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Fearful Face Detection Sensitivity in Healthy Adults Correlates with Anxiety-Related Traits

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Abstract

Threatening faces have a privileged status in the brain, which can be reflected in a processing advantage. However, this effect varies among individuals, even healthy adults. For example, one recent study showed that fearful face detection sensitivity correlated with trait anxiety in healthy adults (Japee, Crocker, Carver, Pessoa, & Ungerleider, 2009). Here, we expanded upon those findings by investigating whether intersubject variability in fearful face detection is also associated with state anxiety, as well as more broadly with other traits related to anxiety. To measure fearful face detection sensitivity, we employed a masked face paradigm where the target face was presented for only 33 ms and was immediately followed by a neutral face mask. Subjects then rated their confidence in detecting either fear or no fear in the target face. Fearful face detection sensitivity was calculated for each subject using signal detection theory. Replicating previous results, we found a significant positive correlation between trait anxiety and fearful face detection sensitivity. However, this behavioral advantage did not correlate with state anxiety. We also found that fearful face detection sensitivity correlated with other personality measures, including neuroticism and harm avoidance. Our data suggest that fearful face detection sensitivity varies parametrically across the healthy population, is associated broadly with personality traits related to anxiety, but remains largely unaffected by situational fluctuations in anxiety. These results underscore the important contribution of anxiety-related personality traits to threat processing in healthy adults.

Keywords

Intersubject variability; masked fearful faces; state anxiety; neuroticism; harm avoidance; and social anxiety

INTRODUCTION

Threatening stimuli hold a privileged status in the brain, which makes sense from an evolutionary perspective, as identifying and reacting quickly and efficiently to such stimuli is an important skill for survival (Davidson, Maxwell, & Shackman, 2004; Ohman & Mineka, 2001). Faces displaying fear and anger are types of threatening stimuli that have been shown to elicit this privileged status in the laboratory setting. Fearful faces represent an indirect threat to the viewer, because the person with the fearful expression is afraid of something in the surrounding environment. Angry faces, by contrast, indicate a direct threat to the viewer, because the person with the angry face is upset with the viewer. Angry faces

are found more quickly during visual search than faces displaying positive emotions (Hansen & Hansen, 1988) (Fox et al., 2000). Also, the detection of a target is enhanced when presented immediately after an angry or fearful face (Fox, 2002; Wilson & MacLeod, 2003). Additionally, there is enhanced evoked brain activation to angry and fearful faces relative to neutral faces in both the amygdala and the network of areas that selectively process faces (Morris et al., 1998; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002).

This privileged status for processing threatening faces has been shown to vary among individuals with anxiety, even healthy adults. Healthy individuals with higher levels of state and trait anxiety show a speed advantage for targets presented following an angry face (Mogg & Bradley, 1999). Healthy subjects with greater anxiety are also better able to correctly identify a fearful face when less emotional intensity is shown in that face (Richards et al., 2002), and they are more accurate at categorizing fearful faces (Surcinelli, Codispoti, Montebanocci, Rossi, & Baldaro, 2006; Winton, Clark, & Edelmann, 1995). Thus, while threatening faces confer a behavioral processing advantage, this advantage is not static and instead appears to be related to subclinical levels of anxiety.

Interestingly, these behavioral studies of healthy adults have almost exclusively investigated only those subjects with the highest and lowest anxiety scores within a healthy sample. This method of pre-classification, called the Extreme Groups Approach, excludes a large section of the healthy population and limits the generalizability of the data (Preacher, Rucker, MacCallum, & Nicewander, 2005). Thus, it is unclear whether or not anxiety levels across the entire healthy adult population have a direct relationship to the behavioral advantage for processing threatening faces. Characterizing the continuum of behavior in healthy adults is important because it helps us better understand how behavior becomes dysregulated in mood disorders.

A recent study has begun to shed light on this question by demonstrating a direct correlation between fearful face detection sensitivity and trait anxiety in a small group (N=8) of healthy subjects who were not preselected based upon their anxiety scores (Japee, et al., 2009). The present study aimed to replicate this previous finding in a larger sample of randomly selected subjects and to broaden the results by investigating the relationship between fearful face detection sensitivity and other personality measures related to trait anxiety (i.e. state anxiety, neuroticism, harm avoidance, and social anxiety). Since state anxiety is a measure of situational anxiety, we hoped to determine if fearful face detection sensitivity is affected by fluctuations in anxiety. Neuroticism is broadly related to a general state of negative feelings, which is a risk factor for the development of anxiety disorders (Clark, Watson, & Mineka, 1994). Harm avoidance measures increased responses to negative stimuli (Cloninger, 1986). By probing the link between neuroticism and harm avoidance and fearful face detection sensitivity, we aimed to better understand if this specific sensitivity is related more broadly to negative affect. We also wanted to explore the link between fearful face detection sensitivity and a more specific aspect of anxiety involving social cues, namely social anxiety. We hypothesized that threat detection sensitivity would vary parametrically with these personality measures, where subjects scoring higher on these scales would be better at detecting fearful faces.

METHOD

Participants

Twenty-one right-handed healthy volunteers (16 females; mean age 25 years $\pm$ 7.6 SD) with no past neurological or psychiatric history participated in this study. All subjects gave written informed consent in accordance with protocols approved by the National Institute of Mental Health Institutional Review Board (IRB). Subjects were recruited from the National

Institutes of Health general community via email advertisements and all subjects were financially compensated for their participation as per IRB guidelines.

Personality Measures

At the beginning of the experiment, all subjects completed the Spielberger State Trait Anxiety Inventory (STAI) (Spielberger & Gorsuch, 1983), the NEO Five Factor Inventory (NEO-FFI) (P. T. Costa & McCrae, 1992), the Harm Avoidance Subscale of the Tridimensional Personality Questionnaire (TPQ-HA) (Cloninger, Przybeck, & Svrakic, 1991), and the Liebowitz Social Anxiety Scale: Self Report (LSAS-SR) (Liebowitz, 1987).

Task

We used the same behavioral paradigm as a previous study (Pessoa, Japee, Sturman, & Ungerleider, 2006). Each trial began with a white fixation cross shown for 300 ms, followed by a 50 ms blank screen, followed by a pair of faces presented consecutively (Figure 1A). The first of the two faces, the target, was either a fearful, happy, or neutral face presented for 33 ms. The second of the two faces was always a neutral face presented for 117 ms, which served as a mask. The target face was immediately replaced by the masked face with no gap in between. Subjects were instructed to press a button denoted as “fear” when they perceived the first face to be fearful and to press another button denoted as “no fear” when they did not perceive the first face to be fearful. Subjects were also instructed that the first face would appear rapidly and the pair of faces could appear as one single face. They were asked to make the fear/no fear decision as fast and as accurately as possible, and then wait for a confidence rating screen to appear. A confidence rating screen appeared after every pair of faces and was presented for 1.5 s. Subjects were asked to rate their decision of fear/no fear by pressing 1 of 3 buttons: 1 = low confidence, 2 = moderate confidence, and 3 = high confidence. Subjects had 1.5 s to make the “fear/no fear” decision and another 1.5 s to rate their confidence in that decision. The total trial duration was 3.5 s. Each subject was shown 54 images of each target face type (fearful, happy, and neutral). Faces subtended approximately 1.5 degrees of visual angle.

Stimuli

Face stimuli were obtained from the Ekman set (Ekman, 1976), the Karolinska Directed Emotional Faces (KDEF) set (Lundqvist, 1998), as well as from a set of faces developed and validated at NIMH (Ishai, Pessoa, Bickle, & Ungerleider, 2004). Fearful, happy, and neutral targets were used. Happy faces were included to closely match fearful faces in terms of low-level features, such as brightness around the mouth and eyes, as both fearful and happy faces tend to be brighter than neutral ones in these regions. Thus, the inclusion of happy faces precluded subjects from utilizing a strategy of “detecting” fearful faces by simply using such low-level cues. The inclusion of happy faces also precluded subjects from adopting a strategy of indicating “fear” whenever facial features deviated from those of a neutral face. All stimuli were presented on an LCD laptop screen at a 60 Hertz refresh rate using the Presentation software package (www.neurobs.com). Target presentation durations were checked within Presentation, and by using a photodiode and an oscilloscope, to ensure accuracy.

Data Analysis

Data were analyzed using receiver operating characteristic (ROC) curves (Green & Swets, 1966; Macmillan & Creelman, 1991). We created ROC curves for each subject individually in a manner previously described (Japee, et al., 2009; Pessoa, et al., 2006; Pessoa, Japee, & Ungerleider, 2005). These curves were calculated using the probability of reporting ‘fear’ given that the target was not a fearful face [$P(\text{‘Fear’}|\text{not Fear})$, i.e. false alarm] and the

probability of reporting 'fear' given that the target was a fearful face [$P('Fear'|Fear)$, i.e. hit] for every confidence rating (three levels for reporting 'fear' and three for reporting 'no fear'). We used these six different proportions of false alarms and hit rates to create the ROC curve, where the false alarm rate was plotted on the x axis and the hit rate was plotted on the y axis. We calculated each subject's fear detection sensitivity (A') by measuring the area under the ROC curve. An A' value of 0.5 indicated chance performance on the task. The higher the A' value was above 0.5, the higher the level of threat detection sensitivity for a given subject.

Correlations between A' and the composite personality measures of interest were corrected for alpha inflation by a Bonferroni correction. The same procedure was adopted for the correlations between reaction time to fearful and non-fearful faces and personality. The five composite personality measures were trait anxiety, state anxiety, neuroticism, harm avoidance, and social anxiety. Additional correlations were performed for scale specific traits (e.g. harm avoidance subscales). Intercorrelations among the five composite personality measures were also subjected to a Bonferroni correction. While we administered the NEO to all subjects, only the neuroticism composite measure was used in these analyses due to its relationship to the development of anxiety disorders (Clark, Watson, & Mineka, 1994).

In order to better understand the relationship between state and trait anxiety, we conducted a multiple regression analysis of both 33 ms A' and also reaction time for fearful and non-fearful faces. This allowed us to investigate the effect of state anxiety while controlling for trait and vice versa.

RESULTS

Personality measurement means and spreads (Table 1) reflected the previously reported values for healthy adults: state anxiety (previous: 36.17 ± 10.96 SD) and trait anxiety (previous: 36.15 ± 9.53 SD) (Spielberger & Gorsuch, 1983), neuroticism (previous: 15.57 ± 7.47 SD) (McCrae & Costa Jr, 2004), harm avoidance (previous: 10.6 ± 6.0 SD) (Cloninger, et al., 1991), and overall social anxiety (previous: 29.3 ± 20.9 SD) (Blair et al., 2008; Goldin, Manber, Hakimi, Canli, & Gross, 2009).

To quantify fear detection sensitivity, we computed the area under the ROC curve (A') for each subject. The average A' was 0.73 ± 0.11 SD (range = 0.52–0.93). Only two subjects had A' values that were not significantly different from 0.5 (the value expected by chance). Therefore, the vast majority of our subjects (19/21) could reliably detect a masked fearful face presented for 33 ms. As we were interested in modeling the natural variation of fear detection sensitivity, we included all twenty-one subjects in the analysis and we correlated A' values with personality traits.

Detection sensitivity (A') for fearful faces significantly correlated with trait anxiety (Figure 1B). However, A' did not correlate with state anxiety (Figure 1C). Further, the relationship between trait anxiety and fearful face detection sensitivity remained the same after controlling for the linear effect of state anxiety, confirming that the effect of trait anxiety on fear detection sensitivity was independent from the effect of state anxiety in our sample. Additionally, while state anxiety did not significantly correlate with any composite personality measures, all other composite personality trait measures significantly correlated with each other (i.e. trait anxiety, neuroticism, harm avoidance, and social anxiety) (Table 2).

Fear detection sensitivity also significantly correlated with neuroticism (Figure 1D) and showed a trend (p corrected = 0.10) towards a significant correlation with harm avoidance

(Figure 1E). However, fearful face detection sensitivity did not significantly correlate with overall social anxiety after correcting for alpha inflation (Figure 1F).

In addition to A' , we also correlated each subject's mean correct RT for fearful faces and non-fearful faces with our five composite personality measures. The only personality measure that significantly correlated with RTs was state anxiety, which negatively correlated with RT on correctly identify fearful face trials ($r = -0.55$, p uncorrected = 0.01, p corrected = 0.05) but did not significantly correlate with RT on correctly identify non-fearful face trials ($r = -0.23$, p uncorrected = 0.33). This result indicates that subjects who were faster to correctly identify a face as fearful also had higher levels of state anxiety. This result was not driven by a global RT advantage independent of valence, because state anxiety did not correlate with RT to correctly identify a face as not fearful. This effect also appears to be less influenced by trait anxiety, as state anxiety remained correlated with RTs to fearful faces after correcting for the influence of trait anxiety ($r = -0.45$).

DISCUSSION

The current study confirmed a prior report (Japee, et al., 2009) that trait anxiety scores among randomly selected healthy adults correlate with a behavioral advantage for detecting fearful masked faces. Additionally, we found that this behavioral advantage also correlates with other personality measures, including neuroticism and harm avoidance, indicating that heightened fearful face detection sensitivity is a broad consequence of personality traits related to negative mood.

In contrast to these personality measures, state anxiety scores did not correlate with fearful face detection sensitivity; state anxiety scores did, however, correlate with RTs to correctly identify fearful faces. Subjects scoring higher on the state anxiety inventory were faster to correctly identify fearful faces. This result is an indication that state anxiety plays a role in the speed of detecting fearful faces but not in the ability to detect fearful faces per se. This result further implies that fear detection sensitivity is related to deeply rooted personality traits and not to situational fluctuations in anxiety in our sample.

Neuroticism is a personality trait related to a general increase in negative emotions (P. T. Costa, Jr. & McCrae, 1980) and susceptibility for anxiety and depression (Clark, Watson, & Mineka, 1994). Therefore it is not surprising that subjects who were better able to detect fearful faces also scored high on this personality trait. The TPQ Harm Avoidance scale measures how much a person avoids highly harmful situations, thereby reflecting amplified responses to negative stimuli (Cloninger, 1986). While neuroticism and harm avoidance scales measure global tendencies towards anxiety and more negative emotions, we also tested whether fearful face detection sensitivity correlated with a more specific subtype of anxiety, namely, social anxiety. Given that our stimuli were social in nature, we expected that subjects scoring higher on social anxiety would be those who showed enhanced fearful face detection sensitivity. This was not confirmed in our study, indicating that fearful face detection sensitivity may not be related to this more specific subtype of anxiety.

While our study focused exclusively on healthy adults, a similar effect has been seen in healthy children, where trait anxiety scores were found to correlate with a behavioral advantage for detecting probes presented in the same location as previously presented angry faces (Telzer et al., 2008). Additionally, that study discovered that trait anxiety scores also correlated with a neural enhancement for angry faces in the dorsolateral prefrontal cortex. These results in children suggest that trait anxiety in healthy individuals modulates not only the enhanced behavioral response to threatening faces, but also the enhanced neural response associated with enhanced behavior.

In our study task-relevant fearful faces elicited a behavioral advantage, particularly for those subjects with higher levels of trait anxiety. Other work has shown that fearful faces elicit a behavioral disadvantage when the faces are task-irrelevant and distracting, particularly for those healthy subjects with higher levels of anxiety (Ewbank et al., 2009; Ladouceur et al., 2009). The results of those studies combined with the present findings suggest that anxiety and anxiety-related traits bias healthy adults towards threatening faces and this bias creates either an advantage for performance when the threatening face is task-relevant or a disadvantage for performance when the threatening face is task-irrelevant.

The generalizability of our work to the healthy human population is limited in two ways. First, we have a moderate sample size of healthy individuals ($N=21$) and therefore more subjects are needed to confirm if the effects seen in this study generalize to the healthy population. The second limitation of our study is that our sample randomly contained a large number of female subjects (16/21) and given our moderate sample size we do not have enough information to adequately address potential gender differences. However, we hypothesize that males would follow the same pattern of results because previous research has found no difference in the average or the distribution of trait anxiety scores between males and females (Spielberger & Gorsuch, 1983).

In conclusion, we have demonstrated that healthy adults scoring higher on personality traits related to trait anxiety had a heightened sensitivity to detect fearful faces, while healthy adults scoring lower had a reduced sensitivity. This sensitivity was found to vary parametrically across the healthy trait anxiety spectrum but did not correlate with state anxiety. Our work suggests that healthy adults possessing higher levels of anxiety-related traits have an enhanced fear detection system that is unaffected by situational fluctuations in anxiety. Additionally, our results underscore the importance of assessing cross-population variability in personality, behavior, and the relationship between them in tasks containing threatening stimuli.

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citation

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Figure 1. Task Design and Correlations between Fearful Face Detection Sensitivity and Personality Traits

A. Illustration of a single trial. A fearful (F), happy (H), or neutral (N) target face was presented for 33 ms and then immediately followed by a neutral face mask presented for 117 ms. Subjects were asked to press a button to indicate if the first face they had seen was either fearful or not. They then waited for a rating screen to appear at which time they were asked to rate their confidence in their previous response on a scale of 1 to 3. B. In accordance with a previous study (Japee, et al., 2009), we found that the detection sensitivity (A') for fearful faces presented for 33 ms positively correlated with trait anxiety. C. By contrast state anxiety did not correlate with A'. A' measures did, however, positively correlate with neuroticism (D), and harm avoidance (E), – all of which are traits related to trait anxiety. Subjects who rated higher on these personality traits were better able to detect a briefly presented masked fearful face. After correction for alpha inflation, social anxiety (F) did not correlate significantly with A'. ** $p < 0.01$ corrected, * $p < 0.05$ corrected, + $p < 0.01$ corrected Figure 1A adapted from Japee, et al. (2009).

Table 1

Personality Measure Scores and Correlations with Fearful Face Detection Sensitivity

All Subjects N = 21		
Personality Measure Scores	Mean ± SD	Correlation with 33ms A': r value (p value)
Spielberger State and Trait Anxiety Inventory (STAI)		
State Anxiety	30.10 ± 8.62	0.17 (0.45)
Trait Anxiety	35.95 ± 9.46	0.65 (0.002)**
NEO – Five Factor Inventory (FFI)		
Neuroticism	16.67 ± 8.87	0.55 (0.01)*
Tridimensional Personality Questionnaire - Harm Avoidance Subscale (TPQ-HA)		
Harm Avoidance	10.52 ± 7.31	0.50 (0.02)+
HA 1: Anticipatory worry & pessimism	4.20 ± 3.72	0.62 (0.003)
HA 2: Fear of Uncertainty	2.95 ± 1.77	0.39 (0.08)
HA 3: Shyness with strangers	2.05 ± 1.94	0.23 (0.31)
HA 4: Fatigability & asthenia	1.81 ± 2.40	0.37 (0.10)
Liebowitz Social Anxiety Scale: Self Report (LSAS-SR)		
Overall Social Anxiety	30.81 ± 15.75	0.48 (0.03)
Fear of Performance	9.81 ± 3.98	0.39 (0.08)
Avoidance of Performance	6.52 ± 4.18	0.46 (0.04)
Fear of Social Interaction	8.05 ± 4.38	0.40 (0.07)
Avoidance of Social Interaction	6.43 ± 4.95	0.47 (0.03)
Total Fear	17.86 ± 7.88	0.42 (0.06)
Total Avoidance	12.95 ± 8.77	0.48(0.03)

The five composite measures of interest are found in bold.

** p 0.01 corrected,

* p 0.05 corrected,

+ p 0.10 corrected

Table 2

Intercorrelations Among Personality Measures.

	State Anxiety	Trait Anxiety	Neuroticism	Harm Avoidance	Social Anxiety
State Anxiety					
Trait Anxiety	0.48				
Neuroticism	0.39	0.83			
Harm Avoidance	0.27	0.73	0.72		
Social Anxiety	0.16	0.66	0.67	0.75	

All r values presented in bold are significant at p = 0.05 corrected.