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They're watching you: The impact of social evaluation and anxiety on threat-related perceptual decision-making

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Abstract

In day-to-day social interactions, we frequently use cues and contextual knowledge to make perceptual decisions regarding the presence or absence of threat in facial expressions. Such perceptual decisions are often made in socially evaluative contexts. However, the influence of such contexts on perceptual discrimination of threatening and neutral expressions has not been examined empirically. Furthermore, it is unclear how individual differences in anxiety interact with socially evaluative contexts to influence threat-related perceptual decision making. In the present study, participants completed a 2-alternative forced choice perceptual decision-making task in which they used threatening and neutral cues to discriminate between threatening and neutral faces while being socially evaluated by purported peers or not. Perceptual sensitivity and reaction time were measured. Individual differences in state anxiety were assessed immediately after the task. In the presence of social evaluation, higher state anxiety was associated with worse perceptual sensitivity, i.e., worse discrimination of threatening and neutral faces and slower RT following threatening cues. In the absence of social evaluation, higher anxiety was associated with better perceptual sensitivity and faster RT. These findings suggest that individual differences in anxiety interact with social evaluation to impair the use of threatening cues to discriminate between threatening and neutral expressions. Such impairment in perceptual decision making may contribute to maladaptive social behavior that often accompanies evaluative social contexts.

Keywords

Perception; Decision-making; Anxiety; Social evaluation; Threat; Peers

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Imagine sitting in class with your peers during a review session for an upcoming exam. The professor announces that each student will be called on at random to give an answer to a review question. After an answer is given, the rest of the class will vote on whether the student's response is correct. The professor calls on you. You look at one of your peers and perceive their facial expressions as negative. Was this an accurate perception? Did the threat of social evaluation influence your decision of whether the expression was negative or innocuous? This is an important question because inaccurate discrimination of a negative versus neutral expression is likely to generate a set of damaging downstream cognitive and social consequences. In the case of the review session, an inaccurate discrimination of your peer's facial expression may, for example, cause you to change your correct response to an incorrect one. Furthermore, in such socially evaluative situations, individual differences in anxiety levels may compound the influence of social evaluation on perceptual decision making regarding facial expressions. The interaction between social evaluation and individual differences in anxiety may either enhance or hinder perceptual decisions. In the present study, we empirically examined the influence of social evaluation and individual differences in anxiety on discrimination between threatening and neutral facial expressions.

Perceptual decision-making involves choosing one option out of a set of alternatives based on available sensory information (Heekeren et al. 2008). Most research on perception of threatening stimuli has focused on “bottom-up” processing, attributing faster and more accurate detection of threats to automatic stimulus-driven processes (Lundqvist et al. 1999; Lundqvist and Ohman 2005; Öhman et al. 2001b; Vuilleumier 2005; Vuilleumier and Driver 2007). This level of processing is evolutionarily conserved across many species and has been demonstrated via faster detection of stimuli such as snakes, spiders and threatening expressions (Eastwood et al. 2001; Schupp et al. 2004; Staugaard 2010; Tipples et al. 2002; New et al. 2007; Öhman et al. 2007; Öhman et al. 2001a). However, “top-down” factors such as cues and contexts that signal the presence of threatening faces may also influence perceptual decision-making by generating perceptual or attentional sets that indicate the relevance of a particular expression for decision-making (Feldman Barrett et al. 2011; Mohanty and Sussman 2013). Such cues and contexts therefore lead to better discrimination of subsequently presented threatening versus neutral facial expressions (Imbriano et al. 2019; Sussman et al. 2016; Szekely et al. 2017, 2019).

Recent research also shows that visual perception in general but, for faces in particular, is strongly influenced in a top-down manner by higher-order social contextual factors such as stereotypes, attitudes, goals, and social knowledge (Barrett and Bar 2009; Freeman and Johnson 2016; Otten et al. 2017). This research shows that these social processes can bias face perception via top down influence on sensory cortices that encode face representations (Stolier and Freeman 2016). Social contextual factors such as the presence of another facial expression can bias perception of facial expressions such that a neutral expression is perceived as sadder when it follows a happy face (Russell and Fehr 1987), and a surprised face is perceived in line with the contextual expressions (Neta et al. 2011). Faces are frequently encountered in social evaluative contexts which may bias their perception. Social evaluative contexts are characterized by high levels of stress and arousal (Andrews et al. 2007; Dickerson and Kemeny 2004; Mullen et al. 1997). Previous work has shown that during a functional magnetic resonance imaging scan, something as subtle as being shown a cue that indicates an individual is being watched by others is enough to induce neural activation in brain regions like the medial prefrontal cortex (Somerville et al. 2013) which are implicated in emotion regulation (Blanco et al. 2009). However, perceptual decision making regarding threatening and neutral faces in the context of social evaluation has not been examined.

In addition to social evaluative contexts, perception of facial expressions is also influenced by individual differences in anxiety (Attwood et al. 2017; Doty et al. 2013). However, it is unclear how social evaluation interacts with individual differences in anxiety to influence discrimination of threatening and neutral faces. In the present study, participants completed a perceptual decision-making task in which they used threat- and neutral-related cues to discriminate between threatening and neutral faces while being socially evaluated (or not) by purported peers. Cues were followed by perceptually degraded faces that encouraged participants to use cue-generated threatening and neutral perceptual sets in their decision making. In line with studies showing that individual differences in anxiety and social contextual factors bias face perception (Attwood et al. 2017; Barrett and Bar 2009; Doty et al. 2013; Freeman and Johnson 2016; Otten et al. 2017), we hypothesized that individuals with more severe anxiety would have worse discrimination between threatening and neutral faces (i.e., worse perceptual sensitivity) following threatening cues in socially evaluative compared to non-social evaluative contexts.

Method

Participants

Seventy-four participants (Female = 62.2%) between the ages of 18 and 27 completed the study for course credit. All participants were randomly assigned to complete a threshold identification task and then a cued discrimination task while being evaluated by purported peers (N = 35, females = 51.4%, M = 19.74 ± 1.50 years), or without being evaluated by purported peers (N = 39; females = 71.8% , M = 19.79 ± 2.00 years). Evaluated and non-evaluated groups did not differ based on age, $t(72) = .13$, $p=.90$, or gender, $X^2(1) = 3.25$, $p = .09$. Additional participants were excluded from analyses due to poor behavioral performance (< 50% accuracy during the cue task, N = 11), or failure to be deceived in the evaluation condition (N=17). The twenty-eight excluded and seventy-four included participants did not differ in age, $t(97) = -.59$, $p=.56$, or gender $X^2(1) = .04$, $p = 1.0$. An additional 26 participants were excluded from all analyses due to a software malfunction. All participants were recruited from the Stony Brook University's Psychology Department, and provided informed consent to participate in the study, which was approved by the Institutional Review Board.

Stimuli

The threshold and cued discrimination tasks utilized fearful face (FF) and neutral face (NF) images as stimuli (N = 16; Tottenham et al. 2009), which were modified from color to gray scale (512 × 512 pixels). The SHINE toolbox for Matlab was used to equalize luminance and spatial frequency (Willenbockel et al. 2010). SHINE minimizes confounds due to low-level image properties and has been used successfully to examine effects of top-down processes on face perception (Fiset et al. 2008). Masks were presented immediately after the presentation of each face image during both tasks to increase the perceptual difficulty for differentiating between the two face-types. These masks were generated by averaging four images (2 FF and 2 NF). The mask images were then divided into 100-pixel squares and randomly reorganized, yielding images that were in the same size as the face stimuli images. Finally, as with the stimuli images, the masks were processed by SHINE.

Threshold Identification

The threshold identification task was completed to determine a participant's individual threshold for detecting FF and NF images. The participant-specific FF and NF threshold levels were then used in the subsequent cued-discrimination task. The threshold was defined as 75% correct for each face-type (Summerfield et al. 2006). For each trial, a fixation cross (2- 3 s) was followed by a perceptually degraded FF or NF image (100 ms) which was immediately followed by a mask (300 ms) against a light gray background (Fig. 1A). Participants identified the face as fearful or neutral by pressing one of two keyboard buttons. The task included 8 blocks of 16 trials (8 FF and 8 NF), resulting in 64 FF, and 64 NF trials. These faces could be presented at a contrast scale that ranged from full contrast (1), to complete removal of contrast resulting in a uniform gray square (0; Fig. 1B). Initially, FF and NF images were presented at 0.1, a low-level contrast, at which images are visible but difficult to see. Each participant's threshold was determined using separate adaptive staircases for FF and NF faces, to make images' contrast more or less challenging, depending on the accuracy of each preceding response. Staircases used a Weibull psychometric function such that an incorrect answer led to an easier-to-see stimulus (image presented at a higher contrast level) on the next trial, while a correct answer led to a more perceptually challenging stimulus presentation (lower contrast) on the next trial (Watson and Pelli 1983).

Cued Discrimination Task

In the cued discrimination task, participants used cues to discriminate between subsequently presented FF and NF images. The cued discrimination task had the same trial structure and stimuli as the threshold identification task with three differences (Fig. 1D). First, a cue, the letter "F" (FC) or the letter "N" (NC) was presented for 1 s prior to the presentation of each face stimulus. Participants were told that the letter "F" indicated that they would be making a "fearful or not" decision, the letter "N" indicated that they would be making a "neutral or not" decision for the subsequently presented faces and that cues were not indicative of the probability of an FF or NF stimulus. Second, FF and NF were perceptually degraded and presented at each participant's predetermined 75% perceptual threshold (using the Thresholding task above). Since utilization of top-down information is greater when the sensory evidence is poor, the faces were perceptually degraded to encourage participants to use FC or NC generated "fearful or not" or "neutral or not" perceptual sets in their decision making. They made this decision by pressing one of 2 keyboard buttons corresponding to fearful or neutral decision (Fig. 1C). Each FF and NF stimulus was shown four times after each FC and NC label type. Hence, in the experiment, participants used a "perceptual set" imposed by the FC or NC to discriminate between the same set of FF and NF. Third, to prevent improvement in perceptual performance due to practice effects, FF and NF images were perceptually degraded and presented at one of eight contrast levels ranging from 6% less to 8% more than the participant's previously determined threshold level. For example, if a participant's threshold for FF was 0.1, they were subsequently shown images ranging from 0.094 to 0.108 (Adini et al. 2004). Reaction time (RT) and accuracy were recorded.

Social Evaluation Manipulation

A social evaluative context was established via a peer evaluation manipulation. Prior to a participant's arrival, a research assistant placed a webcam on the computer monitor and faced it away from the participant's seat. Between completing the threshold identification task and before beginning the cued discrimination task, participants were told that the goal of the study was to see if being evaluated by peers impacts performance. For the evaluation condition, the experimenter manually turned the webcam to face the participant and explained that a group of college students in another room would be watching and evaluating the participant on their performance. To increase the plausibility of this cover story, the experimenter also called another experimenter to check on the status of the purported group who would be watching the participant, and had the other experimenter call back two-minutes later when all purported peers were ready to participate. Those randomized to the no-evaluation condition were told they would not be watched or evaluated during their visit, that a webcam on the computer was only used for participants in a different condition, and that it would remain off and turned away from them. At the end of the study, participants in the evaluation condition completed a funnel debriefing (Bargh and Chartrand 2000), which concluded with a yes/no question that assessed whether they believed peers were watching them throughout the task. Only participants who believed they were being watched were included in analyses. To more fully capture the experience of participants across both groups, all participants were asked to respond to the following questions: How evaluated or judged did you feel during the experiment? (1; not judged at all– 10; very judged); How well do you feel you did on the task? (1; not well at all– 10; very well).

Self-report measures

After the computer tasks and prior to debriefing, participants were assessed for individual differences in state anxiety by completing the State version of the State-Trait Anxiety Inventory (STAI-S; (Charles Donald Spielberger 1989; Chales Donald Spielberger et al. 1983). The STAI-S is a 20-item self-report questionnaire that assesses severity of state-related anxiety symptoms. It has adequate test-retest reliability: coefficients ranging from .65 to .75, and internal consistency: coefficients ranging from .86 to .95, over a 2-month period (Charles Donald Spielberger 1989; Chales Donald Spielberger et al. 1983). Scores on the STAI-S can range from 20 to 80, with higher scores indicating higher levels of anxiety.

Analytic Procedure

Independent samples t-tests were conducted to determine if evaluated and non-evaluated groups differed in perceived evaluation, gender, age, state anxiety, or how well participants felt they did on the task. For the cued discrimination task, perceptual sensitivity (ability to discriminate FF and NF) was assessed by computing *d' (Z(hit rate) – Z(false alarm rate))* (Keating 2005). Two separate paired-sample t-tests were performed to examine whether

FC, relative to NC, improved perceptual sensitivity (*d’*) and RT across the whole sample. To determine the interactive effect of social evaluation and individual differences of state anxiety on *d’* following FC and NC, two separate regression analyses using PROCESS macro for SPSS (IBM Corp., 2017) were performed with evaluation group (evaluated, non-evaluated) entered as the moderator, mean centered STAI-S scores as the independent variable, and their interaction predicting *d’* (dependent variable). To examine the effect of cues on RT, these analyses were replicated separately for RT for identifying FF and NF following the cues as the dependent variable. To further aid in interpretation of results, post-hoc power analyses were conducted in R using the "pwr" package and pairwise simple slopes comparison analyses of all significant interactions were conducted using the "emmeans" package. Because of gender differences in state anxiety (Female: M = 40.24, SD = 9.89; Male: M = 35.29, SD = 9.89; $t(72) = -2.09$, 95% CI [−9.68, −.23], $p = .04$), gender was entered as a covariate in all analyses.

Results

Manipulation check.

A manipulation check confirmed that the evaluated group reported higher levels of perceived evaluation or judgment (i.e., “how judged did you feel”) than the non-evaluated group (see Table 1). There were no differences between the two groups for gender, age, state anxiety, or how well participants felt they did on the task (see Table 1). Next, we examined whether cues (FC vs. NC) influenced discrimination of facial stimuli (FF vs. NF) across both groups (*M* and *SD* on Table 2). Compared to NC, FC lead to greater perceptual sensitivity (*d’*; $t(73) = 6.81$, 95% CI .45, .82], $p < .001$) and faster RT ($t(73) = -12.30$, 95% CI [−.13, −.09], $p < .001$). These results replicate prior studies (Sussman et al. 2016) and indicate that FC leads to more sensitive and faster discrimination of FF and NF.

Perceptual sensitivity (*d’*) following FC’s.

We then examined the effect of social evaluation and individual differences in state anxiety on *d’* following FC’s. Results showed there were no main effects for state anxiety ($b = .02$, $t(69) = 1.83$, 95% CI [−.00, .05], $p = .07$) or social evaluation group ($b = .23$, $t(69) = 1.19$, 95% CI [−.15, .60], $p = .24$). However, an interaction between social evaluation and individual differences in state anxiety emerged for *d’* ($\Delta R^2 = .09$, $F(1,69) = 7.98$, $f^2 = .10$, 95% CI [−.09, −.02], $p < .01$). Post-hoc power analyses indicated sufficient power (75.8%) for this test. Pairwise simple slope analyses indicated that evaluation groups differed ($t(69) = 2.83$, $p < .01$) such that greater levels of anxiety were associated with worse perceptual sensitivity for the socially evaluated group (b = .−03,, 95% CI [−.05, −.00]) and better perceptual sensitivity for the non-evaluated group ($b = .02$, 95% CI [.00, .05]).

Perceptual sensitivity (*d’*) following NC’s.

We also examined the effect of social evaluation and individual differences in state anxiety on *d’* following NC (see Fig. 2A). Results showed, there were no main effects for state anxiety ($b = .02$, $t(69) = 1.52$, 95% CI [−.00, .05], $p = .13$) or social evaluation group ($b = .37$, $t(69) = 1.75$, 95% CI [−.05, .78], $p = .08$) and no interaction between social evaluation and anxiety $\Delta R^2 = .02$, $F(1,69) = 1.55$, f^2=. 02, 95% CI [−.07, .02], $p = .22$) in predicting *d’*.

Thus, no further analyses were performed for NC trials. Post-hoc power analyses indicated low power (21.8%) for this interaction. Thus, null results should be interpreted with caution.

RT following FC's.

Next we tested the effect of social evaluation and individual differences in state anxiety on RT for identifying FF following FC's (see Fig. 2C). There were no main effects of state anxiety ($b = -.00$, $t(69) = -.06$, 95% CI [−.00, .00], $p = .95$) or social evaluation group ($b = -.05$, $t(69) = -1.00$, 95% CI [−.14, .04], $p = .32$). However, there was a significant interaction between social evaluation and individual differences in state anxiety ($\Delta R^2 = .05$, $F(1,69) = 3.78$, $f^2 = .05$, 95% CI [−.00, .02], $p = .056$). Post-hoc power analyses indicated only moderate power (46.2%) for this test. Although results should be interpreted with caution, pairwise simple slope analyses indicated that evaluation groups differed ($t(69) = -1.94$, $p = .056$) such that greater levels of anxiety were associated with slower RT for identifying FF for the evaluated group ($b = .01$, 95% CI [.00, .01]) and faster RT for identifying FF for the non-evaluated group ($b = -.00$, 95% CI [−.01, .01]). Similar analyses for NF RT's, showed no main effects of state anxiety ($b = -.00$, $t(69) = -.82$, 95% CI [−.00, .00], $p = .41$) but a main effect of social evaluation group emerged ($b = -.09$, $t(69) = -2.02$, 95% CI [−.19, .00], $p = .05$) such that holding constant for gender and individual differences in state anxiety, participants in the social evaluation group had slower RT. No interaction between social evaluation and individual differences in state anxiety emerged ($\Delta R^2 = .01$, $F(1,69) = 1.05$, $f^2 = .01$, 95% CI [−.00, .01], $p = .31$). Post-hoc power analyses indicated low power (17.0%) for this interaction. Thus, null results should be interpreted with caution.

RT following NC's.

Finally, we tested the effect of social evaluation and individual differences in state anxiety on RT for identifying FF and NF following NC's (see Fig. 2C). For FF RT's, there were no main effects of state anxiety ($b = -.00$, $t(69) = -.46$, 95% CI [−.01, .01], $p = .65$), social evaluation group ($b = -.06$, $t(69) = -1.23$, 95% CI [−.15, .04], $p = .22$), or an interaction between the two ($\Delta R^2 = .02$, $F(1,69) = 1.81$, $f^2 = .03$, 95% CI [−.00, .02], $p = .18$). Post-hoc power analyses indicated low power (26.1%) for this test. Similarly, for NF RT's, there were no main effects of state anxiety ($b = -.00$, $t(69) = -.73$, 95% CI [−.01, .00], $p = .47$), social evaluation group ($b = -.03$, $t(69) = -.69$, 95% CI [−.12, .06], $p = .49$), or an interaction between the two ($\Delta R^2 = .02$, $F(1,69) = 1.30$, $f^2 = .02$, 95% CI [−.00, .01], $p = .26$). Post-hoc power analyses indicated low power (20.6%) for this interaction. Thus, null results should be interpreted with caution.

Discussion

Adaptive behavior in social situations requires fast and accurate perceptual decisions regarding the presence or absence of threat in facial expressions. Perceptual decisions made during these situations are influenced by the inherent complexity and dynamism of social environments. As a result of this, we become more reliant on cues and perceptual sets to make perceptual decisions regarding stimuli occurring in these contexts. Despite the fact that early perceptual decisions likely play a critical role in shaping subsequent social cognition and behavior, little is known about *how* social evaluative contexts influence perceptual decision-making. Even less is known about how individual differences in anxiety may interact with social evaluative contexts to influence perceptual decision making. The present study is a first step towards determining how social evaluation and individual differences in state anxiety influence perceptual decision-making. Our results demonstrated with considerable effect sizes, that in the absence of social evaluation, greater state anxiety facilitated better perceptual sensitivity and faster identification of threatening versus neutral faces following threatening cues. However, in the presence of social evaluation, greater state anxiety was associated with worse perceptual sensitivity, and slower identification of threatening versus neutral faces following threatening cues.

In daily life, individuals must contend with contextual factors and anticipatory cues that provide information about what stimuli are relevant and likely. Consistent with earlier studies (Sussman et al. 2016), we found that across our sample threatening cues resulted in more sensitive and faster perceptual decision-making than neutral cues. It is possible that threat cues increase attention in anticipation of the stimulus thereby leading to better detection of the cued stimulus features (Desimone and Duncan 1995). Threat cues may also give rise to more precise perceptual templates, ultimately resulting in better target detection (Lu and Dosher 1998). Indeed, more specific and informative templates have been shown to lead to improved detection of expected stimuli (Schmidt and Zelinsky 2009). Furthermore, template formation may be aided by better visual imagery for threat cues (Imbriano et al. 2019). Threat cues may increase arousal, and higher arousal is effective in biasing selective attention towards task-relevant stimulus characteristics (Mather and Sutherland 2011). Finally, in line with the predictive coding framework, threat cues may help assign greater precision to threatening face related sensory input leading to better attention and better discrimination (Feldman and Friston 2010).

However, our study showed that the facilitating effect of threat cues on perceptual decision making was not universal. Rather, the effect of threat cues on perceptual decision making depended on social evaluative contexts as well as individual differences in state anxiety. In this study, participants were randomly assigned to be purportedly evaluated or not evaluated. In the absence of social evaluation, higher levels of state anxiety were associated with more sensitive discrimination of threatening and neutral faces following threatening cues. It is possible that this occurred via either of the mechanisms highlighted above leading to better detection of threatening vs neutral faces. In the absence of social evaluation, higher levels of state anxiety may lead to the formulation of specific and well-defined threat-related templates that facilitate discrimination of subsequently presented faces. Furthermore, higher levels of state anxiety may increase anticipatory attention to threatening cues (Mathews and MacLeod 1985; Quigley et al. 2012), resulting in faster detection of subsequently presented stimuli. Finally, higher levels of state anxiety may also be associated with greater arousal which may further sharpen threat cue-related predictive representations, as would be predicted by the arousal-based competition (Mather and Sutherland 2011), thus facilitating subsequent perception.

In the presence of social evaluation, we found that the effect of individual differences in state anxiety were reversed. When participants believed their performance was being evaluated, higher levels of state anxiety were associated with worse discrimination of threatening and neutral faces following threatening cues. Since anxiety is associated with exaggerated beliefs about the probability of encountering threatening stimuli and events (Grupe and Nitschke 2013), greater anxiety levels during social evaluation may lead to inflated expectations regarding the probability of seeing threatening facial expressions following threat cues. This may increase the bias toward responding in congruence with a threatening cue rather than responding according to the proceeding stimuli, resulting in worse perceptual sensitivity (Linares and Aguilar-Lleyda 2019; Yoon et al. 2014). Furthermore, anxiety during social evaluative contexts may engage meta-cognitive processes that diminish attentional resources (Goldin et al. 2009), thereby hampering perceptual decision-making.

Our finding is inconsistent with an earlier investigation that found performance was facilitated following threat cues in the context of a physical threat of shock, particularly among those with higher trait anxiety (Sussman et al. 2016). While seemingly contradictory, several important factors may have contributed to this outcome. First, the current paradigm utilized a qualitatively different method to induce threat than prior work (i.e., social stressor vs. physical pain). While both social and physical pain can generate distress, the evolutionary mechanisms that give rise to both reactions may have disparate origins and utility (Bolles and Fanselow 1980; Herman and Panksepp 1978; Thornhill and Thornhill 1989). Moreover, recent reports suggest affective stimuli in social and non-social domains may be processed differently, particularly among those experiencing anxiety (Ait Oumeziane et al. 2019; Distefano et al. 2018; Quarmley et al. 2019). Higher trait anxiety under threat of shock may influence general vigilance and arousal, facilitating perception in general resulting in better discrimination of threatening and neutral faces (Mather and Sutherland 2011). However, higher state anxiety in a socially evaluative setting may trigger specific expectations regarding socially relevant threatening faces thereby biasing decision making and resulting in worse discrimination between threatening and neutral faces (Russell and Fehr 1987).

Limitations and Conclusion

This study has several limitations. First, participants were 18-27-year-old college students from a high socioeconomic status (SES) county in the United States. Including a wider SES and age range would help to generalize effects to the broader population. Second, while the study sought to assess individual differences in state anxiety and their relationship with perceptual decision making in social evaluative contexts, an added benefit would be if we could demonstrate that social elevation also elevates levels of state anxiety. However, a lack of baseline measures of state anxiety prevents us from doing so. Third, we used a relatively subtle manipulation to induce a social evaluative context. Less subtle inductions, where evaluation and negative feedback is more salient, may have yielded greater effect sizes in our results. We selected a relatively subtle manipulation to guard against potential ceiling effects and to ensure that there would be a range of state anxiety across individuals. Future research that employs a less subtle manipulation may be warranted. Finally, we utilized fearful rather than angry faces for our stimuli. This is consistent with prior work demonstrating that fearful faces are rated as more threatening (Taylor and Barton 2015) and provoke greater activation in threat-related neural circuits (Whalen et al. 2001). However, further variants of this task may consider using additional negative facial expressions to test the generalizability of effects.

Despite these limitations, the present study takes a critical first step towards isolating the effect of social evaluative contexts and individual differences in state anxiety on perceptual decision making. It highlights the importance of considering individual differences in the response to contextual features of the environment when testing perceptual biases. Moreover, it underscores the fact that the facilitation or impairment conferred by these individual differences may influence a cascade of behavioral decisions that, in turn, determine the outcome of a social interaction. Overall, these results may have important implications for isolating the pathophysiology of maladaptive social behavior that often accompanies anxiety, and for understanding how social situations may influence perceptual decision making in a social context.

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References

Adini Y, Wilkonsky A, Haspel R, Tsodyks M, & Sagi D (2004). Perceptual learning in contrast discrimination: The effect of contrast uncertainty. Journal of Vision, 4(12), 993–1005, doi:10.1167/4.12.2. [PubMed: 15669907]

Ait Oumeziane B, Jones O, & Foti D (2019). Neural Sensitivity to Social and Monetary Reward in Depression: Clarifying General and Domain-Specific Deficits. Frontiers in Behavioral Neuroscience, 13, 199, doi:10.3389/fnbeh.2019.00199. [PubMed: 31649515]

Andrews J, Wadiwalla M, Juster RP, Lord C, Lupien SJ, & Pruessner JC (2007). Effects of manipulating the amount of social-evaluative threat on the cortisol stress response in young healthy men. Behavioral Neuroscience, 121(5), 871–876, doi:10.1037/0735-7044.121.5.871. [PubMed: 17907819]

Attwood AS, Easey KE, Dalili MN, Skinner AL, Woods A, Crick L, et al. (2017). State anxiety and emotional face recognition in healthy volunteers. 16, doi:10.1098/rsos.160855.

Bargh JA, & Chartrand TL (2000). The mind in the middle: A practical guide to priming and automaticity research. Handbook of research methods in social and personality psychology. (pp. 253–285): Cambridge University Press.

Barrett LF, & Bar M (2009). See it with feeling: affective predictions during object perception. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 364(1521), 1325–1334, doi:10.1098/rstb.2008.0312. [PubMed: 19528014]

Blanco E, Castilla-Ortega E, Miranda R, Begega A, Aguirre JA, Arias JL, et al. (2009). Effects of medial prefrontal cortex lesions on anxiety-like behaviour in restrained and non-restrained rats. Behavioural brain research, 201(2), 338–342, doi:10.1016/j.bbr.2009.03.001. [PubMed: 19428654]

Bolles RC, & Fanselow MS (1980). A perceptual-defensive-recuperative model of fear and pain. Behavioral and Brain Sciences, 3(2), 291–301, doi:10.1017/S0140525X0000491X.

Desimone R, & Duncan J (1995). Neural Mechanisms of Selective Visual Attention. Annual Review of Neuroscience, 18(1), 193–222, doi:10.1146/annurev.ne.18.030195.001205.

Dickerson SS, & Kemeny ME (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. Psychol Bull, 130(3), 355–391, doi:10.1037/0033-2909.130.3.355. [PubMed: 15122924]

Distefano A, Jackson F, Levinson AR, Infantolino ZP, Jarcho JM, & Nelson BD (2018). A comparison of the electrocortical response to monetary and social reward. Social Cognitive and Affective Neuroscience, 13(3), 247–255, doi:10.1093/scan/nsy006. [PubMed: 29373743]

Doty TJ, Japee S, Ingvar M, & Ungerleider LG (2013). Fearful face detection sensitivity in healthy adults correlates with anxiety-related traits. Emotion, 13(2), 183–188, doi:http://doi.apa.org/getdoi.cfm?doi=10.1037/a0031373. [PubMed: 23398584]

Eastwood JD, Smilek D, & Merikle PM (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. Perception & Psychophysics, 63(6), 1004–1013, doi:10.3758/BF03194519. [PubMed: 11578045]

Feldman Barrett L, Mesquita B, & Gendron M (2011). Context in Emotion Perception. Current Directions in Psychological Science, 20(5), 286–290, doi:10.1177/0963721411422522.

Feldman H, & Friston KJ (2010). Attention, Uncertainty, and Free-Energy. Frontiers in Human Neuroscience, 4, doi:10.3389/fnhum.2010.00215.

Fiset D, Blais C, Gosselin F, Bub D , & Tanaka J (2008). Potent features for the categorization of Caucasian, African American, and Asian faces in Caucasian observers. Journal of Vision, 8(6), 258–258, doi:10.1167/8.6.258.

Freeman JB, & Johnson KL (2016). More Than Meets the Eye: Split-Second Social Perception. Trends Cogn Sci, 20(5), 362–374, doi:10.1016/j.tics.2016.03.003. [PubMed: 27050834]

Goldin PR, Manber T, Hakimi S, Canli T, & Gross JJ (2009). Neural Bases of Social Anxiety Disorder: Emotional Reactivity and Cognitive Regulation During Social and Physical Threat. Archives of General Psychiatry, 66(2), 170, doi:doi:10.1001/archgenpsychiatry.2008.525. [PubMed: 19188539]

Grupe DW, & Nitschke JB (2013). Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. Nature Reviews Neuroscience, 14(7), 488–501, doi:10.1038/nrn3524. [PubMed: 23783199]

Heekeren HR, Marrett S, & Ungerleider LG (2008). The neural systems that mediate human perceptual decision making. Nature Reviews Neuroscience, 9(6), 467–479, doi:10.1038/nrn2374. [PubMed: 18464792]

Herman BH, & Panksepp J (1978). Effects of morphine and naloxone on separation distress and approach attachment: evidence for opiate mediation of social affect. Pharmacol Biochem Behav, 9(2), 213–220, doi:10.1016/0091-3057(78)90167-3. [PubMed: 568801]

Imbriano G, Sussman TJ, Jin J, & Mohanty A (2019). The role of imagery in threat-related perceptual decision making. Emotion, doi:10.1037/emo0000610.

Keating P (2005). D-prime (signal detection) analysis. URL http://www.linguistics.ucla.edu/faciliti/facilities/statistics/dprime.htm.

Linares D, & Aguilar-Lleyda D (2019). Decoupling sensory from decisional choice biases in perceptual decision making. 16, doi:10.7554/eLife.43994.

Lu Z-L, & Dosher BA (1998). External noise distinguishes attention mechanisms. Vision Research, 38(9), 1183–1198, doi:10.1016/S0042-6989(97)00273-3. [PubMed: 9666987]

Lundqvist D, Esteves F, & Öhman A (1999). The face of wrath: Critical features for conveying facial threat. Cognition and Emotion, 13(6), 691–711, doi:10.1080/026999399379041.

Lundqvist D, & Ohman A (2005). Emotion regulates attention: The relation between facial configurations, facial emotion, and visual attention. Visual Cognition, 12(1), 51–84, doi:10.1080/13506280444000085.

Mather M, & Sutherland MR (2011). Arousal-Biased Competition in Perception and Memory. Perspectives on Psychological Science, 6(2), 114–133, doi:doi/10.1177/1745691611400234. [PubMed: 21660127]

Mathews A, & MacLeod C (1985). Selective processing of threat cues in anxiety states. Behaviour Research and Therapy, 23(5), 563–569, doi:10.1016/0005-7967(85)90104-4. [PubMed: 4051929]

Mohanty A, & Sussman T (2013). Top-down modulation of attention by emotion. [Opinion]. Frontiers in Human Neuroscience, 7(102), doi:10.3389/fnhum.2013.00102.

Mullen B, Bryant B, & Driskell JE (1997). Presence of others and arousal: An integration. Group Dynamics: Theory, Research, and Practice, 1(1), 52–64, doi:10.1037/1089-2699.1.1.52.

Neta M, Davis FC, & Whalen PJ (2011). Valence resolution of ambiguous facial expressions using an emotional oddball task. Emotion, 11(6), 1425–1433, doi:10.1037/a0022993. [PubMed: 21707167]

New J, Cosmides L, & Tooby J (2007). Category-specific attention for animals reflects ancestral priorities, not expertise. Proceedings of the National Academy of Sciences, 104(42), 16598–16603, doi:10.1073/pnas.0703913104.

Öhman A, Carlsson K, Lundqvist D, & Ingvar M (2007). On the unconscious subcortical origin of human fear. Physiology & Behavior, 92(1-2), 180–185, doi:10.1016/j.physbeh.2007.05.057. [PubMed: 17599366]

Öhman A, Flykt A, & Esteves F (2001a). Emotion drives attention: Detecting the snake in the grass. Journal of Experimental Psychology: General, 130(3), 466–478, doi:10.1037//0096-3445.130.3.466. [PubMed: 11561921]

Öhman A, Lundqvist D, & Esteves F (2001b). The face in the crowd revisited: A threat advantage with schematic stimuli. Journal of Personality and Social Psychology, 80(3), 381–396, doi:http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-3514.80.3.381. [PubMed: 11300573]

Otten M, Seth AK, & Pinto Y (2017). A social Bayesian brain: How social knowledge can shape visual perception. Brain and Cognition, 112, 69–77, doi:10.1016/j.bandc.2016.05.002. [PubMed: 27221986]

Quarmley ME, Nelson BD, Clarkson T, White LK, & Jarcho JM (2019). I Knew You Weren’t Going to Like Me! Neural Response to Accurately Predicting Rejection Is Associated With Anxiety and Depression. Frontiers in Behavioral Neuroscience, 13, 219, doi:10.3389/fnbeh.2019.00219. [PubMed: 31632249]

Quigley L, Nelson AL, Carriere J, Smilek D, & Purdon C (2012). The effects of trait and state anxiety on attention to emotional images: An eye-tracking study. Cognition & Emotion, 26(8), 1390–1411, doi:10.1080/02699931.2012.662892. [PubMed: 22646929]

Russell JA, & Fehr B (1987). Relativity in the perception of emotion in facial expressions. Journal of Experimental Psychology: General, 116(3), 223–237, doi:10.1037/0096-3445.116.3.223.

Schmidt J, & Zelinsky GJ (2009). Search guidance is proportional to the categorical specificity of a target cue. Quarterly Journal of Experimental Psychology, 62(10), 1904–1914, doi:Doi 10.1080/17470210902853530. [PubMed: 19459137]

Schupp HT, Öhman A, Junghöfer M, Weike AI, Stockburger J, & Hamm AO (2004). The Facilitated Processing of Threatening Faces: An ERP Analysis. Emotion, 4(2), 189–200, doi:10.1037/1528-3542.4.2.189. [PubMed: 15222855]

Somerville LH, Jones RM, Ruberry EJ, Dyke JP, Glover G, & Casey BJ (2013). The Medial Prefrontal Cortex and the Emergence of Self-Conscious Emotion in Adolescence. Psychological Science, 24(8), 1554–1562, doi:10.1177/0956797613475633. [PubMed: 23804962]

Spielberger CD (1989). State-trait anxiety inventory: a comprehensive bibliography: Consulting Psychologists Press.

Spielberger CD, Gorsuch R, Lushene R, Vagg P, & Jacobs G (1983). Manual for the state-trait anxiety scale. Consulting Psychologists.

Staugaard SR (2010). Threatening faces and social anxiety: A literature review. Clinical Psychology Review, 30(6), 669–690, doi:10.1016/j.cpr.2010.05.001. [PubMed: 20554362]

Stolier RM, & Freeman JB (2016). Neural pattern similarity reveals the inherent intersection of social categories. Nature Neuroscience, 19(6), 795–797, doi:10.1038/nn.4296. [PubMed: 27135216]

Summerfield C, Egner T, Greene M, Koechlin E, Mangels J, & Hirsch J (2006). Predictive Codes for Forthcoming Perception in the Frontal Cortex. Science, 314(5803), doi:10.1126/science.1132028.

Sussman TJ, Szekely A, Hajcak G, & Mohanty A (2016). It’s all in the anticipation: How perception of threat is enhanced in anxiety. Emotion, 16(3), doi:10.1037/emo0000098.

Szekely A, Rajaram S, & Mohanty A (2017). Context learning for threat detection. Cognition and Emotion, 31(8), doi:10.1080/02699931.2016.1237349.

Szekely A, Rajaram S, & Mohanty A (2019). Memory for dangers past: threat contexts produce more consistent learning than do non-threatening contexts. Cognition and Emotion, 33(5), doi:10.1080/02699931.2018.1507998.

Taylor A, & Barton J (2015). The detection of fearful and angry expressions in visual search. Journal of Vision, 15(12), 1354–1354, doi:10.1167/15.12.1354.

Thornhill R, & Thornhill NW (1989). The evolution of psychological pain. In Sociobiology and the social sciences. (pp. 73–103): Texas Tech University Press.

Tipples J, Atkinson AP, & Young AW (2002). The eyebrow frown: a salient social signal. Emotion, 2(3), 288–296, doi:10.1037/1528-3542.2.3.288. [PubMed: 12899361]

Tottenham N, Tanaka JW, Leon AC, McCarry T, Nurse M, Hare TA, et al. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. Psychiatry Research, 168(3), doi:10.1016/j.psychres.2008.05.006.

Vuilleumier P (2005). How brains beware: neural mechanisms of emotional attention. Trends in Cognitive Sciences, 9(12), doi:10.1016/j.tics.2005.10.011.

Vuilleumier P, & Driver J (2007). Modulation of visual processing by attention and emotion: windows on causal interactions between human brain regions. Philosophical Transactions of the Royal Society B: Biological Sciences, 362(1481), doi:10.1098/rstb.2007.2092.

Watson AB, & Pelli DG (1983). Quest: A Bayesian adaptive psychometric method. Perception & Psychophysics, 33(2), doi:10.3758/BF03202828.

Whalen PJ, Shin LM, McInerney SC, Fischer H, Wright CI, & Rauch SL (2001). A functional MRI study of human amygdala responses to facial expressions of fear versus anger. (Vol. 1, pp. 70–83). US: American Psychological Association.

Willenbockel V, Sadr J, Fiset D, Horne GO, Gosselin F, & Tanaka JW (2010). Controlling low-level image properties: The SHINE toolbox. Behavior Research Methods, 42(3), doi:10.3758/BRM.42.3.671.

Yoon KL, Yang J-W, Chong SC, & Oh KJ (2014). Perceptual Sensitivity and Response Bias in Social Anxiety: An Application of Signal Detection Theory. Cognitive Therapy and Research, 38(5), doi:10.1007/s10608-014-9619-7.

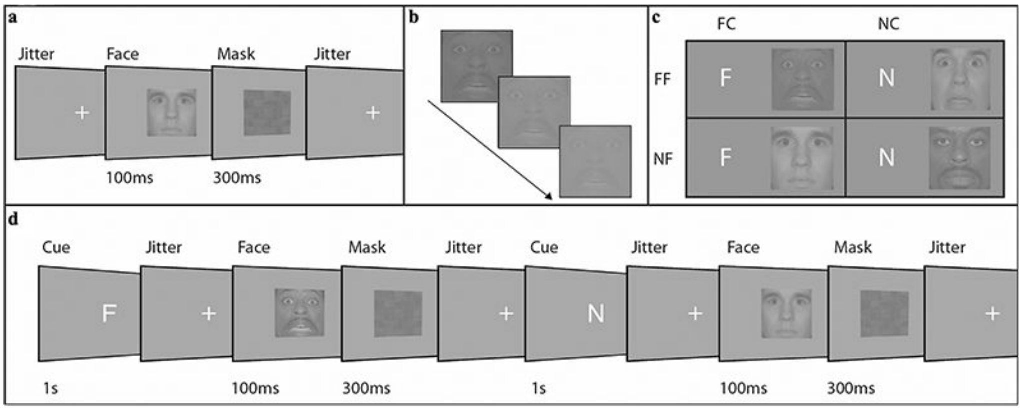

Fig. 1.

a: Threshold task timeline Panicipants performed a 2-alicmaiive force-choice dncnminaUtm task an degraded fearful and neutral faces to determine perceptual thresholds (75*. correct! for each stimulus type. The duration of the fixation cron presentation was jittered and varied between 2 and 3 a. **b:** Adaptive staircases. which mode images harder or easier to tee based on ιobject re «pomes, were used in the threshold task to find each participant's perceptual threshold for fearful and neutral faces **c:** Cue and stimulus combinations in the cued and discrimination task fear cue'fearful face (FC'FF). neutral cue feat tul face fNCFF), fear cucncutral face (FC'NFl. and neutral cue neutral face (NONF)· **d:** Cued shscnminaUon task timeline Participants viewed the same fearful and neutral faces, but the images were preceded by "F" or "N" cues which indicated whether the upcoming dcciMon was "fcarlul lace or not" or "neutral face ut not " The duration of the fixation cross presentation was jittered and varied between 2 and 3 s Facet used m that figure arc from the N'imStim Face Stimulus Set (Tottenham et at. 2009), a publicly available set of emotional face tumult The model· pictured above have consented to hav ing images of their faces published in scientific journals.

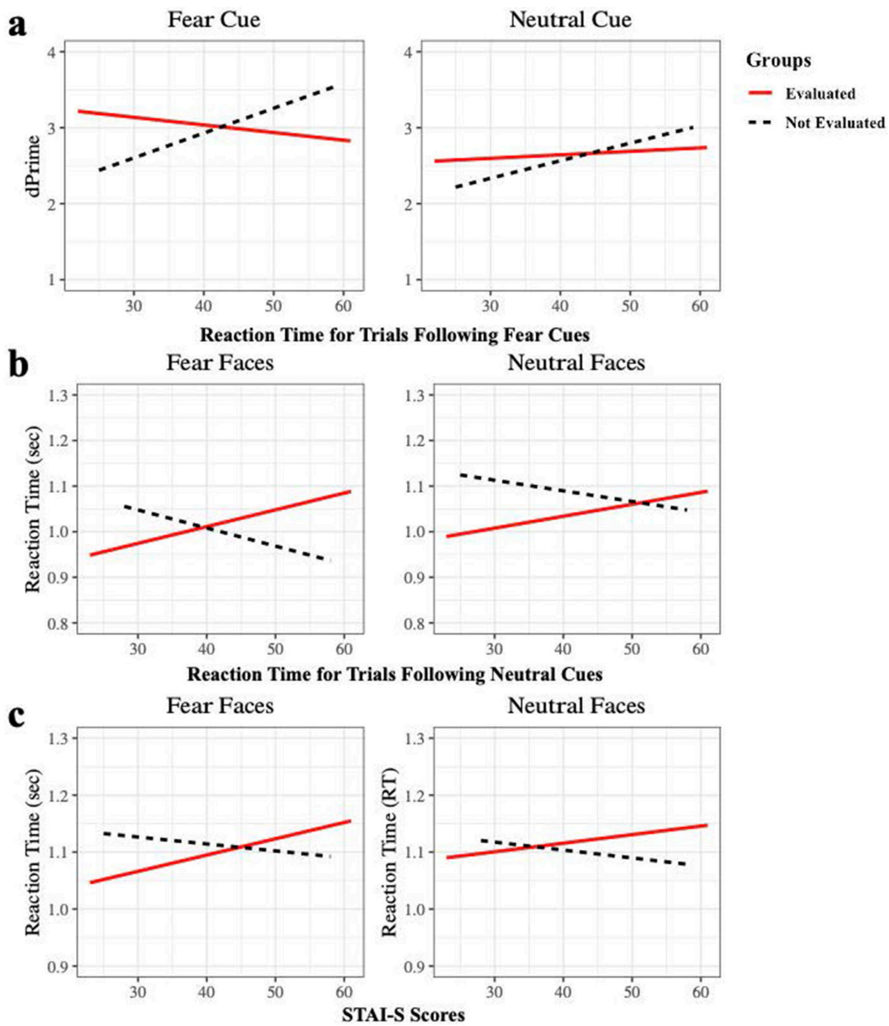

Fig. 2.

a: Perceptual sensitivity (dPnmc or *d")* for fear and neutral cue trials in the evaluated or not evaluated groups **b:** Reaction time for trials with fear cues preceding fear or neutral faces m evaluated or not evaluated groups, **c:** Reaction time for trials with neutral cues preceding fear or neutral faces in evaluated or not evaluated groups.

Table 1

Demographic, anxiety, and evaluation variables for evaluated and non-evaluated groups.

Variable	Non-Evaluated		Evaluated		Group Comparisons
	$N_M = 11$ / $N_F = 28$		$N_M = 17$ / $N_F = 18$		
	Mean	**SD**	**Mean**	**SD**	
Age	19.79	2.00	19.74	1.50	$t(72) = 1.25$, $p = .90$
STAI-S	39.31	9.65	37.31	10.65	$t(72) = .85$, $p = .40$
Perceived Evaluation	3.82	2.25	5.24	1.99	$t(70) = -2.82$, $p = .006$
Perceived Performance	6.79	1.60	6.83	1.67	$t(71) = -.10$, $p = .92$

Notes. Evaluated = purported peer evaluation group; Non-evaluated = not peer evaluated group; M=Male; F=Female; STAI-S = State version of the State-Trait Anxiety Inventory.

Table 2

Mean, and Standard Deviations of d', and Reaction Time (RT).

Variable	Non-Evaluation		Evaluation	
	Mean	SD	Mean	SD
d′ FC	3.20	.90	3.30	.83
d' NC	2.50	.93	2.75	.88
RT FC	1.07	.19	1.01	.17
RT NC	1.17	.20	1.13	.17

Notes. Evaluation = purported peer evaluation group; Non-Evaluation = no peer evaluation group; *d′* = Perceptual Sensitivity; FC = Fear Cue; NC = Neutral Cue; RT = Reaction Time.