-group contexts. This cognitive bias, driven by heightened sensitivity to subtle or ambiguous emotional cues, emphasizes how anxiety can influence both individual and collective emotional evaluations, affecting responses in social and interpersonal communication.

Although our findings offer valuable insights, certain limitations should be noted. The statistical power might have been reduced due to the nature of the induction method, which affected only one-half of our participants, leading us to exclude those who did not exhibit successfully induced anxiety. Additionally, the constrained range of emotional intensity levels in the ensemble stimuli may have limited our ability to observe how extreme emotional variability affects perception. Expanding the range of intensity levels, in future studies could provide further insight into the role of saliency and outliers in ensemble perception. Furthermore, research should investigate how specific negative emotions and presentation time interact with anxiety to influence perceptual biases in various social contexts.

Investigating how anxiety influences attentional focus within groups, such as biased attention towards specific expressions, would provide further clarity on how attention mediates ensemble perception in anxious individuals.

Conclusion

In summary, our study highlights the complex interplay between state anxiety, the noise-cancellation, and the subsampling mechanism in perception of emotions. The crowd amplification effect, driven by anxiety-induced biases, is particularly pronounced in low-intensity conditions, as anxiety heightens sensitivity to subtle emotional cues while impeding effective noise cancellation. Although the impact of anxiety on amplifying emotional biases was significant, accuracy remains relatively consistent. These findings suggest that anxiety shapes both individual and ensemble perception in social contexts, emphasizing the importance of further research into how these biases may impact social cognition and behavior in naturalistic settings.

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